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Adaptability of Karnaugh Maps

Enhancement of Solar Biomass Dryer

Highlights

Design and Fabrication of Power

Modeling and Applications of a Solar

Discovering Thoughts, Inventing Future

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Design and Fabrication of Power Generation through Speed Breaker

By Vishal Gupta, Vishal Singh, Akhilesh Kumar, Vivek Agnihotri
& Mayank Kumar

Abstract- In the present scenario energy is the primary need for human life. Energy is responsible for development of any country's economy. But in this fast-moving world, population is increasing day by day and the conventional energy sources are diminishing. Moreover, these non-renewable energy sources are polluting and responsible for global warming. Therefore, to overcome this problem we need to implement the technique of optimal utilization of conventional sources for conversion of energy. So non-conventional sources are needed to be developed for power generation which are clean environment friendly and sustainable. So, this project includes how to utilize the energy which is wasted when the vehicle passes over a speed breaker. Our project is to enlighten the street utilizing the jerking pressure which is wasted during the vehicle passes over speed breaker in roadside. We can tap the energy generated and produce power by using the speed breaker as power generating unit.

Keywords: design, simulation and fabrication, renewable energy.

GJRE-A Classification: FOR Code: 290501



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Design and Fabrication of Power Generation through Speed Breaker

Vishal Gupta^α, Vishal Singh^σ, Akhilesh Kumar^ρ, Vivek Agnihotri^ω & Mayank Kumar[¥]

Abstract- In the present scenario energy is the primary need for human life. Energy is responsible for development of any country's economy. But in this fast-moving world, population is increasing day by day and the conventional energy sources are diminishing. Moreover, these non-renewable energy sources are polluting and responsible for global warming. Therefore, to overcome this problem we need to implement the technique of optimal utilization of conventional sources for conversion of energy. So non-conventional sources are needed to be developed for power generation which are clean environment friendly and sustainable. So, this project includes how to utilize the energy which is wasted when the vehicle passes over a speed breaker. Our project is to enlighten the street utilizing the jerking pressure which is wasted during the vehicle passes over speed breaker in roadside. We can tap the energy generated and produce power by using the speed breaker as power generating unit. The kinetic energy of moving vehicle can be converted into mechanical energy of the shaft through rack and pinion mechanism, then this mechanical energy can be converted into electrical energy using dynamo which will be saved with the use of a battery. The energy we save can be used in the night time for lighting street lights. Therefore, for this arrangement we can save lot of energy which can be used for the fulfilment of future demands and if implemented then it will be very beneficial for government. The principle involved is potential energy to electrical energy conversion. When the vehicle moves over the inclined plates. It gains height resulting in increase in potential energy, when the breaker comes down, then rack moves and rotate the pinion which is connected to shaft. The output of this shaft is coupled to a dynamo to convert potential energy into electricity.

Keywords: design, simulation and fabrication, renewable energy.

I. INTRODUCTION

In today's growing world, the use of renewable energy is increases as non-renewable resources are decreasing. Pollution and global warming are increasing by using more conventional sources. In my paper, I have talked about the power generation through speed breaker and every component and mechanism involved in making it. As we are seeing the consumption of the energy is continuously increasing, and electricity production is constant. Due to which there is shortage of electricity. According to Ward's auto journal, 1.2 billion vehicles have been calculated in 2021. This means we

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have a good opportunity that we can save the energy production for this.

On the other hand, pollution such as noise pollution and air pollution is increasing and badly affecting our life and mother earth. The need for energy has created many powers stations due to which the pollution is increasing even more. So, we did and figured out from our idea per thought that we can generate effective power with the help of the speed breaker system without any fossil fuels without any harmful gases.

II. PROPOSED METHODOLOGY

a) Block Diagram

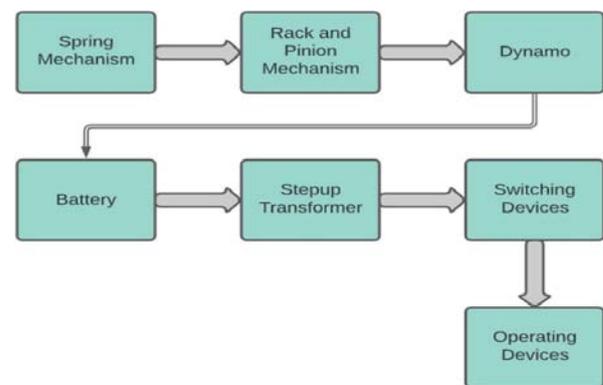


Fig. 1: Block diagram

b) Design and Construction Details

1. Cad software
Auto cad Catia
2. Rack & Pinion, Spring, Shaft, Sliding rack rail, Electric Dynamo
3. Wooden board/Iron sheet, Battery, PCB board

c) Design Procedure

First, we will prepare a base on which the whole mechanism will rest. With the help of square pipe, the base of rectangular shape is prepared. Use welding or clamps to join the pipes. On top of that rectangular base, we will prepare the base of the spring mechanism. And make the hump movable with the help of sliding rack rail. Rack is attaching to the sliding rack rail then due to motion in rack, it rotates the pinion in rotatory motion. Pinion will attach directly to the dynamo and the output of the dynamo will be directly connected to the battery and the power stored in the battery will be used for street lights.

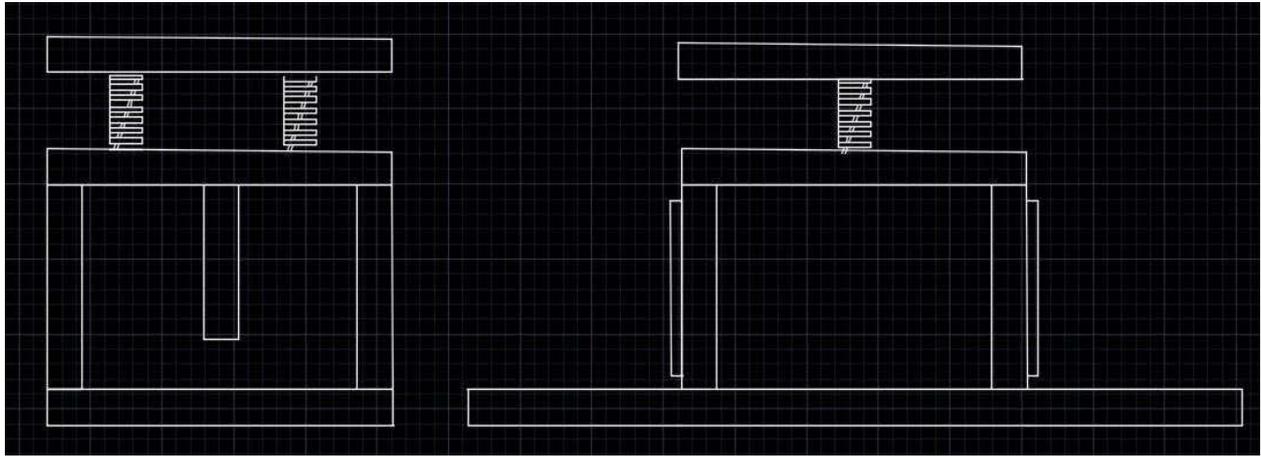


Fig. 2: Design of speed breaker

d) Working Procedure

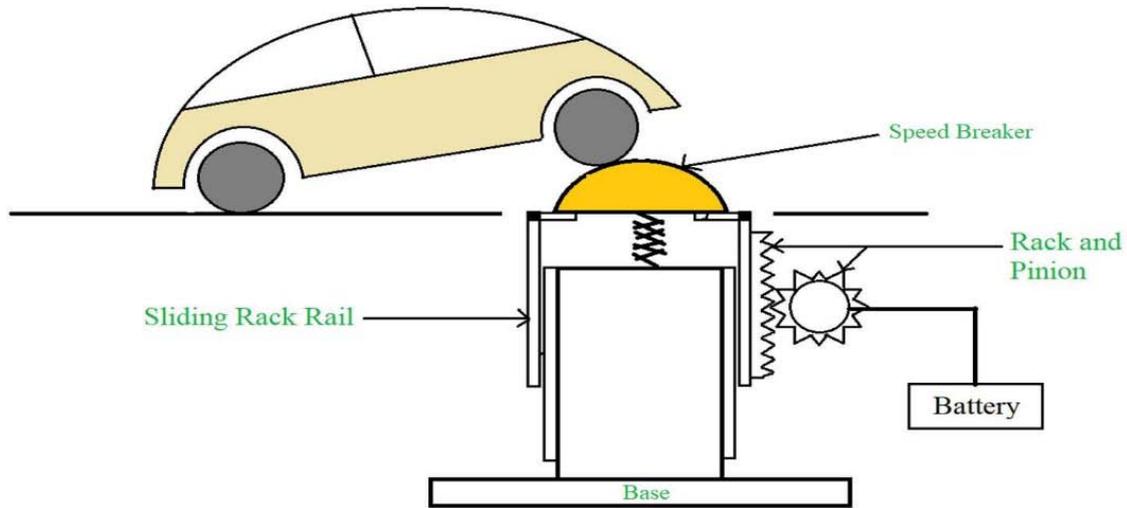


Fig. 3: Working model (Source Wikipedia)

When the vehicles are moving, it has kinetic energy and if the vehicle is at height, it has potential energy which is being wasted. This potential energy can be utilized to produce power by using a special arrangement which is called "Power Hump". It is an electro-mechanical system which works on electrical and mechanical technology and generates power. When a vehicle passes through a speed breaker, the power hump moves in a downward direction, due to which the spring is pressed and the rack moves downward. Rack has teeth that mesh with pinion gear. The reciprocating motion of the rack causes the rotating motion in the pinion. The pinion is connected to the shaft and the same shaft is also connected to the dynamo. When the shaft rotates with the certain RPM, it transfers Mechanical Energy to the dynamo. This mechanical energy is converted into electrical energy because of the dynamo. The generated power can be amplified and stored by using different electrical devices such as battery.

III. CALCULATION

a) Power Calculation

Let us assume that,

The mass of the vehicle moving over the speed breaker, (m) = 200 Kg Height of the speed breaker, (h) = 15 cm

We know that,

$W = mg$ (weight of the vehicle) where, m = mass of vehicle

g = acceleration due to gravity

$$\therefore W = 200 \times 9.8 = 1960 \text{ N}$$

Distance moved by speed breaker, (d) = 15 cm

$$\therefore W = 1960 \times 0.15 = 294 \text{ joule}$$

Power, (P) = work done / second

$$\therefore P = 294/60 = 4.9 \approx 5 \text{ watts}$$

Power developed for 60 min = 300 watt And Power developed for 24 hr. = 7.2 kW

Hence, our system produces 250V voltage and 24A current

b) *Obtained result*

We are using 5-watt LED bulbs because gives same brightness as incandescent. In one kilometer 50 bulbs are needed

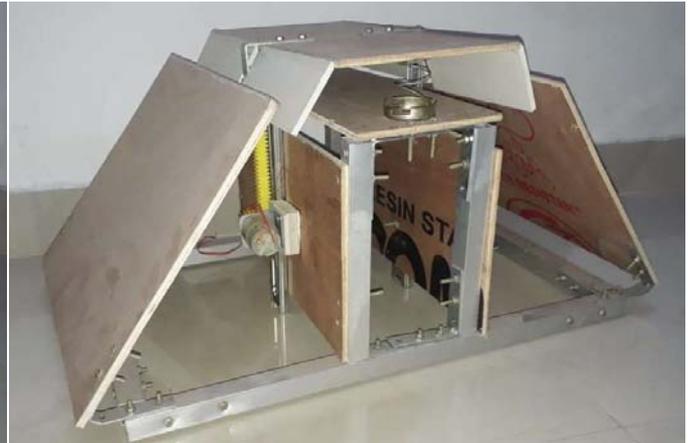
∴ Total power required = $5 \times 50 = 250\text{watt}$

This power generated by vehicle is sufficient for 10 street lights in night time.

IV. ACTUAL PROJECT DESIGN



a



b

V. ADVANTAGES

1. Less area is required for installation of the power system.
2. Pollution will not generate as it is renewable energy.
3. Transportation and maintenance will be a favor and any damage can be easily repaired.
4. Accidents on the road will decrease.
5. By using this system, electricity can be easily generated throughout the year.
6. Power can be generated at very low cost and future demand can be easily met

VI. RESULT

Obtained result: We are using 5-watt LED bulbs because gives same brightness as incandescent. In one kilometer 50 bulbs are needed

∴ Total power required = $5 \times 50 = 250\text{watt}$

This power generated by vehicle is sufficient for 10 street lights in night time.

VII. CONCLUSION

The demand for electricity will increase in the coming time and if seen, it is increasing every day. Speed breaker power generation is able to reduce this demand to some extent. The aim of our research that we should make a system which is not polluting and energy can be produced without manpower. There are many countries where electricity is not present properly, so with the help of this, the power shortages happening in the country can be removed. This research paper can

also be modified when we directly connect pinion to dynamo, so as to minimize the difficulties and complexities.

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On the Diffusion Mechanism in Melts of Condensation and Non-Condensation Polymers at High Temperatures

By Stoyko Fakirov

University of Auckland

Abstract- As recently assumed (DOI:10.3144/expresspoly mlett.2019.25), the diffusion mechanism in melts of noncondensation and condensation polymers at high temperatures must be rather different due to the intensive exchange (trans) reactions resulting in dissipation of condensation macromolecules into single repeating units. Considering these peculiarities of condensation polymers, it is concluded that the Reptation concept can be used for explaining the diffusion mechanism of non-condensation polymers (e. g. polyolefins) in the entire temperature interval while for condensation polymers it is applicable only in the range between T_m and approximately $(T_m + 100)^\circ\text{C}$. At much higher temperatures, where the exchange reactions are extremely intensive, the diffusion mechanism seems to be the same as in the case of low molecular weight substances.

Keywords: *diffusion mechanism; condensation polymers; exchange- (trans) reactions; reptation model.*

GJRE-A Classification: *FOR Code: 091399*



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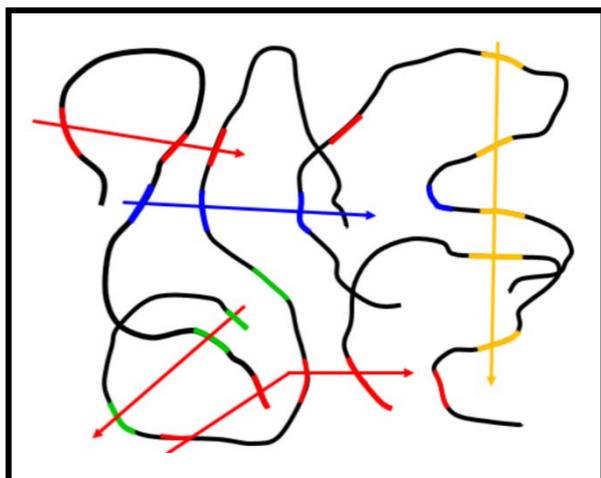


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Graphical Abstract-



The experimental data regarding the frequency of exchange reactions in melts of condensation polymers show at least 10 reactions in a minute in one macromolecule (at low melt temperatures) and more than 100 reactions, but in a second (at high melt temperatures). At such temperature, the single independent kinetic elements are short fragments of macromolecules, and the diffusion mechanism in melts of condensation polymers seems to be the same, as that in the low molecular weight substances.

Keywords: diffusion mechanism; condensation polymers; exchange- (trans) reactions; reptation model.

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I. INTRODUCTION

Diffusion is a physical process that refers to the net movement of molecules from a region of high concentration to one of lower concentration. The material that diffuses could be a solid, liquid or gas. In the case of solids some additional requirements are needed – the temperature must be above the melting temperature of the respective crystals or above the glass transition temperature of amorphous solids.

a) *The diffusion mechanism in low molecular weight substances*

The diffusion process in low molecular weight substances is well studied. Its basic characteristic feature is that independent kinetic entities are the whole molecules, that is, the whole molecules move but not parts of them only. The mass transfer could be represented as a process consisting of “jump-like” steps.

Let remind the picture of diffusion and flow in the case of low molecular weight liquids. If molecules have spherical shape, and they are densely packed, between the spheres (A) there are empty places (B), as shown in Figure 1. According to the ideas of Frenkel [1] the molecules vibrate with a given frequency. At some of vibrations the molecule “jump” in the neighboring empty place (e.g. $A \rightarrow B$, Figure 1). After several vibrations around the new equilibrium state with the same frequency, the molecule “jump” again into another empty place. In this way is realized the process of self-diffusion of liquid molecules expressed in displacement of center of gravity of molecules, i.e. a flow takes place.

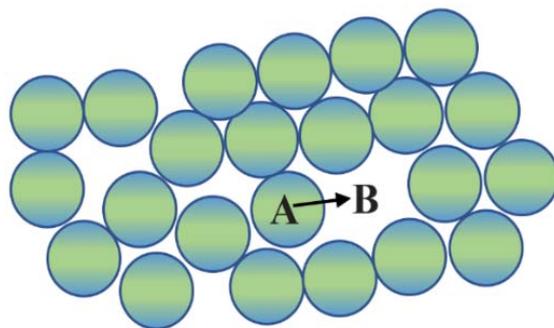


Figure 1: Schematic the packaging of spherical molecules in a liquid (A), and the non-occupied (free) volume (B)

b) *The diffusion mechanism in high molecular weight substances*

The model shown in Figure 1 can be applied to polymer liquids (polymers in a molten state), at least partially, because the empty places are not big enough to accommodate the whole macromolecules comprised of many thousand linked atoms. In addition, a large amount of activation energy for displacement of whole molecules is needed. According to Eyring, it is 1/4 to 1.3 of the evaporation heat. If one summarizes this value for all repeating units of a macromolecule, one obtains a value which is much larger than the energy needed for breaking the chemical bonds leading to a chemical degradation of macromolecules. By the way, for the same reason the polymers do not exist in a gas state – before to evaporate the macromolecules decompose usually reaching the monomer state.

Solution of this situation can be found if we consider the fact that the independent kinetic units in macromolecules, particularly those comprised of flexible chains, are not the whole molecules but their segments. Then we can assume that the spheres in Figure 1 do not represent single molecules but segments of macromolecules, where between the segments there are also non-occupied places. What is more, for thermodynamic reasons, the number of these free places strongly increases with the rise of temperature. The more they are in a unit volume the more flexible are the molecules.

For flexible macromolecules it is possible the displacement of small sections of molecule without involving the rest of them, and for this are not needed large activation energies. It is experimentally proven when the growing molecule reaches the size of the segment, the activation energy of the viscous flow does not depend any more on the degree of polymerization. Just due to the subsequent displacement of small

sections of macromolecule it is possible to move the whole molecule; the direction of this displacement is determined by the external force. It follows that polymer molecules moves not via “jumping” of whole molecule but via displacement of its small sections similarly to the movement mechanism of reptiles and worms.

The above-described model is applicable to polymers with not extremely high molecular weight, at least below their critical chain length, which for vinyl polymers equals twice the weight-average degree of polymerization. This limitation is related with the onset of entanglement and a modified model is required to account for the ability of long chains to translate and diffuse through the polymer matrix.

II. THE “REPTATION MODEL”

The problem of diffusion mechanism of large flexible chains was solved by de Gennes [2] and Edwards [3], who formulated the fundamental concept of “*Reptation model*”. In the de Gennes approach, the polymer chain is assumed to be confined in a hypothetical tube, the contours of which are defined by the position of the entanglement points in the network. In this way, the single polymer chain, trapped inside the “tube”, is not allowed to cross any of the obstacles. This situation is presented graphically in Figure 2a. The macromolecules may move in a snake-like fashion among the obstacles, that is via *reptation* [2]. Lateral chain motion is severely restricted by the presence of neighboring chains. Mechanistically, reptation can be viewed as the movement of a “kink” in the chain along its length (Figure 2b). The amorphous polymers are the most often studied ones, as, for example, the polybutadiene because of its low glass transition temperature and high chain flexibility at room temperature.

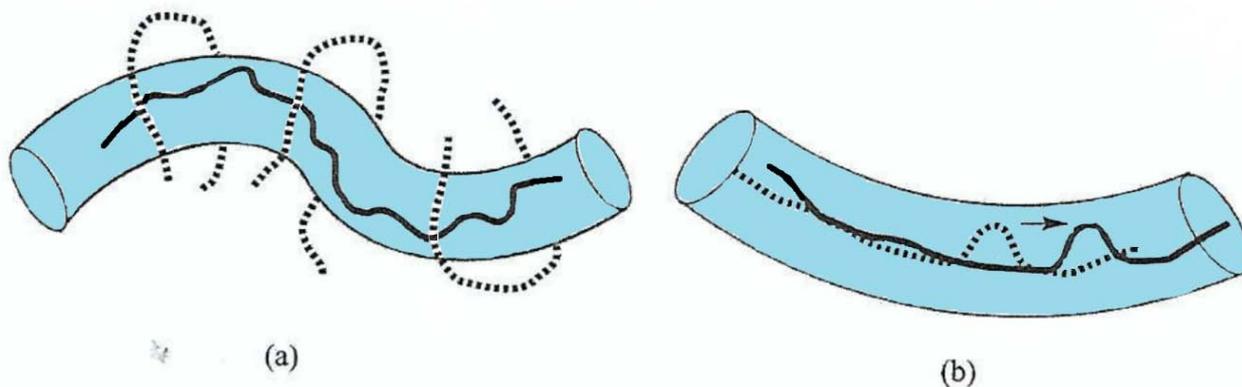


Figure 2: Schematic representation: a) – a polymer chain confined in a hypothetical tube contoured by fixed obstacles (depicted by dotted lines), and b) – movement of a “kink” along the chain until it reaches the end of the chain and leaves it. Successive motions of this kind translate the chain trough the tube and eventually take it completely out of the tube.

III. FURTHER DEVELOPMENT OF THE “REPTATION MODEL” AND ITS CRITICISM

In a quite early time [4] it was well understood that the mobility and self-diffusion of polymer molecules in concentrated systems or in the molten bulk state is largely controlled by entanglements between the molecules. These entanglements are a result of the chain-like nature of the molecules and of their extended, coil-like configuration. The conformation and mobility of polymer molecules in dilute solution, which are relatively simpler case, helped in consideration of self-diffusion in the more concentrated states and in the bulk polymer melt. The molecular self-diffusion controls several special properties of polymers as transport of biological macromolecules within living tissue, the morphology of semi-crystalline polymers and the flow properties of plastic melts - these are part of a broad spectrum of polymer properties controlled by the rearrangement and diffusion of polymer molecules.

Although the nature of polymers has been recognized for several decades, it is relatively later that a clear understanding of their self-diffusion in concentrated systems has begun to emerge. The physical picture is rather different to that associated with non-polymeric materials as mentioned in the Introduction. There are essentially two reasons for this: the sheer size of the molecules involved, and their intertangled nature. A typical polymer molecule consists of several thousand monomer molecules, connected as a long flexible chain; in addition, it may adopt an exceptionally large number of different configurations, because there is, generally, easy rotation about the backbone bonds [5]. In the bulk material, this chain folds up in the form of a loose coil, occupying a volume many times that of the chain itself. Since the volume of the coil not occupied by the chain is nonetheless filled with polymer, it follows that any given polymer molecule is interpenetrated by, and intertangled with other molecules very intimately. Because of this, a polymer chain cannot diffuse by random thermal hops in which it moves as a single unit, as is essentially the case with smaller molecules and atoms as described above. Its translational motion, rather, and the way in which it disentangles itself from its neighbors, are cooperative processes, which represent the sum of random motions of all monomers along the chain; a polymeric molecule may thus be subject to long-range interactions - such as entanglements, which small molecules do not experience [4].

Fundamental contributions to the development of the ideas of self-diffusion in polymer melts have done by L. Leibler, M. Rubinstein and R. Colby covering polymers with various architecture, structure, composition, and other characteristics (e.g. [6-16]).

A peculiarity of almost all studies on relaxation and self-diffusion of a polymer chain in a melt is that

these studies concern exclusively non-condensation polymers, typically polyolefins. To them belong hydrogenated polybutadiene used for evaluation of the self-diffusion coefficient in its melt [17], polyethylene and polystyrene, used for studying the molecular weight and temperature dependence of self-diffusion coefficients [18]. Stars, combs, rings, and polydisperse samples have been used to get a new information on diffusion mechanisms [19].

The self-diffusion coefficient and zero-shear viscosity have been measured in the melt state for a series of three-arm star hydrogenated polybutadienes [20]. Poly (vinyl) acetate-toluene and Neoprene-acetone have been used for evaluation of the diffusion coefficients in polymer-solvent systems for highly concentrated polymer solutions [21].

Self-diffusion and tracer diffusion of hydrogenated and deuterated polybutadienes, both above the entanglement molecular weight have been investigated over a broad range of molecular weight to study the reptation and constraint release in linear polymer melts [22].

In the rather rare publication on polyesters [23] the growth of branched polymer structures up to the gel point has been examined a polyester system at two different branch agent concentrations. In all cases, scaling relationships between various properties were displayed for the whole range of molecular weights [23].

In a review on the tube theory of entangled polymer dynamics [24] it is stated that the dynamics of entangled flexible polymers is an appealing interdisciplinary field where experimental and theoretical physics can work closely with chemistry and chemical engineering. Further on, the role of topological interactions is particularly important, and has given rise to a successful theoretical framework: the “tube model”. In the same review are discussed specially synthesized model materials, an increasing palette of experimental techniques, simulation and both linear and nonlinear rheological response. It is concluded [24] that our current understanding of a series of processes in entangled dynamics: “reptation”, “contour length fluctuation” and “constraint-release” are set in the context of remaining serious challenges. Especial attention is paid to the phenomena associated with polymers of complex topology or “long chain branching”.

Even stronger effects of molecular topology on diffusion have been observed for entangled DNA molecules [25]. Among polymers, DNA is rather unique in that it is naturally found in several different topological forms, including linear, supercoiled circular, relaxed circular, knotted circular, and branched. When long polymers such as DNA are in a highly concentrated state, they may become entangled leading to restricted self-diffusion. The effect of molecular topology on diffusion in concentrated DNA solutions was

investigated and surprisingly large effects were found. It was concluded that the diffusion in entangled DNA solutions strongly depends on topology of both the diffusing molecule and the surrounding molecules [25].

The same problem, namely the entangled polymer dynamics beyond reptation was recently [26] treated in detail. For this purpose, linear and cyclic ds-DNA molecules as model system was used, and a new single-molecule characterization platform by combining super-resolution fluorescence imaging and recently developed single-molecule tracking method, cumulative-area tracking, which enables to quantify the chain motion in the length and time scale of nanometers to micrometers and milliseconds to minutes.

It is manifold demonstrated that the rheological properties of polymer materials microscopically arise from entanglement of polymer chains [2,3]. Decades of theoretical, experimental [27-32], and simulation studies [33-35] suggested that topological states of polymer (e.g. linear, cyclic, etc.) have significant effect on entanglement mode between the chains [36]. Recent studies demonstrated that the topological states of polymer chain are one of the key factors that regulate macroscopic physical properties of polymer materials, including thermal stability of polymer micelles [37,38] and elastic properties of polymer gels [39]. Nanoscopic characterization of the entanglement between topological polymers at the single-chain level would thus provide a foundation for the development of new polymer material.

Motion of a linear polymer chain under entangled conditions has been described by reptation theory [3]. In this theory, as already mentioned, a polymer chain is confined in a transiently existing virtual tube created by entangled surrounding chains. Due to this spatial confinement, the chain cannot move transversely across the tube and displays motion only along the tube as can be concluded from Figure 2. According to this model, motion of the entire chain is determined by the motion of two ends of the chain. It is obvious that the reptation theory cannot fully describe the motion of topologically unique cyclic polymer chains under entangled conditions as cyclic chains do not have chain end [26]. Several theoretical frameworks describing motion and relaxation of entangled cyclic chains have been proposed, including double-folded-reptation, lattice-animal, constraint release, and once-threaded model [40-44]. Contribution of mutual relaxation between entangled chains and decoupling of diffusive motion and chain relaxation on entangled cyclic polymer dynamics have also been suggested [45,46]. Compared with well-accepted reptation model for linear polymers, cyclic polymer dynamics remains elusive [26].

Nuclear magnetic resonance spectroscopy, light and neutron scattering, and viscosity and stress-relaxation measurement have been main tools for characterizing polymer dynamics [47-49]. Reptation

model has been confirmed for linear chains using natural polymers such as DNA [50] and actin filament [51] as well as synthetic polymers [52]. In these studies, although motion and conformational state of single chain were captured directly, quantitative analyses were often conducted based on overall motion and relaxation of the chains such as chain-length-dependent motion of center of mass [26]. Using this new method [26], it was demonstrated that the motion of the linear chains under entangled conditions occurring at the level of both whole chain and entangled segment are consistent with the reptation model. The results obtained suggest also that the motion of the cyclic molecule at the whole chain level is distinct from that of the linear chain because of the topological constraint of the cyclic chain under entangled conditions rather than topology-dependent local chain motion and interaction. It was also proved the existence of hypothesized but unproven modes of the motion of cyclic chains under entangled conditions, including amoeba-like motion of double-folded loop-like region [26].

From this brief review of the development of the reptation theory it could be concluded that the Reptation model can be applied for explaining the self-diffusion mechanism of polymers comprised of flexible chain-like macromolecules, which preserve their chemical composition (even at elevated temperatures, e.g. their melts) during the diffusion process, that is, the diffusion is not paralleled by chemical reactions. The non-condensation polymers inherently fulfilled these characteristic requirements. On the contrary, the condensation polymers are distinguished by chemical peculiarities, which make the application of Reptation model for describing the diffusion in their melts questionable. The subsequent sections of this review deal with the chemical peculiarities of condensation polymers, which could help us in answering the question regarding application of Reptation model to the melts of condensation polymers for explaining of their diffusion mechanism. Finding of this answer is just the target of this study. An additional reason for treating the condensation polymers in this respect is the fact that the reptation theory was supported by experimental results from studies of exclusively non-condensation polymers.

IV. THE CHEMICAL PECULIARITIES OF CONDENSATION POLYMERS [53]

At the beginning let remind a basic knowledge in the polymer science. Polymers are synthesized mostly by two chemical reactions: polycondensation and polymerization. In the first case the functional groups (e.g. -COOH, -OH, -NH₂, and others) of the monomers react and a low molecular weight product (usually H₂O) is separated. In the second case the reaction goes via opening double or triple bonds, or cycles and no low molecular weight product is separated.

interchange reactions of poly(ethylene terephthalate) (PET) can take place 20-30 °C below T_m , e.g., in the solid state. In the solid state, the rate of reaction of this polymer becomes relatively high at temperatures above 225 °C and is catalyzed by the free carboxylic end groups of the polyester [62].

a) *The additional (post) polycondensation and the exchange- (trans) reactions in polymer science and technology*

Among the condensation polymers, possibly, the most important are the polyesters and polyamides (Nylons). This is related with their first and very wide application as textile and technical fibers. Some later, particularly the polyamides, were applied as engineering plastics and during the last 2 - 3 decades PET found a large application as packaging material (mostly for bottles of pressurized soft drinks). It turned out that PET is non-replaceable material in this respect due to its transparency, chemical resistivity, gas and vapor non-permeability, light weight, and others, and for these reasons it enjoys 10% annual increase in its production [63].

Discussing these three rather different areas of applications of condensation polymers it seems important to mention that for each of these cases one must apply a different processing technique: fibers are produced by spinning, engineering plastics – via injection molding, and PET bottles – by means of injection molding and extrusion. For the spinning process one needs polymers with molecular weight around 20 000 because their melt viscosity corresponds to the required viscosity for performing of spinning process. Luckily, this is the molecular weight of the polycondensates after their primary synthesis. For using the injection molding, and particularly the extrusion, for processing the same polymers much higher melt viscosities are needed. Unfortunately, they cannot be reached during the primary synthesis of polymers because of the drastic increase of melt viscosity making further stirring of the reaction mixture impossible.

The solution of the problem has been found in using one of the chemical peculiarities of condensation polymers – their ability to undergo additional (post) condensation even in a solid state, as mentioned above. On the commercial importance of these reactions firstly stressed Flory in the mid-thirties of last century [55] and later described in the open (e.g. [64]) and mostly patent literature because of its commercial relevance.

The additional condensation in solid state is carried out with chips synthesized for fiber production in a reactor (usually under vacuum) at temperatures close but below melting for a couple of hours. Obviously, the importance of the solid-state additional condensation will steadily increase since the increasing needs of packaging materials – because of bad packaging 50%

of the food in the developing countries is spoiled, while in UK this amount is 2-3% [65].

The exchange reactions between condensations polymers also play a significant role in polymer science and technology. Let mention the case of polymer-polymer composites only. The mechanical performance of composite materials depends primarily on the adhesion quality on the interface between the matrix and reinforcement for effective transfer of the load between the two-basic component of the composite. In case these components represent condensation polymers, due to the exchange reactions an ideal adhesion is realized because of establishing chemical bonds between the matrix and reinforcement (e.g. [66, 67]).

Quite similar is the case with the compatibilization phenomenon in polymer blends and polymer-polymer composites involving condensation partner. Since by far the most of polymer pairs are thermodynamically non-miscible, for improving of their compatibility a third component, a “compatibilizer” is used, similarly to the surfactants in low molecular weight mixtures. A good example in this respect is the malleated polypropylene (PP) used in blends and composites of PP with polyesters and polyamides. Maleic anhydride undergoes to trans-reaction with the condensation partner (e.g. [68, 69]).

b) *Chemical healing in condensation polymers*

Self-healing is a well-known phenomenon in nature. The concept of “self-healing” of synthetic materials emerged a couple of decades ago and continues to attract scientific community progressively [70-79]. Self-healing polymers and fiber-reinforced polymer composites possess the ability to heal in response to damage wherever and whenever it occurs in the material. To date, self-healing has been demonstrated by three conceptual approaches: capsule-based healing systems, vascular healing systems, and intrinsic healing polymers [70, 71].

In a recent [80] detailed review on the chemical and physical aspects of self-healing materials it is stated that “*Due to limited chain mobility and a lack of bond reformation abilities, common polymers do not show self-repair attributes*” [80]. How does look the situation in reality?

When two samples of the same amorphous polymer are brought into good contact at a temperature above the glass transition, the interface gradually disappears, and the mechanical strength of the polymer-polymer interface increases until, at long contact times, the full fracture strength of the bulk polymer is regained. At this point the junction surface has become in all respects indistinguishable from any other surface that might be located within the bulk material - the junction has “healed.”

The earliest systematic studies of healing in polymers were related with autoadhesion (direct bonding or self-bonding) and adhesion of polymers [81] undertaken by Voyutskii [82], who proposed a molecular interpretation based on the diffusion of macromolecules. Some later, around 80-ies of the last century, the crack healing in polymeric materials has been a subject of intensive investigation summarized in recent reviews [81, 83-85]. To the same period belongs the formulation of the fundamental concept of "Reptation model", done mostly by de Gennes [2] and Edwards [3]. Their idea was immediately implemented in the molecular interpretation of the healing process [80, 81, 83]. The amorphous polymers are the most often studied ones. The crack healing is modeled at microscopic level by the following healing parameters: (i) center-of-mass Fickian interdiffusion in the healing of elastomers, (ii) average chain segment displacement and formation of new entanglements in the interfacial regions, (iii) change in crossing density of molecular chain end [80,83].

The self-diffusion in a bulk polymer helps to understand the healing process in the best way, but the two processes are not identical [83]. In the case of self-diffusion, the coils move over distances many times their mean diameter, whereas healing is essentially complete in the time it takes a polymer molecule initially next to the junction surface to move halfway across it. The healing time may take minutes, hours, or even days depending on the healing temperature and polymer characteristics [83]. Configurational relaxation in the bulk polymer is usually described by the "Reptation model" [2,3].

The described cases of self-repairing could be called *physical healing* so far one deals with samples which have not been subjected to any chemical treatment prior or during the healing process. An additional reason to precise the terminology is the fact that around the same time (1984) it was demonstrated that self-repairing is possible also because of chemical reactions in the same one- or two-component chemically non-treated polymers [86].

This was possible because a special attention was paid to linear condensation polymers. Like other classes of polymers, their chain flexibility increases with increasing temperature. Besides this physical process during the heating, as mentioned foreheads, chemical changes are also possible. In addition, the diffusion of low-molecular-weight fractions to the surface is a well-known phenomenon for poly(ethylene terephthalate). Such an enrichment of the surface on reactive chain-end groups will enhance the chemical reactions on the surface. It seems quite reasonable to expect that these reactions could take place at the interface between two samples of polycondensation polymer if (i) the contact is good enough, and (ii) suitable reaction conditions are created [86].

This assumption is supported by the observation mentioned above [62] that ester interchange reactions of poly(ethylene terephthalate) take place 20-30°C below T_m , that is, in the solid state.

The new molecular mechanism for the healing phenomenon in semicrystalline linear polycondensates, that is healing resulting from chemical reactions between macromolecules located in the interfacial surface, has been demonstrated by means of strips of commercial PET film. They have been annealed at 258°C to increase their T_m up to 260 – 268°C thus avoiding melt sticking during the subsequent heat treatment [86]. Two such strips are partially overlapped as shown in Figure 3, pressed, and heated in a vacuum at 240°C for 10 to 100 h. By measuring the stress at break, σ_b , outside the contact area and the debonding shear stress, τ_i , the critical overlapping length, l , has been computed. Further experiments [87] lead to the conclusion that transreactions contribute more than solid-state post condensation to the chemical healing.

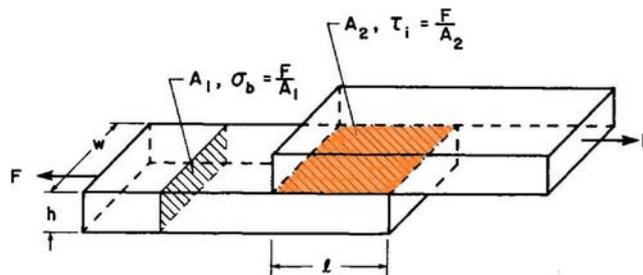


Figure 3: Schematic geometry of samples used for chemical healing experiments: σ_b – tensile strength, τ_i – shear strength [86]. Source: Fakirov S. Chemical healing in poly(ethylene terephthalate). Journal of Polymer Science: Polymer Physics Edition, 22, 2095–2104 (1984). Copyright 1984 John Wiley & Sons, Inc.

If two linear condensation specimens are undergoing the stage of wetting [80, 83], and the temperature is high enough, the solid-state post condensation and interchange reactions start. They result in the completion of the last two stages (diffusion and randomization) [80, 83]. An interesting assumption could be formulated in this case, namely, that to achieve a given extent of recovery, the "chemical" healing needs less time than the "physical" one. There are at least two reasons for this: (i) the "chemical" healing is less diffusion controlled (the most important factor seems to be the perfection of the contact) and (ii) the chemical interaction is possible even in the amorphous areas of the crystalline regions, as schematically represented in Figure 4. The diffusion (e.g., mutual interpenetration of the chains) is considered only in amorphous regions (Figure 4.), which for PET represent less than 50% of the surface [86].

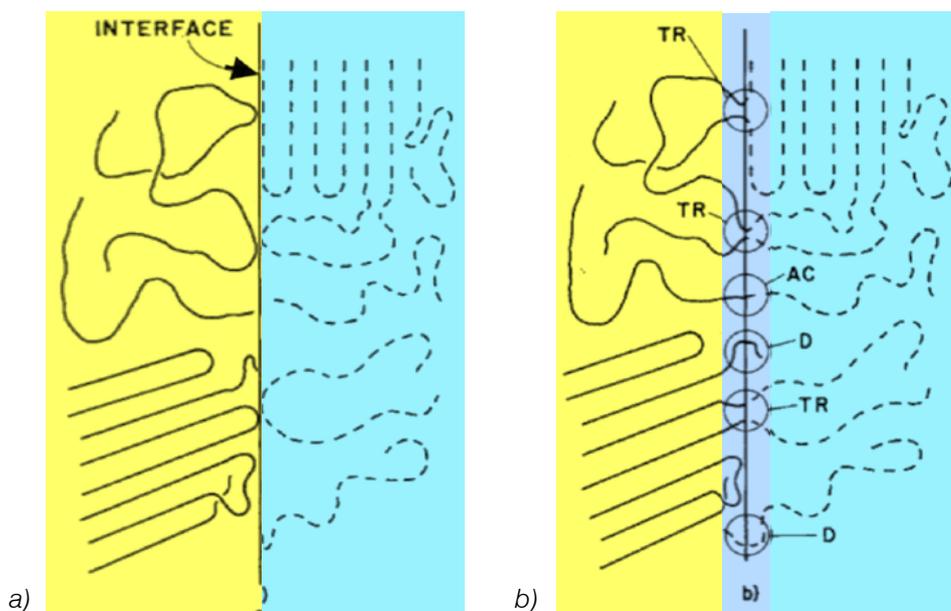


Figure 4: Schematic of chemical healing process in a semicrystalline linear polycondensate at temperature close (but below) to the melting: (TR) -transreaction, (AC) - additional condensation, (D) - diffusion [86]. Source: Fakirov S.: Chemical healing in poly (ethylene terephthalate). *Journal of Polymer Science: Polymer Physics Edition*, 22, 2095–2104 (1984). Copyright 1984 John Wiley & Sons, Inc.

Summarizing it could be concluded that the experiments described demonstrate a new molecular mechanism of the healing phenomenon in semicrystalline linear polycondensates - healing because of chemical reactions between neighboring macromolecules located in the interface surface. To distinguish this case of self-repairing from the previous case, the physical healing, it has been suggested [86] to be called *chemical healing*. Evidently, the chemical healing is quite a general property for all condensation polymers characterized by the ability to undergo transesterifications and/or additional condensation. R. Porter [68] has acknowledged this fact in his review on compatibility and transesterification in binary polymer blends as well as done in the recent monography of H. Kricheldorf [54] on polycondensation.

The common characteristic feature between the physical healing and the chemical healing is the fact that they are observed with chemically non-treated or modified polymers. The self-repairing in these two cases is related with the two basic and inherent properties of macromolecules – the ability to diffuse as well as to undergo chemical reactions (for condensation polymers only!). It seems quite reasonable to call just these two cases of self-repairing “*self-healing*”, since the respective polymers have not been subjected to any chemical treatment before performing the healing procedure or during their primary synthesis by adding a specific comonomer.

At the same time, in the last decade it has been noted that a few classes of reactions (currently they are at least 15 types [88]) offer self-repairing through the cleavage and reformation of specific bonds [80] but

these cases hardly could be called “self-healing”. The reason for this statement is that to perform this type of healing the respective polymer must be subjected to specific chemical treatment or during its basic synthesis a special comonomer must be used. Possibly, for such cases of self-repairing it would be more accurate to use the term “*chemically assisted healing*”.

The importance of the lack of external chemical intervention in proceeding of the self-healing processes is supported also by the interpretation of the term itself. According to Cambridge dictionary, “self-healing” means “*to describe a piece of equipment or system that has the ability to discover and correct faults without needing outside help*”.

Discussing the terminology aspect of the self-repairing phenomenon, one must add that the above-described case of chemical healing with condensation polymers could be further specify as *homochemical healing* [86,87] since it has been demonstrated [89] that chemical healing can be observed also if two chemically different condensation polymers are subjected to healing procedure. In such a case one deals with *heterochemical healing*. Such type of healing has been observed on two pairs of samples – PET and Nylon 66 as well as poly (butylene terephthalate) (PBT) and Nylon 6 [89].

All the above-described experiments on chemical healing [86, 87, 89] have been performed with polyesters and polyamides characterized by relatively good chain mobility. To distinguish the contribution of physical from chemical processes similar experiments have been carried out with polymers known by their inherent strongly restricted molecular and segmental

mobility due to the great rigidity of their macromolecules, as for example the case with cellulose is [90]. Multi-layered sheets of cleanex (fibrous delignified native cellulose) have been annealed at temperatures between 120 and 265°C under or without pressure. The tensile testing demonstrated that the strength is four times and modulus – eighteen times higher for the pressed sample than the non-pressed ones. A conclusion is drawn [90] that the observed welding cannot be attributed to diffusion of macromolecules through the interface; it is due mainly to solid state chemical reactions at the contacting surfaces. It should be mentioned that this same conclusion led to the healing experiments with a liquid crystalline polymer [91].

Further on, an attempt has been made to evaluate in a more precise way the contribution of solid-state chemical reactions to the healing effect between two contacting bulk pieces via chain mobility restrictions on a series of polyamides (Nylon 11, Nylon 12, and Nylon 66) [92]. Strips with higher melting temperatures have been obtained by annealing. To suppress the chain mobility in amorphous regions and to exclude or greatly minimize the diffusion of macromolecules during the healing process, the samples have been partially (only in amorphous regions) cross-linked using the technique of Arakawa et al., [93] based on methoxy methylation.

After such pretreatment of the samples the healing procedure is performed with partially overlapped strips (Figure 3) at temperatures enough below their respective melting to avoid sticking. Since at these healing temperatures the chains in crystallites are also immobilized, one can conclude that the observed welding effect is due exclusively to the chemical reactions on the contact surfaces.

The best proof for the dominant role of the solid-state chemical reactions in the healing process in linear condensation polymers is the observation that under the same healing conditions, the cross-linked samples of Nylon 11 display much higher shear stresses than un-cross-linked ones. It should be added that with cross-linking the shear modulus also changes, which affects the shear stress. If the diffusion of macromolecular chains is the controlling factor in the healing, then dealing with cross-linked samples one must observe the reverse situation [92].

A common characteristic feature of transreactions and the additional condensation regarding the healing effect is that they are possible only if the reaction partners are close enough in the space. Further on, if one considers that the concentration of the partners for transreactions is much higher than that of the terminal groups and that crystallinity and cross-linking suppress mobility, it follows that the probability of collision of the terminal groups is drastically reduced. At the same time crystallization and cross-linking lead to an

increase in the rate of transreactions, due to an increase in the concentration of stressed contact points [95]. In such a situation, the transreaction processes are favored, and it can be concluded that the healing effect is mainly a result of transreactions [92].

As a matter of fact, the most serious support in favor of conclusion about dominating role of chemical reactions in self-repairing process are the healing experiments with polyimide films characterized by extremely high values of their glass transition temperatures, T_g [96]. For example, T_g of Upilex-R (polyimide) is 285°C, and that of Kepton-H (polypyrromellitimide) – between 360 and 410°C. The healing experiments have been performed in the way described above for other polymers, as well as their testing. The applied healing temperature (T_h) has been 250°C, that means below or far below their T_g -values. The selected healing temperature has two important peculiarities: (i) it is high enough for performing of chemical reactions, and (ii) it is not high enough for realization of molecular movement since the respective polymer is at temperature below its T_g where such movement is excluded.

A jump in the temperature dependence of the shear stress of Kepton-H and Upilex-R is worth mentioning. The increase of the activation energy could be explained by chemical reactions taking place at the contacting surfaces [96].

The fact that the healing process is carried out at temperatures below the glass transition temperature of the respective polymer where the molecular diffusion is excluded, gives an idea about the contribution of the physical processes to the healing, that is, the welding in this case is due exclusively to the chemical processes [96].

c) *Sequential reordering in condensation copolymers via transreactions*

The study of transreactions started with the pioneering work of Flory [55]. These reactions have been convincingly confirmed, as mentioned in the previous sections, by studying blends of protonated PET with deuterium labelled (d4) PET by SANS; they take place rapidly in the melt as well as at lower temperatures (some 20-30°C below the melting of PET [62]) resulting in formation of a block copolymer [97]. In the subsequent years they have been widely used for preparation of condensation copolymers starting from blends of homopolymers (e.g. [98]). The blends are converted first into block copolymers and finally into random copolymers because all repeating units are equally likely to react. Therefore, the properties of a blend in which transreactions are possible depend on the rate and degree of completeness of exchange reactions.

In fact, any type of sequential order is characterized by the properties, mostly physical ones.

For example, a copolymer with blocky sequential ordering should crystallize if at least one of the starting homopolymers is crystallizable and that a copolymer with random type of sequential ordering is non-crystallizable. The study of the behavior of the crystalline phase(s) can offer an insight in the occurrence and depth of chemical interactions between the blend components as well as in the sequential order in

copolymers. At the same time, the properties of the amorphous phases will support these conclusions since at the stage of complete randomization, particularly in equimolar blends of condensation polymers, a single glass transition should be observed instead of the two glass transitions, typical of a mechanical blend or of a block copolymer as shown in Figure 5.

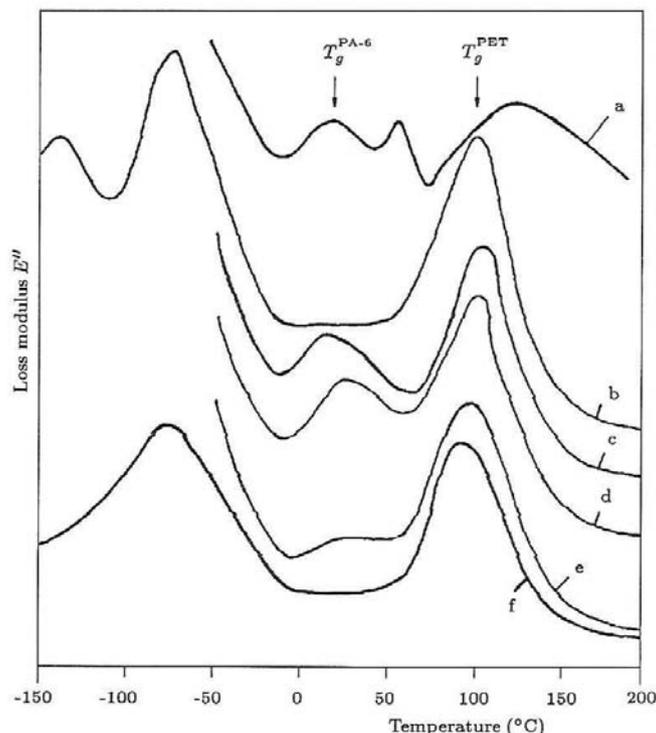


Figure 5: Temperature dependence of the loss modulus E'' in the range from -150 to 200°C . Annealing temperatures and durations are as follows: (a) non-annealed, undrawn; (b) non-annealed) drawn to $\lambda = 4.2$; (c) $T_a = 220^{\circ}\text{C}$, $t_a = 5\text{h}$; (d) $T_a = 220^{\circ}\text{C}$, $t_a = 25\text{h}$; (e) $T_a = 240^{\circ}\text{C}$, $t_a = 5\text{h}$; (f) $T_a = 240^{\circ}\text{C}$, $t_a = 25\text{h}$ [99]. Source: Serhatkulu T., Bahar I., Erman B., Fakirov S., Evstatiev M., Sapundjieva D.: Dynamic mechanical study of amorphous phases in poly (ethylene terephthalate)/nylon-6 blends. *Polymer*, 36, 2371–2377 (1995). Copyright 1995 Elsevier.

The method of dynamic-mechanical thermal analysis (DMTA) is commonly considered as the most reliable technique for the determination of T_g and for this reason it was applied to the PET/PA 6 blend subjected to drawing and annealing. The results are summarised in Figure 5 [99].

Again annealing at lower temperatures, or at higher ones (240°C but for shorter times), leads to the formation of two well-defined and spatially separated amorphous phases, characterized by two glass transition temperatures, T_g^{PET} and T_g^{PA6} for the PET and PA 6 amorphous phases, respectively (Figure 5c,d). Annealing at 240°C for 5 h (Figure 5e) results in a decrease in the PA 6 amorphous fraction. After annealing for 25 h it disappears completely (Figure 5f). This observation indicates that after such a thermal treatment, all of the amorphous PA 6 is involved in a copolymer with the amorphous PET.

Evidence derived from the behavior of the crystalline phases has been obtained on the same blend of PET with polyamide 6, subjected also to drawing after extrusion and annealing for various times around the melting temperatures of the blend components [100]. Wide-angle X-ray scattering (WAXS), Figure 6, demonstrates that the thermal treatment at 220°C for 5 h (Figure 6a) results in a crystalline highly oriented polymer blend. The situation changes drastically after annealing at 240°C for 5 h (Figure 6b) - the PA 6 diffraction patterns are in the form of Debye rings, suggesting isotropy of that component. At the same time, the orientation and perfection of the crystallites in the PET fraction remain unchanged. Prolonged annealing (25 h) at the same temperature (above T_m of PA 6!) leads to the almost complete disappearance of the PA 6 Debye rings (Figure 6c).

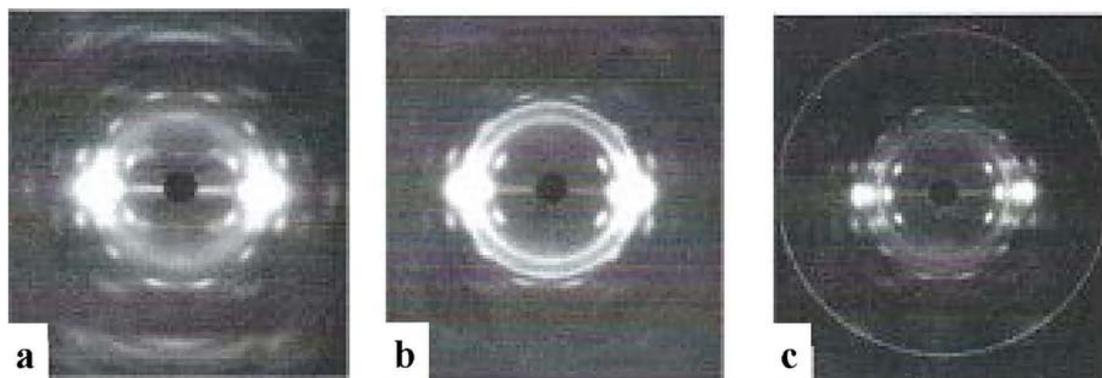


Figure 6: WAXS transmission patterns of PET/PA 6 blend, zone-drawn and annealed at different temperatures and for various durations: (a) $T_a=220\text{ }^\circ\text{C}$, $t_a=5\text{h}$, (b) $T_a=240\text{ }^\circ\text{C}$, $t_a=5\text{h}$, (c) $T_a=240\text{ }^\circ\text{C}$, $t_a=25\text{h}$. The patterns are taken at room temperature after the respective annealing [100]. Source: Fakirov S., Evstatiev M., Schultz J. M.: Microfibrillar reinforced composite from drawn poly(ethylene terephthalate)/nylon-6 blend. *Polymer*, 34, 4669–4679 (1993). Copyright 1993 Elsevier.

The WAXS patterns shown in Figure 6 also demonstrate an important peculiarity of transreactions in condensation polymers – they take place even if one of the reaction partners is in a solid state. The annealing temperature of 240°C is by 20°C above the T_m of PA 6 and at least by 15°C below the T_m of PET. If at this temperature PET is in a molten state it should lose its orientation as PA 6 did during the shorter annealing at 240°C (Figure 6b). Figure 6c proves that PET preserves its orientation during annealing at 240°C , that is, it remains in a solid state. On the possibility of performing of chemical reactions in a solid PET (some 20°C below melting) was indicated even earlier [62].

What is more, the same data from WAXS (Figure 6c) and from DSC (Figure 7, curve (f)) demonstrate that the total amount of PA 6 react with the half of the PET only since the other half builds the crystallites, which are not involved in the chemical interactions (typically, the maximum crystallinity of PET is 50%).

To the same conclusions leads the testing of the same samples by means of differential scanning calorimeter (DSC) [100] as demonstrated by the respective curves displayed in Figure 7.

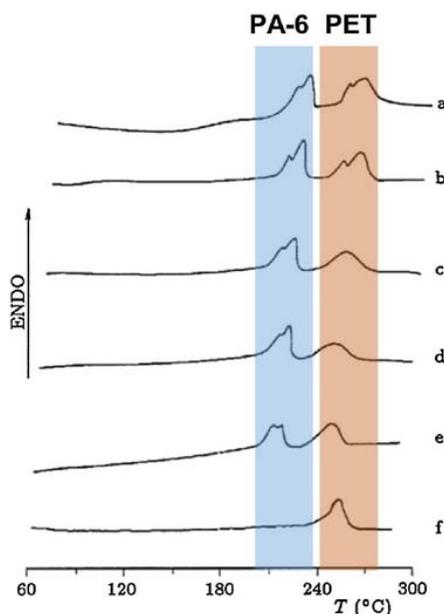


Figure 7: DSC curves of PET/PA 6 blend (ultraquenched, zone-drawn and additionally annealed at different temperatures and for various durations) taken in the second heating mode. Annealing temperatures T_a and durations t_a : (a) unannealed, undrawn; (b) unannealed, drawn 4x, (c) $T_a=220\text{ }^\circ\text{C}$, $t_a=5\text{h}$, (d) $T_a=220\text{ }^\circ\text{C}$, $t_a=25\text{h}$, (e) $T_a=240\text{ }^\circ\text{C}$, $t_a=5\text{h}$, (f) $T_a=240\text{ }^\circ\text{C}$, $t_a=25\text{h}$ [100]. Source: Fakirov S., Evstatiev M., Schultz J. M., Microfibrillar reinforced composite from drawn poly(ethylene terephthalate)/nylon-6 blend. *Polymer*, 34, 4669-4679 (1993). Copyright 1993 Elsevier.

These observations indicate that after such a thermal treatment, the total amorphous PA 6 is involved in a copolymer with the amorphous PET. The behavior of both, the crystalline (Figures 6 and 7) and amorphous [99] phases clearly indicates that the PA 6 starting component does not exist anymore as individual component. This is due to its involvement in a copolymer with a supposedly random structure because of transreactions taking place during prolonged annealing at elevated temperatures.

Table 1: Weight losses (based on the PA 6 content) as a result of selective extraction of PA 6 of a PET/PA 6 blend (1:1 by wt.) after various thermal treatments [100]

	Samples as in Figure 7					
	a	b	c	d	e	f
Annealing temp. (°C)	-	-	220	220	240	240
Annealing time (h)	-	-	5	25	5	25
Weight loss (%)	98	96	91	80	62	22

However, the losses depend strongly on the annealing temperature - for the thermally untreated samples they are about 100% whereas after annealing at 240°C for 25h they drop to about 20% (Table 1, samples (a) and (f)). It can be concluded that practically the entire PA 6 fraction is extracted in thermally untreated samples, in contrast to those annealed at 240°C for 25 h. The rise in the intensity of the IR absorption band at 3300 cm⁻¹, as well as in the range of 2200- 2800 cm⁻¹, which is characteristic of the vibrations of the -CH₂- groups, follows the same trend since the copolymer is enriched in -CH₂- groups, as compared to homo-PET [102]. Thus, it is quite clear that the amount of PA 6 incorporated in a copolymer increases with the rise of the annealing temperature and duration.

The involvement of the total starting amount of PA 6 into a copolymer with PET has been demonstrated also by selective (only PA 6) dyeing with wool-type dyestuff – a complete homogeneous dyeing of the thin slices on the microphotographs after the final treatment is observed, contrasting the partial dyeing in the non-treated samples [101].

The exchange reactions and particularly the sequential order in condensation copolymers prepared via interchange reaction in blends of condensation homopolymers have been studied by Lenz et al. (e.g. [103], Devaux et al. (e.g. [104]), Economy et al. [105,106] and others. The first systematic study on the factors determining the sequential order in these copolymers has been performed by Fakirov et al. (e.g. [107]). These studies ([107]) have been based on the understanding that the exchange reactions resulting in randomization of the copolymers are the same as those leading to regeneration of the blocky character of the copolymers, that is, the sequential order is not determined by the exchange reactions but by other factors present in the system at the given conditions.

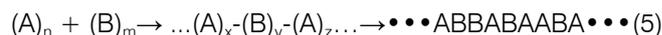
It should be mentioned that the described chemical changes are proven also by following the behavior of other physical properties during melt annealing at various temperatures and durations. For example, application of IR spectroscopy after selective extraction with formic acid, accompanied by weight control of the fraction supports the above conclusions. The weight losses after extraction are given in Table 1.

The exchange reactions are a tool only for realization of one or other sequential order, they do not determine this order! About the type of the sequential order in these studies (e.g. [103]) it has been judged exclusively from the crystallization (T_m) and glass transition (T_g) behaviors.

What is more, using these factors it is possible to control the sequential order in condensation copolymers as it will be demonstrated below.

i. *Melting-induced sequential reordering in condensation copolymers*

The clearest case regarding the factors determining the type of the sequential order is that of the melting-induced sequential reordering. It is generally accepted that because of direct interchange reactions, the blend of homopolymers transforms into a block copolymer which subsequently turns into a random one:



It has been demonstrated [104] that the rates of the direct and reverse reactions are identical. This is quite understandable, considering that the bonding energies of broken and reformed bonds are almost the same in both directions. Nevertheless, randomization proceeds as a practically irreversible process (under given conditions) and eventually a random copolymer obeying Bernoulli statistic is formed [104].

In the case of ester-ester interchain reactions at elevated temperatures, usually above T_m , the randomization is driven only by the large entropy increase originating from the transition of the block copolymer into a random one. This results in the final randomization of the blend and in a drastic change of its properties - crystallization ability, solubility, transition temperatures, etc.

Performing experiments with blends of crystallizable or non-crystallizable polycondensates, the

partners being thermodynamically miscible or non-miscible, it has been unambiguously demonstrated that annealing above the melting temperature results in a complete randomization. At the same time annealing the

random copolymer below the melting temperature (some 20°C) leads to the restoration of the blocky structure. Figure 8 demonstrates these two cases for the blend PET/polyarylate (PAR):

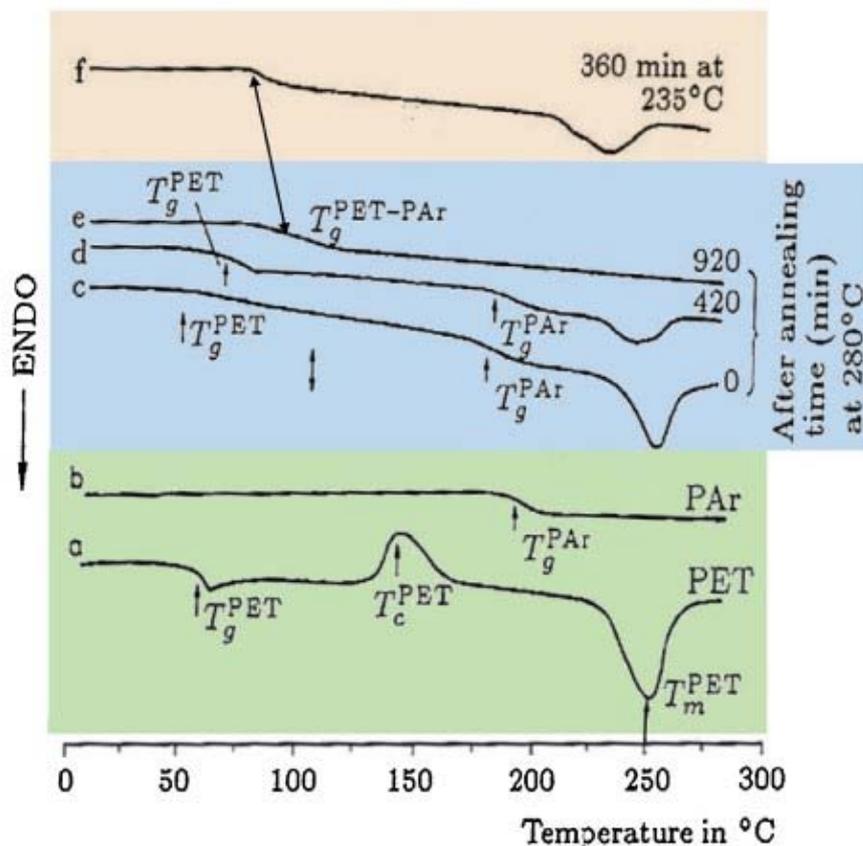


Figure 8: DSC curves of the PET/Par (50/50wt%, or 62/38 molar ratio), taken in heating mode at 10°C/min, after various annealing times at 280°C and 235°C. Sample weight: 7.62 mg. Curves of the starting PET and PAR are given for comparison. Sample weight: 12.0 and 9.0mg, respectively [108]. The color coding is used to illustrate the transition to random (blue) and back to blocky (braunish) state of copolymers; green – the starting homopolymers. Source: Denchev Z., Fakirov S., Sarkissova M., Yilmaz F.: Sequential reordering in condensation copolymers. 2. Melting- and crystallization-induced sequential reordering in miscible poly(butylene terephthalate)/polyarylate blends. *Macromolecular Chemistry and Physics*, 197, 2869–2888 (1996). Copyright 1996 Wiley-VCH Verlag GmbH & Co. KGaA.

Considering the fundamental statement that transreactions do not determine the type of sequential order and that they are just a tool for its realization, it might be possible to observe such a situation, when other factors appear in the system, acting more strongly than and in opposition to those causing randomization to take place. A good example in this respect is the crystallization. It becomes effective when a randomized condensation copolymer is brought to a temperature below the melting of the crystallizable blend component.

ii. *Crystallization-induced sequential reordering in condensation copolymers*

Figure 9 illustrates schematically the transition from a random into a block copolymer, suggesting that crystallization is the driving force for sequential

reordering after cooling a randomized copolymer to a temperature below the T_m of the crystallizable component. It is quite evident that sequences of 2-3 repeating units are not long enough to form a lamella of thickness l_c . The lowest values of l_c are about 50-60 Å, as demonstrated for poly(butylene terephthalate) copolymers [109]. Assuming these values of l_c to be the lower limit and considering that the length of the PET repeat unit in the chain-axis direction is about 11 Å, it is easy to conclude that crystallization of PET can occur only if PET blocks of at least 5-6 repeating units are available. This axiomatic requirement can be considered as the basic driving force toward the blocky structure when crystallization conditions are established [107].

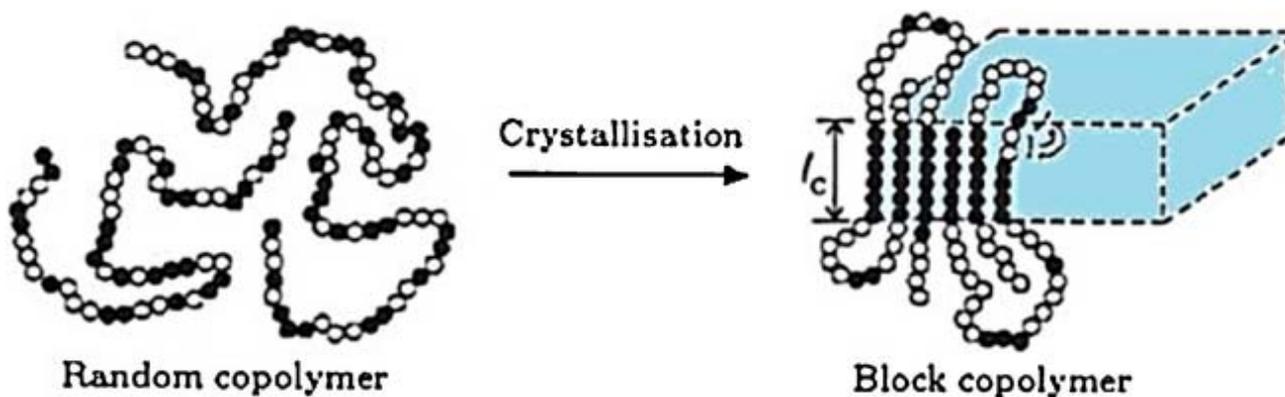


Figure 9: Schematic representation of the transition from random to block copolymer taking place via transreactions under the influence of crystallization [110]. Source: Fakirov S., Sarkissova M., Denchev Z.: Sequential reordering in condensation copolymers. 1. Melting- and crystallization-induced sequential reordering in immiscible blends of poly(ethylene terephthalate) with polycarbonate or polyarylate. *Macromolecular Chemistry and Physics*, 197, 2837-2867 (1996). Copyright 1996 Wiley-VCH Verlag GmbH & Co. KGaA.

The model depicted in Figure 9 demonstrates another important peculiarity of crystallization-induced sequential reordering. Formation of lamellae of thickness l_c not only stimulates sequential reordering in favor of the blocky structure, but also restricts the block length to the value of l_c so one can speak in this case of "microblock copolymers" with quite uniform block length distribution, that is controlled block regeneration.

Crystallization-induced sequential reordering is only one of the possible cases in which the sequential order in condensation copolymers is changed. It was worth looking for copolymer systems where the

transition from a random copolymer to a blocky one is governed by factors not related to crystallization.

iii. *Miscibility-induced sequential reordering in condensation copolymers*

One can design an equimolar terpolymer in a two-stage preparation process. Let us have three condensation homopolymers $(A)_n$, $(B)_m$ and $(C)_p$; the first two, $(A)_n$ and $(B)_m$, are immiscible, while $(B)_m$ and $(C)_p$ are miscible. During the first stage of preparation, randomization in the A/B blend takes place:



After completion of the randomization, the copolymer $(AB)_n$ is melt-blended with the third

homopolymer $(C)_p$ and further randomization occurs, resulting in a random terpolymer:



The randomization takes place in the melt via interchain reactions at temperatures above the melting points of all crystallizable components as manifold demonstrated (e.g. [98]). If the randomized terpolymer

(eq.(7)) is kept for a longer time in the molten state, one can expect changes in the sequential order in favor of the blocky structure:



This expectation is based on the miscibility of the homopolymers $(B)_m$ and $(C)_p$. Since miscibility requires interaction between longer polymer chains, a tendency toward the formation of longer B- and C-sequences should exist. If one considers that transreactions frequently occur in the melt, the formation of blocks (eq. (8)) seems to be very probable as confirmed experimentally [111]. For this purpose, two systems each one comprising 3 homopolymers have been used. The first one consists of poly(butylene terephthalate)/polycarbonate/polyarylate (PBT/PC/PAr) where PBT and PAr are thermodynamically miscible. The second one involves PBT, PA 66 and PAr, where again PBT and PAr are miscible. In both cases the results

obtained confirmed the sequential reordering described schematically by eqs. (6), (7) and (8) [111].

In the above-described cases of sequential reordering in condensation copolymers were discussed the experimental results exclusively from the DSC studies. It should be mentioned that these results and conclusions were supported by parallel studies by means of size exclusion chromatography combined with NMR after selective degradation [112,113]. For some cases it has been used also wide-angle X-ray scattering [110].

In summary, the repeatedly reported randomization of molten condensation block copolymers is observed again and proved by various

techniques sensitive to the changes in the crystalline and/or the amorphous phases. The process is accompanied by a loss of crystallization ability. This *melting-induced sequential reordering* is driven mostly by the entropy increase.

Restoration of crystallization ability is observed after annealing of random condensation copolymers and attributed to regeneration of crystallizable blocks. This *crystallization-induced sequential reordering* is driven by upsetting the random \rightleftharpoons blockpolymer equilibrium during the annealing of the random system.

Restoration of crystallization ability is also observed in random terpolymers obtained by melting-induced sequential reordering of ternary homopolymer blends, in which two of the constituents are thermodynamically miscible over the entire concentration range. The effect is established by subjecting these terpolymers to prolonged annealing at the same temperature as copolymer preparation. In this *miscibility-induced sequential reordering* the process of block restoration is driven by the miscibility factor.

Both randomization and block regeneration are dependent on temperature, transesterification catalyst, and miscibility of blend components. These processes are composition-sensitive and seem to be related to the specific chemistry of the interchange reactions and starting homopolymer structures. The results obtained show that in the transition from block to random copolymer, (i.e., from longer to shorter blocks), the sample crystallizability decreases, attaining eventually a complete amorphization (as revealed by DSC). Likewise, regeneration of melting endotherms in the crystallization-induced reordering process should reflect the restoration of longer blocks of a crystallizable component. All these changes in the sequential order of condensation copolymers affect drastically their structure and properties [114].

The above definitions describing the three most important cases of sequential reordering in condensation copolymers, including also the factors determining the respective type of order, were formulated in refs. [108,110,111], respectively. They were not only well accepted and widely used but were also proven correct through computer modeling and further experiments (e.g. [115]).

It seems important to stress again that all the analysis related with the sequential reordering in condensation copolymers are based on the understanding that exchange reactions do not determine the type of the sequential order; they represent a tool only for realization of a given type of ordering and this type is determined by other factors in the system.

d) *Chemically released diffusion via transreactions*

Studying the new phenomenon of *chemical healing* in condensation polymers [86, 87] as result of

chemical interactions at elevated temperatures, the concept of "*chemically released diffusion*" was formulated [89] and supported later by Economy et al. [106]. This aspect demonstrates that mass transfer in condensation polymers at temperatures close to the melting point, as well as in the melt, is paralleled by chemical reactions mostly of exchange type shown above. The contribution of the latter to the mass transfer depends strongly on the temperature, reaction conditions (pressure, catalyst, media, etc.), and most likely on the number of favorable contacts between the different chains. It is to be expected that this number will increase with increasing temperature because of chain relaxation.

The results described above allow to make some inferences concerning the diffusion mechanism for long chains in linear condensation polymers at elevated temperatures. It seems quite likely that the transport of sections of macromolecules through the bulk is due not only to physical diffusion processes but also to chemical ones. If the temperature is high enough, a section of macromolecule (a segment or repeating unit as the smallest possible section) does not remain in its original macromolecule. Due to transreactions between different molecules, some sections frequently change their neighbors. Furthermore, the chemical composition of the section itself could be changed if transreactions occur between chemically different molecules.

In such cases, that is, when transreactions are possible (transesterification, transamidation, transesterification, etc.), we can speak of "*chemically released diffusion*" of the macromolecular chains as suggested in [89]. This aspect further demonstrates that mass transfer in this type of polymers at temperatures close to the melting point, as well as in the melt, is accompanied by such chemical reactions. The contribution of the latter to the mass transfer depends strongly on the temperature and reaction conditions (pressure, catalyst, media, etc.). It seems that "*chemically released diffusion*" will not be sensitive to molecular weight. The determining factor is most likely the number of favorable contacts between the different chains. It is to be expected that this number will increase with increasing temperature because of chain relaxation. As demonstrated by measurements using small-angle neutron scattering, these contacts are quite intensive [97].

The presence of entanglements (stressed points) will favor the exchange reactions, as mentioned above [95]. The higher their concentration, the larger the contribution of chemically released diffusion. The efficiency of the stressed points depends on temperature in the same way as in the case of "neighboring" contact and for the same reason.

The concept of chemically released diffusion was seriously supported by similar experiments with

chemically cross-linked polyesters performed by Economy et al. [105,106].

Concluding this subsection, it seems interesting to cite an opinion regarding the chemically released diffusion, expressed in a review article on the recent advances of hierarchical and sequential growth of macromolecular organic structures on surface [116]:

"Before continuing, a distinction should be made between "self-assembly", which is commonly used to evoke the formation of both supramolecular and covalent phases on-surface, and "chemically released diffusion". Indeed, numerous published or being published articles comprise the terminology "self-assembly" whereas the right term is "chemically released diffusion". Indeed, "self-assembly" refers to the self-organization of molecular tectons on surface without necessarily involving a chemical modification of the molecular tectons and this terminology is well-adapted for supramolecular phases for which the cohesion is ensured by weak intermolecular interactions between elemental building blocks. Contrastingly, chemically released diffusion refers to mass transfer occurring in polycondensates due to the permanent exchange of fragments existing between molecular segments under growth (i.e., via transreactions). This concept developed in the early 1980s by Prof. Stoyko Fakirov is more adapted to describe the formation of covalent phases on surface, the chemical composition of the polymer under growth continuously evolving by exchange reactions" [116].

V. KINETICS OF EXCHANGE REACTIONS IN MELTS OF CONDENSATION POLYMERS

The above rather detailed analyses of the occurrence of additional condensation and exchange-(trans) reactions in condensation polymers was done with the only purpose to demonstrate that these reactions not only exist but they play important role in polymer science and technology. Only using these types of reactions, it is possible to manufacture special polymer materials as bottle grade PET, condensation copolymers from polymer blends, realization of the compatibilization phenomenon in polymer blends, etc.

The same reactions, particularly the exchange reactions, offer a new insight on fundamental theoretical properties of polymer systems as for example the diffusion mechanism in melts and solutions of condensation polymers as demonstrated in the foregoing paragraph dealing with the chemically released diffusion. The evaluation of the contribution of exchange reaction in the diffusion process and its mechanism assumes a better knowledge of kinetics of exchange reactions in melts of condensation polymers.

The fundamental development of the kinetics of condensation reactions in polymer chemistry has been done by Carothers [117] and Flory [55] with later

contributions of other researchers [98]. Various techniques have been used for studying the additional condensation and exchange reactions as IR spectroscopy (e.g. [104]), NMR spectroscopy (e.g. [118]), WAXS (e.g. [119]), and others. Of particular importance for the purpose of the current review are the studies performed by means of small angle neutron scattering (SANS) on blends of protonated and deuterated species (e.g. [120-122]).

For example, Kugler et al. studied the rate of the interchain transreactions between deuterated and non-deuterated PET chains at 280°C and calculated approximately 10 transesterification reactions occurring per molecule per minute [97]. This means that for fiber grade PET (with a molecular weight of $\sim 20\,000$, i.e. degree of polymerization $n \sim 100$) each minute fragments of 10 repeating unit leave a given molecule and join another neighboring one. With increase of the melting temperature the exchange reactions become more intensive and the migrating blocks considerably shorter.

The potential for very rapid transreactions in the copolyesters has been demonstrated by heating a 50/50 mixture of the two homopolymers of poly(acetoxy benzoic acid) and poly(2,6-hydroxynaphtoic acid) at 450°C – the rates are more than 100 ester interchange reactions per chain per second [105]! In addition to the temperature, transreactions are favored by the presence of entanglements, as mentioned above – the higher their concentration the more intensive exchange reactions.

The experiments on chemical healing with cross-linked polyamides [92] and polymers distinguished by extremely high glass transition temperatures [96] demonstrated that the chemically released diffusion is a principal mode for mass transfer in condensation polymers. Further on, the mechanism by which the adhesive bond forms in both liquid crystalline polymers and thermosetting polyesters has been investigated using secondary ion mass spectroscopy (SIMS) and neutron reflection techniques [106]. These complementary analytical techniques have been used to examine the entire range of physical and chemical diffusion distances possible in the aromatic copolyesters. Long range effects could be examined by SIMS while neutron reflection would be able to detect localized interfacial diffusion. The contrast across the interface for the aromatic copolyesters has been achieved by observing the interpenetration between thin films of deuterated and non-deuterated copolyesters.

No observable changes in SIMS depth profile were registered with annealing after 10 h at 280°C. Since the depth resolution of SIMS is 500 Å, any changes on the polymer-polymer interface are predicted to occur over length scales of less than 500 Å. Neutron reflection data suggest that the actual amount of interpenetration is less than 300 Å after 11 h at 280°C [106].

Since the individual films were cured into infinite molecular weight networks prior to joining and annealing, physical diffusion of individual polymer chains or fragments across the interface would not be possible. Thus, the only mechanism available for adhesion across the polymer-polymer interface would be chemical interdiffusion through rapid high-temperature interchain transreactions [106].

VI. ON THE APPLICABILITY OF “REPTATION MODEL” TO MELTS OF CONDENSATION POLYMERS

Coming back to the basic question regarding the diffusion mechanism in melts of non-condensation and condensation polymers at high temperatures, it seems important to try to assess the applicability of the “Reptation model” to melts of condensation polymers. The presented above data on the peculiar only for condensation polymers chemical reactions and their importance for polymer science and technology demonstrate that the classical picture of self-diffusion in polymers, or the “Reptation model”, as proposed by de

Gennes [2] and Edwards [3], needs to be complemented. Contrasting the non-condensation polymers where the “Reptation model” is the only mechanism for explaining the diffusion process, the case of condensation polymers seems to be more complex. At lower temperatures (for example, up to $T_m + 100^\circ\text{C}$) it looks that the diffusion mechanism is according to the Reptation concept but with some peculiarities - parallel occurring exchange reactions (transesterification, transamidation, transesterification, etc.). If the temperature is high enough, a given fragment no longer appertains to its initial macromolecule. Due to transreactions between different macromolecules, macromolecule's fragments frequently change their immediate neighbors. Furthermore, the chemical composition of such a fragment can change, if transreactions occur between chemically different macromolecules.

This process of continuous leaving from a given macromolecule of fragments, which join another macromolecule (or even the same) is schematically presented in Figure 10.

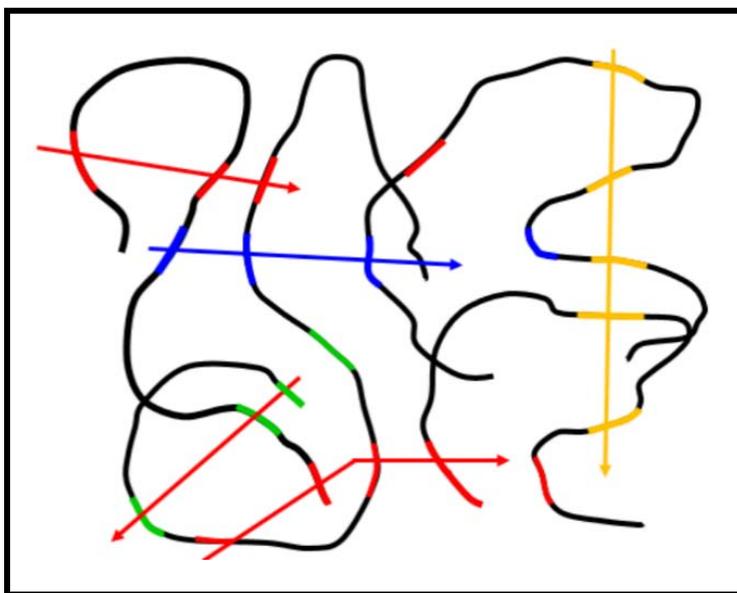


Figure 10: Schematically the diffusion mechanism in melts of condensation polymers – fragments of a given macromolecule are leaving it and are incorporated in a neighbouring second, third, fourth ... macromolecule via transreactions. The colour coding demonstrates the fragments and their direction of movement, which is not necessarily according to a straight line. The use of two colours only would realistically reflect the case of a blend of two chemically different condensation polymers.

Completely different is the situation at much higher temperatures. As already mentioned above, in the melt of condensation polymers in each macromolecule, each second takes place breaking the contacts between the neighbouring repeating units. Before establishing a contact (chemical bond) with new (or previous repeating units) the fragment can move, diffuse. However, these fragments move as a single repeating unit (or as small blocks of them) and not as

whole long macromolecules. What is more, the macromolecules as long real chains do not exist anymore since the chemical bonds between the repeating units are frequently broken and re-established again (but not necessarily between the previous neighboring repeating units). The macromolecules as stable chains with constant chemical composition appear when the temperature is lowered and the intensity of transreactions is drastically reduced.

In molten blends of condensation homopolymers, one can distinguish two stages of diffusion, due mostly to the different driving force of the mass transfer. During the very first moments of chemical interactions between two homopolycondensates, a

block copolycondensate is formed, which further randomize in a random copolycondensate according to eq. (9). The driving force for these changes in the sequential order is the entropy increase during the transitions:



It is also possible to say that the driving force is the concentration gradient leading to a homogeneous distribution of the two chemically different repeating units in the whole volume.

During the second stage, when complete randomization is achieved, the driving force for the mass transfer is the Brownian motion only. The independent kinetic elements, in this case, are the smallest fragments of macromolecules comprising one or a few repeating

units. Their motion is schematically illustrated in Figure 11, where the single black particles represent the fragments, which leave a given macromolecule and join another one. This takes place continuously, resulting in mass transfer in an arbitrary direction. This diffusion mechanism is rather a like to that of the low molecular substances and is quite different from the diffusion mechanism illustrated by the "Reptation model", as recently suggested [123].

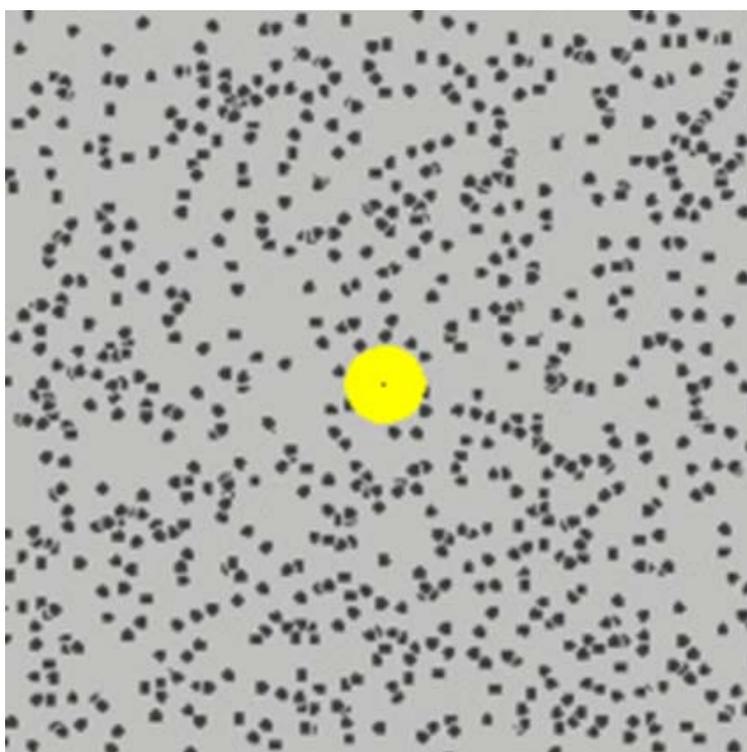


Figure 11: Schematically the diffusion mechanism in melts of condensation polymers at extremely high temperatures ($T_m + 100$ °C and above). The single independent kinetic elements (black particles) are short fragments of macromolecules, comprising one or a very small number of repeating units, which move in any possible direction. Large, flexible, entangled, and stable formations (macromolecules), to which one could apply the "Reptation model" for explaining the diffusion mechanism, are missing. (The motion can be seen by clicking here). The yellow object represents a particle with much larger sizes.

Slightly different is the situation when one deals with a melt of a single polycondensate. In such cases, the first stage is missing, since practically there is no entropic contribution to the mass transfer and the diffusion is related to the Brownian motion only, as visualized in Figure 11.

Let stress again that the main task of this study is to demonstrate that the diffusion mechanism in melts of condensation polymers above some temperatures could be different from the mechanism offered by the

Reptation model, which is based on the concept of segmental motion of macromolecules. Above a given molecular weight (or degree of polymerization) independent kinetic entities are not the macromolecules as a whole formation but their segments. The segments comprise one or a few repeating units (in a case of flexible molecules) or the whole macromolecule (in a case of rigid molecules as those of liquid crystalline polymers) and allow us to describe the behavior of

polymers by means of the laws derived for the low molecular weight substances[5].

This means that for the describing the kinetic properties of macromolecules (deformations, diffusion, mass transfer, etc.) we are using not the whole molecules but their segments, i.e. much shorter formations than the whole molecules. This approach, namely considering the macromolecules as comprised of many kinetically independent elements for describing many polymer properties is applicable to all polymers, the non-condensation and condensation ones. The same approach is a basic element of the "Reptation model" – movement in a snake-like way.

At the same time, as already discussed, an inherent property of condensation polymers is their ability to undergo intensive interchange (trans) reactions in their melts above some temperatures. This means further dissipation of macromolecules to shorter sections. The situation is like the case of "decomposition" of macromolecules to segments, but there is a substantial difference between the two cases. While segments do not exist as real independent formations, the sections comprising one or a few of repeating units really exist. They not only exist but they move in a rather freeway in the melt as independent kinetic elements. Since their sizes are in range of the sizes of the common non-polymeric molecules, their diffusion mechanism must be close to that of low molecular weight substances and different from the diffusion mechanism of macromolecules suggested by the Reptation concept.

The fact that the macromolecules of condensation type do not exist anymore at higher melt temperature as whole entities, but as truly short sections is well established and accepted. For some unknown reasons, this fact is not considered by the specialists researching the diffusion and mass transfer processes in melts of condensation polymers. Possibly because all studies related with the Reptation concept have been performed with non-condensation polymers, as also demonstrated by a recent review on modeling of entangled polymer diffusion in melts and nanocomposites [124].

VII. CONCLUDING REMARKS

Summarizing the above considerations, we could conclude that the diffusion mechanism in polymer melts could be at least of two types. Depending on molecular weight and temperature, or more precisely, dealing with substances with relatively low molecular weights (monomers, oligomers, that is before reaching the molecular weight of the segment) independent kinetic elements are the whole molecules and the diffusion mechanism is the same as that in the melts of low molecular weight substances.

With the further rise of the molecular weight, i. e. above that of the segment, the independent kinetic elements are the segments. Their number in a single macromolecule depends on its flexibility – the higher the flexibility the shorter the segment length and the larger their number is [5]. The diffusion mechanism is segmental to which could be applied the Reptation concept.

Dealing with melts of condensation polymers it should be noted that the outlined two diffusion mechanisms are valid for melt temperatures not much higher than the melting temperatures. With further rise of melt temperature (for example, for PET it is above $(T_m + 100^\circ\text{C})$) very intensive exchange reactions take place, which results in a drastic change of the diffusion mechanism – the independent kinetic elements are not the molecules neither the segments but the repeating units or their small blocks with sizes typical for the molecules of low molecular weight substances. It follows that the diffusion mechanism for this range of temperatures is the same as that for the case of the melts of low molecular weight substances.

In conclusion, the diffusion mechanism in polymer melts could be of two types – molecular and segmental. The Reptation concept can be applied to segmental type of diffusion only. It follows that for melts of condensation polymers at extremely high melt temperatures the "Reptation model" cannot be used for explanation of the diffusion mechanism since independent kinetic elements are the repeating units, that is the mechanism is molecular.

In Figure 12 an attempt is undertaken to present schematically the described situation stressing on the individual kinetic elements and the respective diffusion mechanism in melts.

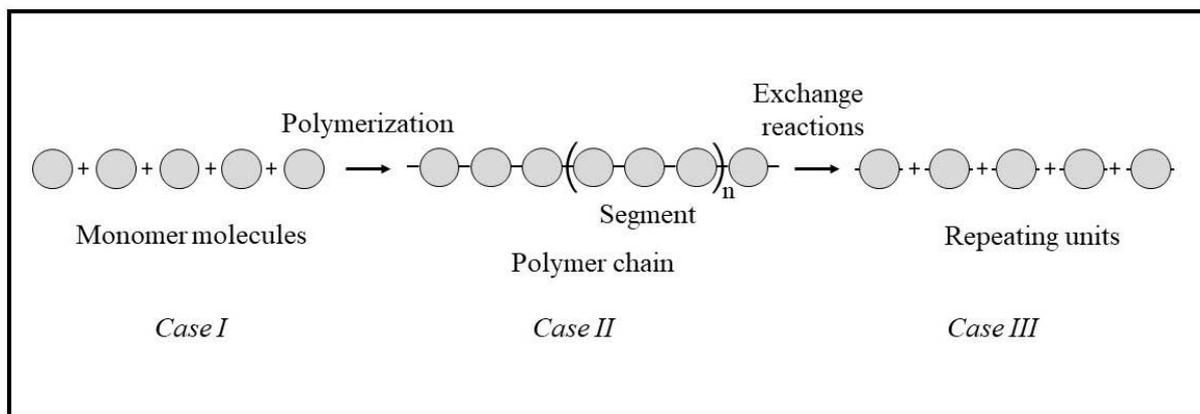


Figure 12: Schematically the formation of polymer chains (Case II) from monomer molecules (Case I) and dissipation of chains into chemically non-bonded repeating units (Case III): \circ - monomer molecules, $\text{---}\circ\text{---}\circ\text{---}\circ\text{---}$ - polymer chain comprised of chemically bonded segments, \circ - repeating unit. Diffusion mechanism: Case I - “jump-like” (Frenkel), Case II – “snake-like” (de Gennes), Case III: - as Case I.

Finally, it seems important to mention that the phenomenon taking place in the melts of condensation polymers at extremely high temperatures was analyzed 40 years ago and called “*chemically released diffusion*” [89]. Some later this approach was supported by Economy et al. [106]. Very recently [53], it was discussed again in relation to chemical peculiarities of condensation polymers, as well as commented by Pigot and Dumur [116] in their review on recent advances of hierarchical and sequential growth of macromolecular organic structures on surface. They state that the concept of chemically released diffusion is more adapted than “self-assembly” to describe the formation of covalent phases on surface, the chemical composition of the polymer under growth continuously evolving by exchange reactions [116].

The dissipation of macromolecules into single repeating units because of proceeding of exchange (trans) reactions in the melts of condensation polymers is well-known and many-fold documented fact [53-55, 68,69,86,87,89-92,96-98,103-108,110-115,118-122]. Nevertheless, it remains neglected by the researchers studying various processes in polymer melts (flow, diffusion, mass transfer, deformation, and others) as well as their mechanisms. A good example in this respect is the fact that studies on reptation mechanism have been performed exclusively on non-condensation polymers (e.g. [17-20]).

The role of the independent kinetic entities in melts can be played by the single (small) molecules, by the segments (in case of macromolecules), and by the chemically non-bonded repeating units (in case of condensation polymers at the highest possible temperatures) as schematically shown in Figure 12. The “Reptation model” can be used for explanation of diffusion mechanism only in cases of segmental type of motion. This means that the Reptation concept is not

applicable to melts of condensation polymers at highest possible temperatures where the diffusion is realized by the single chemically non-bonded repeating units.

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Modification and the Performance Enhancement of Solar Biomass Dryer

By Tanvir Ahmed & Tanjid Zaman

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Abstract- Drying is an important agricultural process, particularly for crops, and shriveled products are used all over the world. The performance of drying green chili was also tested in this article, which created an alternate way of drying agricultural products. The goal of this study is to provide a solar biomass hybrid dryer with improved design, construction, and performance testing. During most hours of the trial, the temperature within the solar collector and dryer was sufficiently higher than the ambient temperature, according to the results obtained during the test period. The temperature of the ambient air at the collector intake ranged from 30 to 35 degrees Celsius. The temperature of the air at the collector's outlet ranged from 54 to 64 degrees Celsius, while the temperature of the drying chamber ranged from 51 to 60 degrees Celsius, making it suitable for drying green chili and a variety of other agricultural products. The collector was found to be 46.54 percent efficient. The findings revealed that the alteration of the collector, which produces turbulent air flow and improves chamber wall insulation, affects drying. Based on the results of this study, the created solar biomass hybrid drier is cost-effective for small-scale crop growers in rural areas of developing countries.

Keywords: *dryer; chili; solar collector; moisture, solar energy, biomass, hybrid, agriculture.*

GJRE-A Classification: *FOR Code: 091399p*



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Modification and the Performance Enhancement of Solar Biomass Dryer

Tanvir Ahmed^α & Tanjid Zaman^σ

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I. INTRODUCTION

Vegetables, fruits, and harvests are necessary for long-term storage without compromising product quality. The most common method for drying agricultural products is unsafe open-air sun drying. However, it has a severe problem with wind dust and infestation, and the product may be seriously damaged to the point where it loses market value, resulting in a loss of food quality that could have distressing economic consequences on the local and international market. When compared to open sun drying, solar dryers can reduce the drying time by about 65 percent, improve the quality of the dried product in terms of hygienic, safe moisture content, cleanliness, color, and taste, and protect the product from dust, rain, and insects. The payback period ranges from 2 to 4 years, depending on the rate of utilization.

II. LITERATURE REVIEW

The features of thin layer solar drying of Brooks and Amelie mangoes were investigated by Dissa [1]. Purohit found a cost-benefit analysis of a solar drier for drying agricultural produce in India [2]. Ferreira studied the technological feasibility of solar drying for agronomical products, namely harvests, in Brazil [3]. Solar drying, according to Tiwari and Barnwal, is an excellent method of food preservation because the product is protected from dust, rain, animals, and insects while drying [4]. Amer has developed and tested a new hybrid sun drier for banana drying [5]. For tomato drying, Hossain has developed a prototype hybrid solar dryer [6]. E. Tarigan created a hybrid drier with natural convection and a biomass backup heater [7]. A direct solar-biomass drier was also created by Vijay and Prasad [8]. Bangladesh has an annual solar radiation availability of up to 1700 kwh/m². Rajshahi receives the most sun radiation, with measurements ranging from 180.30 to 250 cal/cm²/min. Rajshahi had the lowest cloud broadcasting, with values ranging from 0.34 to 6.36 okta [9]. Also, Various numerical models have been developed to improve the performance of a solar biomass dryer by using the pre-heat method [10, 11]. Improved pyrolysis system can also increase the efficiency of the solar biomass dryer [12].

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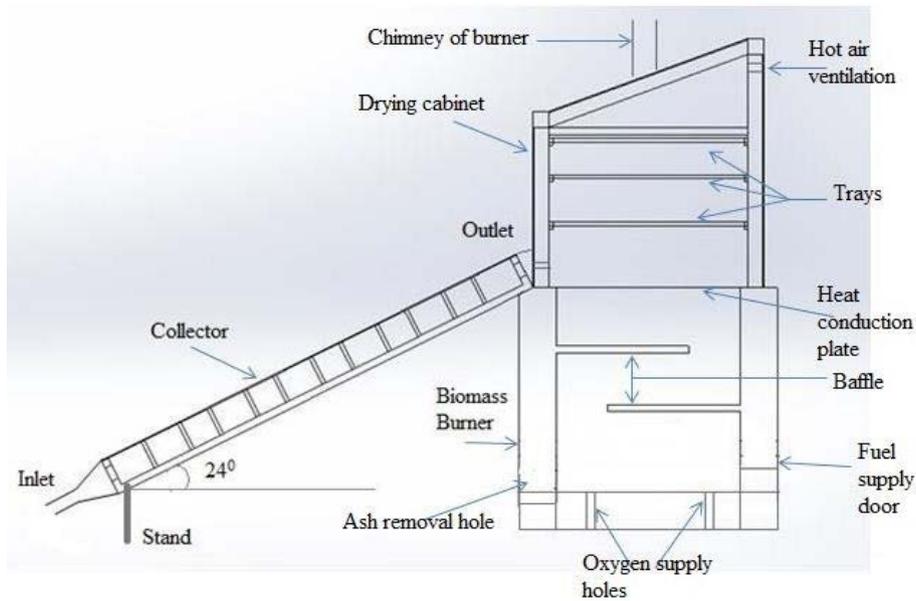


Fig. 1: The schematic view of the experimental setup

However, if combined heating from solar and charcoal firings is provided, it will be more efficient [13, 14]. The goal of this study is to create a hybrid solar drier with a biomass backup heater that can achieve the highest heat transfer for drying green chili. Two metal baffle plates were employed within the burner to maximize heat transfer to the burner wall and to prolong the existence of exhaust gasses inside the burner. The burner materials were the bricks that store heat during biomass combustion and give the stored heat to the dryer during inclement weather, such as a cloudy day or at night, resulting in a rapid boost in efficiency.

III. DESIGN OF STUDIED SYSTEM

A biomass burner with chimney, a centrifugal blower, a solar air heating collector, and a drying chamber make up the solar dryer. Figures 1 and 2 depict the experimental setup's schematic view and front view, respectively.

The solar collector consists mostly of a top open box with a 5 mm thick transparent glass cover. To reduce heat losses from the collector atmosphere's internal area to the exterior surface, a 0.019 m thick insulation system was introduced. Because Rajshahi's latitude is 24 degrees, the collector's inclination angle is 24 degrees. The drying cabinet and dryer frame were made of well-seasoned woods that could survive insects and the elements. The rectangular box cabinet, which measured 0.76m x 0.63m x 1.17 m, had a back outlet vent to create and control the convection flow of air through the dryer. For added heating, the cabinet's ceiling was covered with 5mm thick transparent glass sheets. The drying trays in the drying chamber were made of a double layer of fine chicken wire mesh with a somewhat wide structure to allow drying air to travel through the food.



Fig. 2: Photograph of the Experimental Setup

IV. DESIGN MODIFICATION OF SOLAR COLLECTOR

The design of the solar collector in the present arrangement was changed because it was not adequate. Because the fins inside the collector were arranged in increasing height order, the distance between each fin and the transparent glass cover

varied. Because of the huge space between the fin and the glass cover, air travelling through the collector from the blower took less time because it passed over the fins rather than through them. As a result, the air consumed less heat. Because the lower half of the collector was made of plywood, heat was easily dissipated, lowering the efficiency.

Table 1: Design parameter of solar collector

Parameters	Values
Area	1.61 m ²
Length	1.51 m
Width	1.04 m
Surface treatment	Black paint
Absorber plate	Aluminum sheet
Glazing	Normal glass of thickness 5 mm
Black insulation	Cork sheet of thickness 25 mm, glass wool
Casing	Wood
Collector tilt	24°
Distance between fins and transparent glass	0.5 inch
Fin height	2.50 inch

The solar collector's design parameters are listed in Table 1. Some alterations had been made for the sake of improvement.

- Fin height was increased uniformly to 2.50 inches instead of increasing height
- The transparent glass cover was adjusted at a distance 0.5 inch above the fins
- Wood was used for construction of lower part instead of plywood
- The thickness of insulation was increased, and insulation was done more effectively
- Aluminum sheet was used for absorber plate in the place of GI sheet.

V. EXPERIMENTAL PROCEDURE

In several modes of operation, the experiment was carried out in the forced convection solar biomass

hybrid dryer. A thermometer was used to measure ambient temperatures, collector output temperature, and drying chamber outlet temperature every half hour of drying. The beginning and end weights of the goods, as measured by an electronic balance, were the only remaining results noticed. An anemometer was placed between the blower and the collector to monitor the air flow rate. During the experiments, the mass flow rate of air was 0.03 kg/s. The experiment was performed on different solar days in both a natural convection under open sun and a biomass dryer with a forced convection mode, with the results compared to the open sun drying results.

VI. INSTRUMENT USED IN EXPERIMENT

The experiment was carried out with a variety of instruments, which are indicated in table 2.

Table 2: Instrumentations used in experiment

SL No.	Parameters to be measured	Instruments	Accuracy
1	Temperature	Thermometer	± 0.5°C
2	Solar radiation	Photovoltaic trainer	± 1 w/m ²
3	Air velocity	Anemometer	± 2.5%
4	Mass	Electronic Balance	0.01g
5	Air supply	Blower	N/A

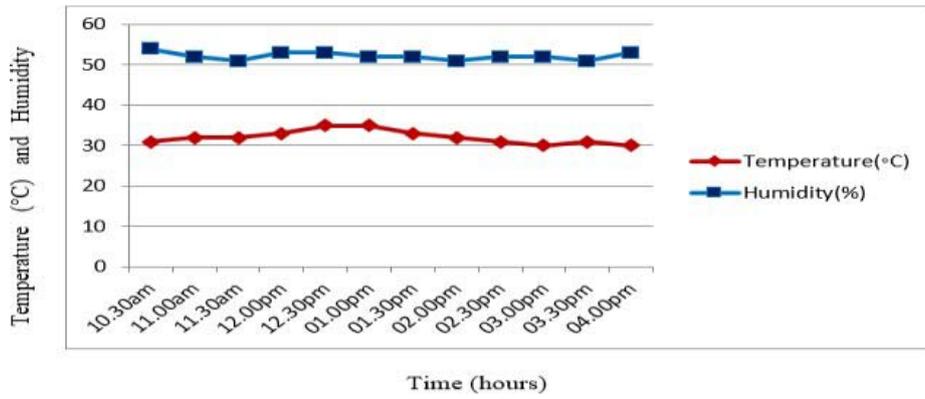


Figure 3: Variation of Humidity & Temperature corresponding to the time of the day

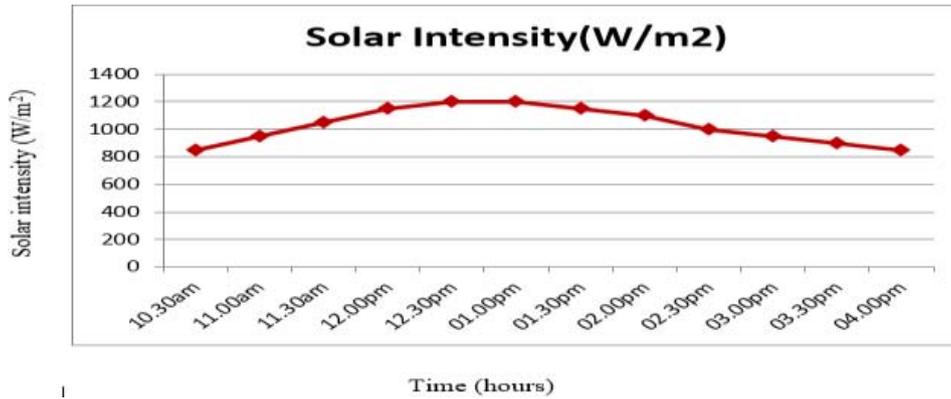


Figure 4: Variation of solar intensity corresponding to the time of the day

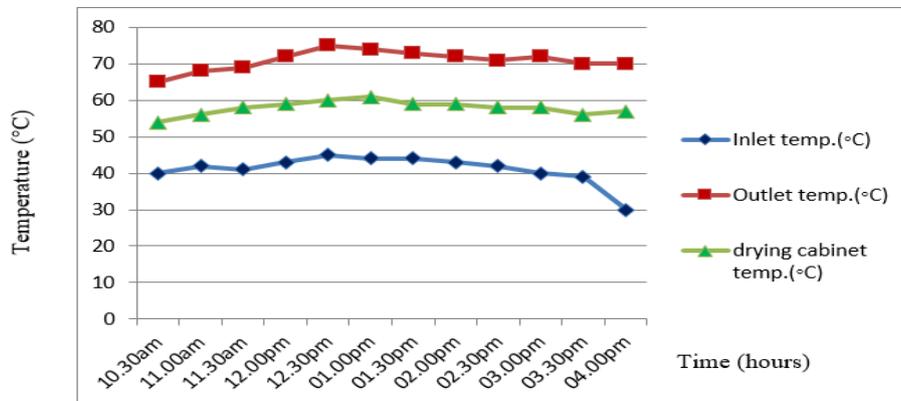


Figure 5: Variation of Inlet, outlet and drying chamber temperature recorded in the month June

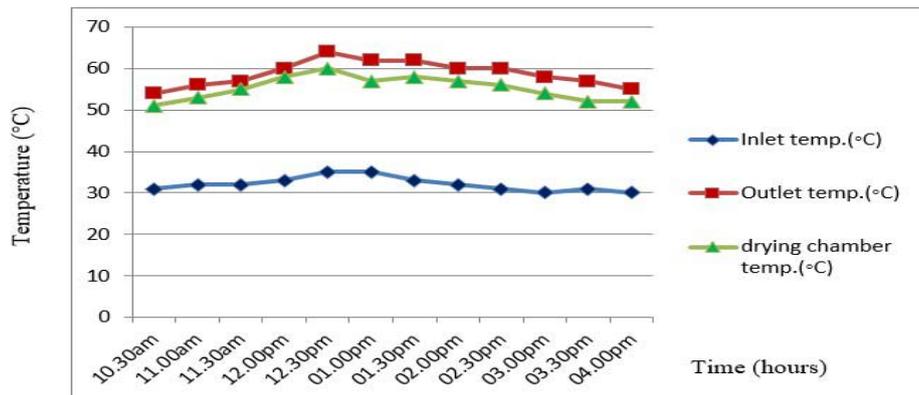


Figure 6: Variation of Inlet, outlet and drying chamber temperature recorded in the month October

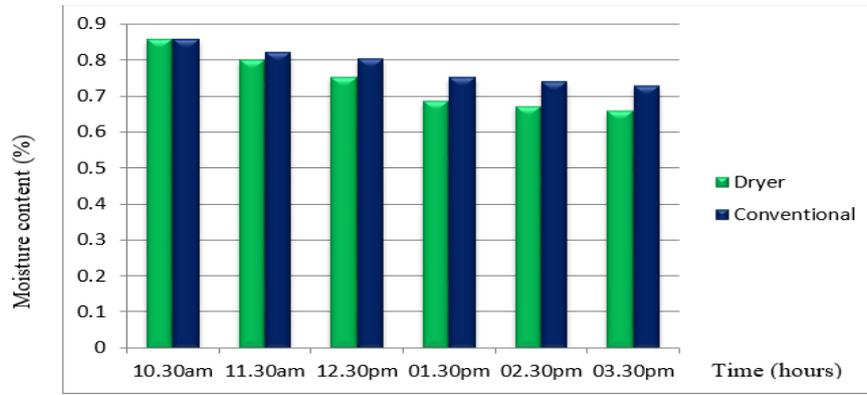


Figure 7: Variation of moisture content with time of existing setup

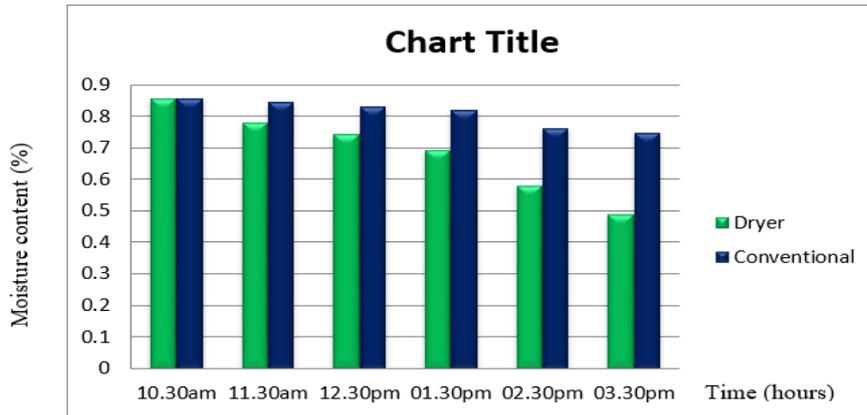


Figure 8: Variation of moisture content with time of Modified new

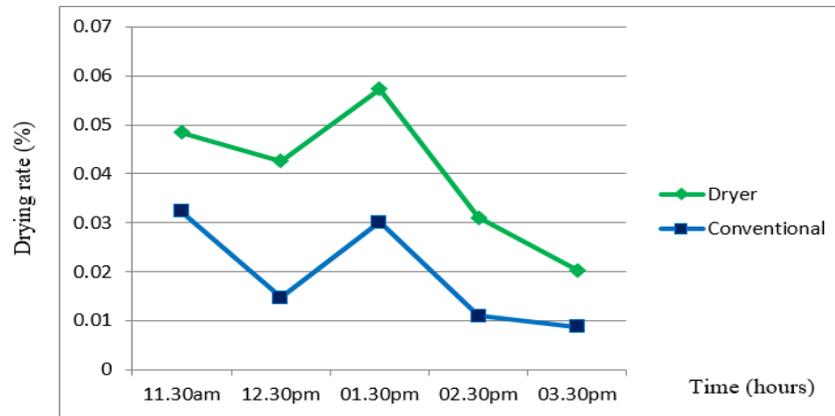


Figure 9: Drying rate with time of the day for existing setup (June, 2016)

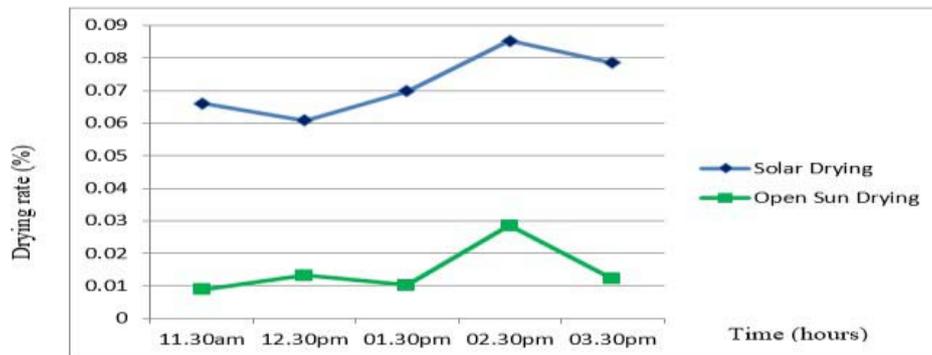


Figure 10: Drying rate with time of the day for modified setup (October, 2016)

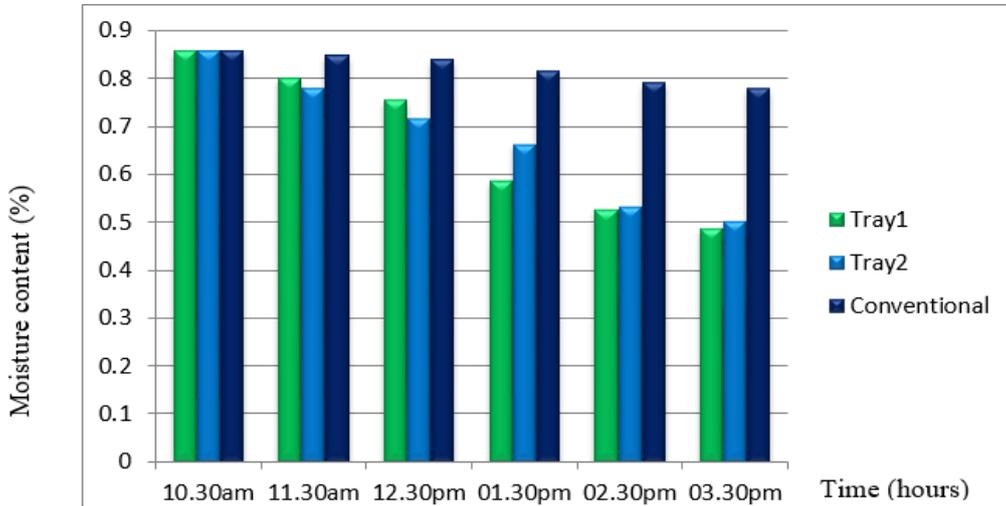


Figure 11: Variation of moisture content in different trays and conventional mode with time with Modified new setup

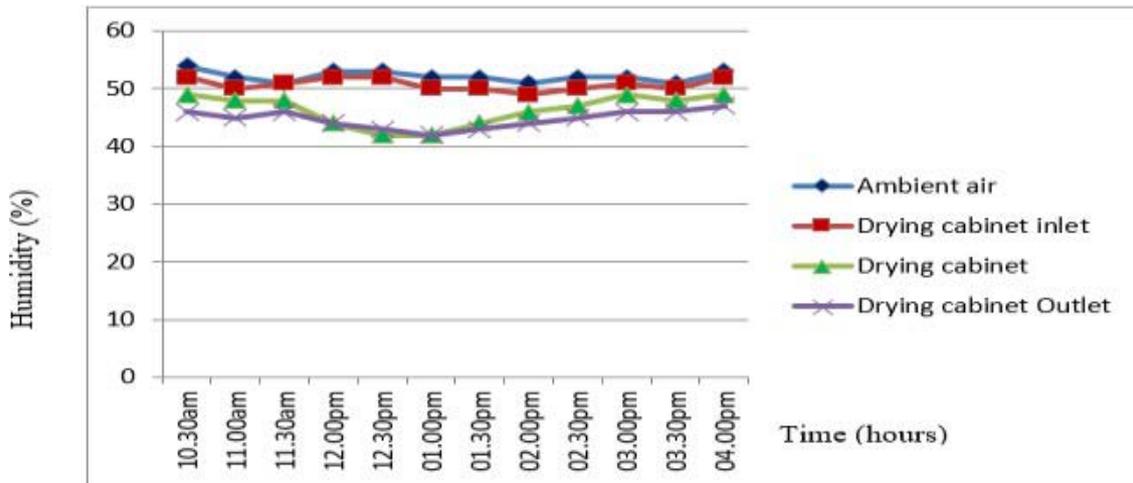


Figure 12: Variation of humidity of inlet air of collector, outlet air of collector, ambient air, drying cabinet and drying cabinet outlet

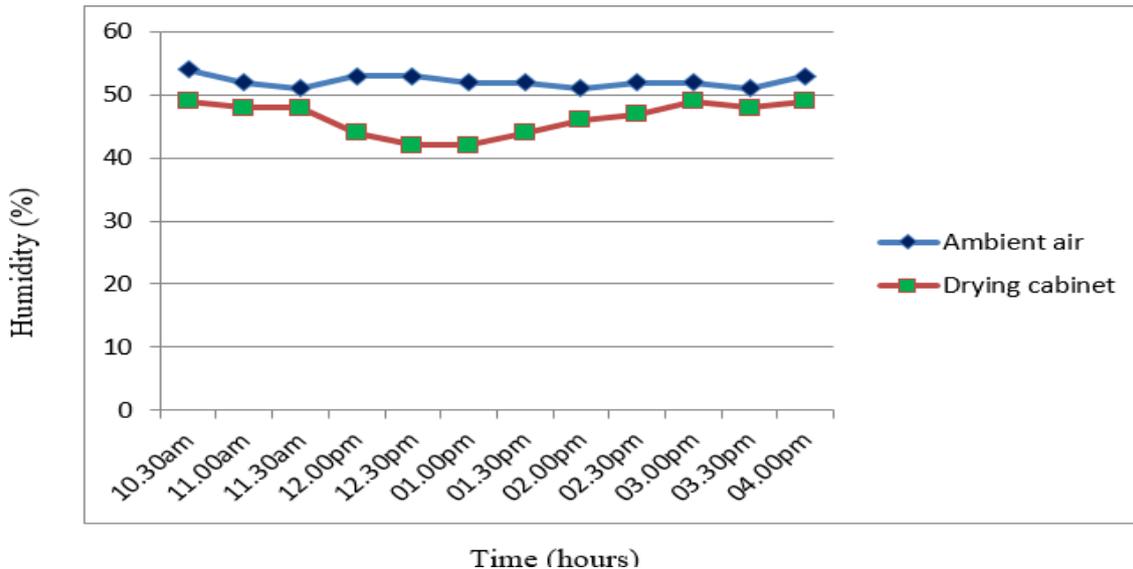


Figure 13: Variation of humidity of ambient air and inside of drying cabinet

VII. RESULT & DISCUSSION

The experiments were performed in rajshahi, bangladesh (latitude= 24°22' n and longitude= 88°36' e) during 2016. Performance test of the existing solar collector was done during the month june and the performance test of modified collector was done during september and october.

- Weather Condition

Figure 3 depicts the decreasing rate of humidity as the temperature rises. Solar radiation fluctuated from 850 w/m² to 1200 w/m² during the experiment, which was monitored using a solar photovoltaic trainer. Figure 4 depicts the daily variation in sun intensity. Maximum sun radiation was recorded during the hours of 10.30 a.m. and 4.00 p.m.

- Performance test of solar collector

Figures 5 and 6 illustrate the results achieved by running the existing solar collector from 10.30 a.m. to 4 p.m. in june and october 2016, respectively, at a mass flow rate of 0.03 kg/s. On the test day, the ambient air temperature at the collector intake ranged from 30 to 45 degrees celsius. The temperature of air at the collector's outlet ranges from 65 to 75° c, while the temperature in the drying chamber ranges from 54 to 61° c. On the test day in october, however, the ambient air temperature at the collector intake ranged from 30o to 35o c. The temperature of air at the collector's outlet ranged from 54 to 64 degrees celsius, while the temperature in the drying chamber ranged from 51 to 60 degrees celsius, which is ideal for drying green chili.

- Comparison with respect to moisture content

Figures 7 and 8 demonstrate the beginning moisture content and ultimate moisture content of the product utilized, green chilli, in both conventional and solar drying modes. The initial moisture content of 1kg of green chilly was 85 percent, and the ultimate moisture content was 65 percent using the previous solar collector. The final moisture content attained after adjustment was 49 percent. It was possible to reduce roughly 16 percent of the extra moisture from green chilly by making these modest changes.

- Comparison with respect to drying rate

Figures 9 and 10 depict the drying rate as a function of time of day for the original and modified setups, respectively. The average drying rate from the old solar collector was 0.039932 kg/hr, while the average drying rate from the improved solar collector was 0.07211 kg/hr. The weight loss was larger in solar drying mode than in traditional sun drying, according to the findings.

- Performance test of modified solar collector

Figure 11 shows the changes in moisture content in different trays and conventional mode over time in october 2016 with a modified solar collector by

placing 1kg of green chilly in the upper tray, referred to as tray1, 1kg in the bottom tray, referred to as tray2, and 1kg in the open atmosphere for conventional drying mode. Each person's weight was collected at one-hour intervals until 3.30 p.m. it demonstrates that tray 1 has a lower moisture removal rate than tray 2 until 12.30 pm, after which tray 1's moisture removal rate has increased. Because tray1 is exposed to direct sunlight as well as heat from the solar collector, and because the intensity of the sun is highest between 12.30 pm and 2.00 pm, the moisture removal rate of tray1 is increasing at that time.

- Variation of humidity

In the month of october, figure 12 depicts the fluctuation in humidity of the collector's inlet air, outlet air, ambient air, drying cabinet, and drying cabinet outlet in (percent) as a function of time of day. The graph indicates that as the temperature rises, the humidity falls. During the day, the highest humidity of ambient air is 54 percent and the minimum is 50 percent, as shown in the graph. The humidity in the drying cabinet inlet ranges from 49 to 52 percent. The humidity of ambient air and the humidity in the drying cabinet are compared in figure 13.

VIII. CONCLUSION

The solar collector of a forced convection type solar dryer with a backup biomass heater was updated in design for improved efficiency and used for drying. The drying performance of green chili was examined using the original setup and the modified new setup in three different modes of operation: conventional drying, sun drying, and hybrid drying. Depending on the mode of operation, the temperature within the drying chamber ranges from 44 to 75° c. The average efficiency of an existing sun collector was 37.49 percent, with outlet air temperatures ranging from 52 to 71 degrees celsius, but with the improved new solar collector, the efficiency was 46.54 percent. The entire reduction in traditional sun mode drying was 12.94% in the present setup, whereas the total reduction in solar drying was 36.6%. The total reduction in traditional sun mode drying was 10.97%, whereas the total reduction in solar drying was 20.79%. As a result, the change of the solar collector was beneficial to the total setup, as the collector's efficiency increased from 37.49 percent to 46.54 percent. The performance was satisfactory, and following the modifications, we were able to overcome the issue of not having enough sun radiation during the day by obtaining consistent drying, which is desirable for most agricultural products.

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Adaptability of Karnaugh Maps to Implement and Solve Complex Control Problems of Pneumatic and Electro-Pneumatic Systems

By Adriano A. Santos & António Ferreira da Silva

Abstract- Industrial dynamics increasingly require fast responses with low setup times. In pneumatic equipment, the response to the flexibility demanded by consumers requires adaptability of the equipment and constant changes in production cycles. This answer is usually achieved by rebuilding the entire system, reconstruction of the control system, to respond to the new work cycle. To solve this problem, within certain limits, we present a new approach to pneumatic control that allows us to quickly operate at three different demands in production cycles. In practice, we try to define a triple control sequence using Karnaugh Maps. Thus, we propose an approach that allows obtaining the equations of command of the triple sequence based on the Karnaugh Maps. This methodology will simplify the design of the sequence control scheme, either by pure pneumatic control or electro-pneumatic systems.

This approach guarantees not only the operation of the circuits, three sequences but also the minimization of the command variables necessary for the implementation of the control circuit.

Keywords: *multiple pneumatic control; industrial automation; karnaugh maps; PLC; ladder, pneumatic sequential circuits, artificial intelligence.*

GJRE-A Classification: FOR Code: 290501



ADAPTABILITY OF KARNAUGH MAPS TO IMPLEMENT AND SOLVE COMPLEX CONTROL PROBLEMS OF PNEUMATIC AND ELECTRO-PNEUMATIC SYSTEMS

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I. INTRODUCTION

The use of compressed air as an energy source dates back to immemorial times. Its first use dates to the year 250 BC. For centuries it has been used in different ways, and its distribution and use, under several pressures, has become widespread and has become a fundamental element in all production and service processes. Pneumatics, as a controlled energy source, derives from the Greek term Pneuma, which means breath or breath.

Compressed air is a source of energy and control used in various operations that pass through simple acts of drilling, riveting, deburring, etc., perfectly framed in the automation of processes. Compressed air replaces human strength, providing a uniform and constant production capacity with high production rates. This form of energy, when combined, is capable of operating in parallel with mechanical, electrical, and electronic systems and with oil-hydraulic systems.

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However, the combination of different control and performance systems will require players to have a great knowledge of the technologies to be integrated into any automation process, not only as control elements (pneumatic, oil-hydraulic, or electric) but also from the initial point of view of the power transmission. In this sense, the control of pneumatic systems can be carried out pneumatically (pure pneumatics, control, and pneumatic actuation), electrically (a hybrid system that combines electric or electronic control with pneumatic actuation) or combined with oil-hydraulic systems (control or performance of the hydraulic elements).

Pneumatically, the movements of the actuators, whether translational or rotation, are obtained by alternating redirection of compressed air in the actuator chambers. Thus, to control this redirection, directional control valves alternately redirect the flow of compressed air to the actuator chambers. The directional valve ensures the escape of air from the opposite chamber, constructive form of the valve box (see Figure 1). In this sense, the control of the directional movements of the actuators aims to execute the defined sequences, whether they are combinatorial or sequential cycles. The approach to the construction of pneumatic control systems will be possible according to the following methodologies [1]:

First: The designer tries to perform the control combine pneumatic signals to solve the problem, intuitive mode. The implementation of this pneumatic control methodology, with combinatorial or sequential cycles, becomes very complex. Electrical control presents a high degree of development and implementation difficulty.

Second: The designer tries to perform pneumatic control of combinatorial or sequential cycles using Cascade methodology, Shift Register Modules or Sequential Modules [2], and the Festo Quick Stepper technology [3]. These methodologies can be used to solve any potential pneumatic control issues. Electrical control has a high degree of implementation difficulty.

Third: The designer tries to perform control using Karnaugh Maps (KM) methodology. Any potential control problem for combinatorial or sequential cycles can be solved with this methodology. The design of the electrical control scheme is easy to implement, either

with relays or with Programmable Logic Controllers (PLCs).

In this article, we will address the problem of implementation and pneumatic and electro-pneumatic control of sequential cycles, based on equations extracted from KM. This methodology, based on the ON/OFF control of pneumatic and electro-pneumatic circuits, will allow controlling the desired cycle or cycles, as well as minimizing the command equations and components used in their implementation [4].

The authors presented, in previous works [4-6], the construction rules of KM using a single sequence and the implementation of control equations for pneumatic circuits and their adaptability to relay electro-pneumatic control and with PLCs. In [7], Silva and Santos extract the equations of movement using Artificial Intelligence (AI). References [4] and [6] also presented the adaptability of the equations obtain by KM to Ladder Diagram (LD) language (electro-pneumatic control based on Programmable Logic Controller, using a Siemens S7 200 PLC). In this work, the authors present a new approach to solve sequential cycle of pneumatic or electro-pneumatic circuits with triple-path and the problems associated with the points of divergence and convergence to maintain the synchronization of all the movements and walls of the three sequences.

In section 2, the authors give a brief description of control techniques for pneumatic electro-pneumatic circuits. It is also representing the rules to pneumatics circuits and conventionally representation for movements, command orders, and switch position. A description of the Cascade implementation and KM methodology is also presented. A case study is presented. We discuss the implementation and handling of KM for the control of a triple-path pneumatic circuit in Section 3. Section 4 presents pneumatics control implementation and the adaptability of the equations

deducted from KM into electrical control signals, electrical control with relays, and Ladder Diagram language, electro-pneumatic implementation. Section 5 concludes the paper.

II. PNEUMATIC CONTROL TECHNIQUES

The control of a typical pneumatic component is performed by a set of directional control valves and a cylinder. This set of components is the combination of control, actuation, and position elements that define the entire construction of any pneumatic actuation system present in almost all pneumatic machines. Other elements that can be used in the circuits, such as the logic elements (AND & OR), aim to ensure that the combination of signals and the supply of compressed air to the cylinders is carried out according to the defined logic at the exact moment.

Conventionally we associate the actuators with capital letters, the indication of the actuator, while at the limit switches, the indication of the position of the actuators, lowercase letters. In this sense, we will represent by A+ the forward movement of the cylinder and by A- the reverse movement of a cylinder called A. The associated directional control valve will be assigned the same letter (A) where the forward order of the cylinder will correspond, according to the equations obtained by KM, to the command A1 (A+) and its reverse to the command A0 (A-). The limit switches, at the end of the cylinders, positioning forward and backward, we will call a0, return valve, and a1 to the advance valve. These two positions indicated the recoil "0" and forward "1" state. In Figure 1, we present a schematic of the set of elements necessary to control a cylinder. In this figure, we represent the limit switches with capital letters since they are now associated with the command specifications of the simulation software, so in this case, a0 will correspond to A0 and a1 to A1.

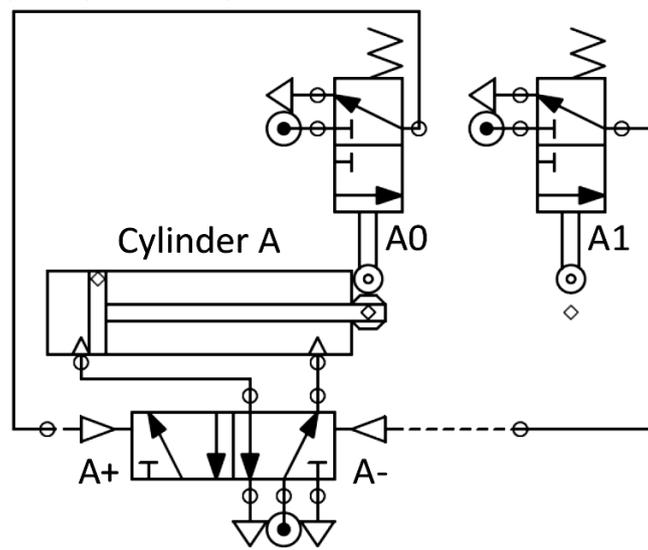


Fig. 1: Simplified representation of a pneumatic circuit.

Then, the representation of a sequence of forward and return movements of two cylinders A and B will be indicated as follows: $A+ \setminus B+ \setminus A- \setminus B-$. This

description of the cylinder movements translates in a simple and comprehensive way the cycle of operations of each cylinder.

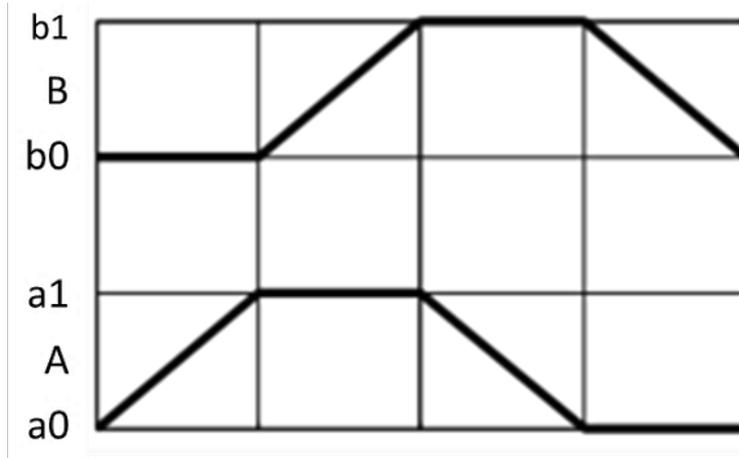


Fig. 2: Step diagram for the sequence $A+ B+ A- B-$ [1]

The movements of the cylinders can be, also, represented using a step diagram that represents the evolution of the movements as a function of time, sequence, or both. The sequential step diagram shows the sequential evolution of the cylinders, while the temporal one reports the behavior of the cylinders as a function of time. In Figure 2, we show the step diagram of the cycle.

cycles that may or may not need memories. Control of the cylinders, actuation elements is carried out according to the present information and the knowledge of the past states (states obtained by combining primary and secondary variables and/or memories). Memories are defined by a construction of directional control valves, connected in cascade, directing the air flow to one and only one of the pressure groups. This construction ensures that at any given moment, only one of the pressure groups is active, that is, pressurized.

a) *Pneumatic Cascade Method*

Cascade methodology is normally used to solve control problems associated with pneumatic sequential

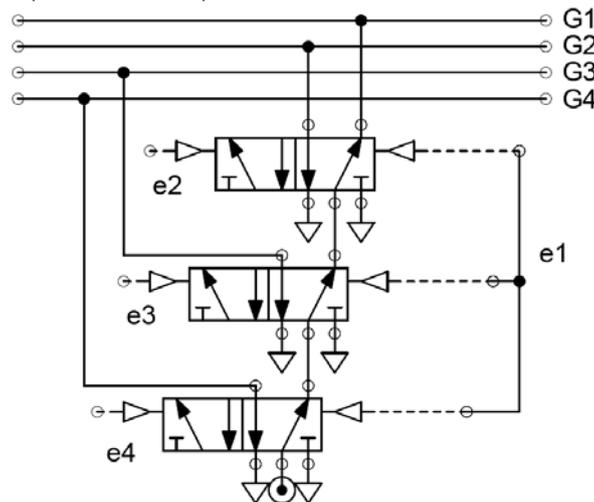


Fig. 3: Representation for a pneumatic control memory of four groups

The definition of pressure groups is done by dividing the sequence of movements. The division is constituted by consecutive groups of movements ensuring, that, in each one of them, there is no repetition of movements of any cylinder. In other words, the repetition of letters in the group is not allowed. In this sense, a sequence consisting of two cylinders (A and B) and with the following movements, for example:

$$A+ \setminus B+ \setminus A- \setminus A+ \setminus B- \setminus A-$$

will be divided into 4 groups, 1, 2, 3, and 4 (G1 to G4):

$$\underbrace{A+ \setminus B+}_1 \mid \underbrace{A-}_2 \mid \underbrace{A+ \setminus B-}_3 \mid \underbrace{A-}_4$$

Switching to each group is carried out with the orders $e1$ to $e4$, which will correspond to the change to

the Group "G1", G2, G3, and G4, respectively. Figure 3 shows the construction of memory with four groups and the respective switching signals.

b) *Pneumatic and Electro-pneumatic Karnaugh Maps*

Karnaugh maps are normally used to simplify and minimize Boolean functions [8]. On the other hand, and since pneumatic cylinders may be associated with Boolean behavior, their industrial applicability to the control of pneumatic and electro-pneumatic sequential circuits will be a reality. In this sense, consider a sequence defined by $A+ \setminus B+ \setminus B-\setminus A-$, sequence in "L" (double-crossing point), consisting of two independent

cylinders with a double effect. Then, the correspondence between the various active variables, limit switches, and the orders to be executed, control of the directional valves (see Figure 1), will be the basis of the initial construction of the KM. Its initial dimension results from the number of cylinders, in this sequence, it will be two, based on the ratio of $2n$ (two raised to two cylinders) [4]. The drawing of the movements starts in the upper left corner of the map, proceeding with the mapping of the subsequent orders according to the evolution of the sequence[4] [9]. Figure 4 shows the KM for this sequence (L-cycle) defined above.

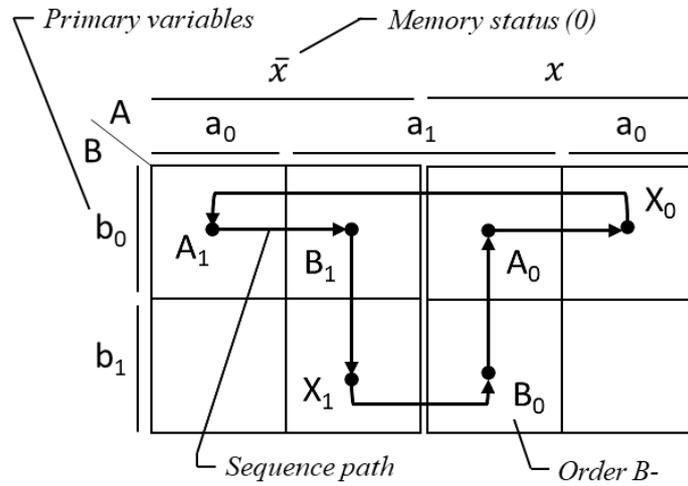


Fig. 4: Karnaugh Map for two cylinders (A and B) with one memory (x)

III. KARNAUGH MAPS FOR COMPLEX CIRCUIT -TRIPLE-PATH LOGICAL SEQUENCE

The scheme shown in Figure 5 represents a drilling machine used to produce configurations shown in the figure. Three cylinders produce oblong holes (cylinders B and D in simultaneously, followed by the C),

while the fourth (cylinder A) is used to perform the longitudinal drilling on top of the part.

Due to the manufacturing impositions, the system is prepared to work in three distinct modes, according to push-button S1, S2, and S3.

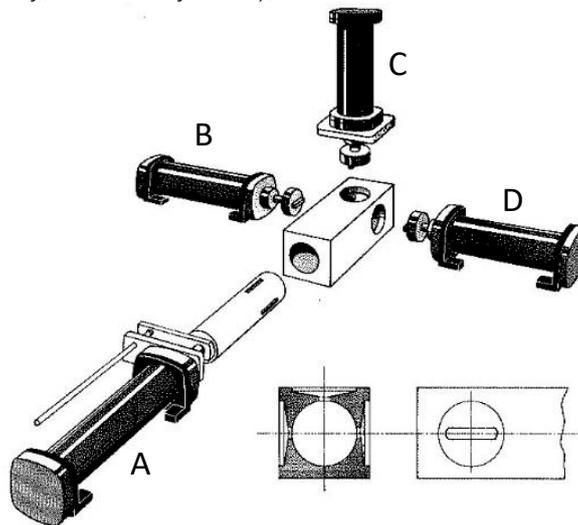


Fig. 5: Drilling machine [10]

In the first mode (S1), all cylinder's work, while in the operating mode, S2 cylinder C is suppress, maintaining the sequence of the remaining movements. Push-button S3 once again changes the sequence by suppressing the simultaneous movement of cylinders B and D, maintaining the remaining sequence. These conditions do not affect the initial design of the map but condition the common path considered, as well as the specific points of divergence and convergence. Table 1 shows the sequences of push-button S1, S2, and S3 modes.

Table 1 Sequence displacement for push-button S1, S2, and S3 steps

The representation of movements of a sequence is, normally, fulfilled by an algebraic form or by a step motion diagram. In the present case, we have three sequences combined, that although they can present different paths. So, their representation in the step diagrams must be reduced to the sequence that presents more movements since, in addition to being more complex, it is also common to the others (part of the sequence is overlap). Thus, to understand the applicability of this methodology, we will represent, individually, the movements of each of the three sequences. In Figure 6, we present the step diagrams of these three sequences (S1, S2, and S3).

The black path represents the movements of the S1 sequence and, consequently, the partial overlap of the three sequences. The red step diagram represents the S2 sequence (cylinder C inoperative), while the green step diagram represents the S3 sequence (cylinder B and D inoperative). Although with different movements, part of the paths in red and green represents a partial overlap of the sequence in black (S1).

Karnaugh's map are drawing considering, first, the sequence with the greatest number of movements or, in this case, also with the greatest number of cylinders in motion (A, B, C, and D, sequence S1). So, based on the movement of all sequences, the final configuration of the KM is shown in Figure 7. Initial movement of all sequences will be performed in the upper left corner of the map. The design of the sequence evolves inside and across the map, associating the corresponding forward and backward orders.

The map will grow, by horizontal or vertical unfolding, according to the impossibility of making any movement (occupied destination cell), as explained in [4]. The black path represents the largest sequence (S1) and, consequently, part of the overlaps of the sequences S2 and S3. Red and green paths represent the path of the remaining sequences. Cell $a_0 b_0 c_0 d_0 x$ is the initial cell of all the movements, so in this case, the entire x side of the map will be responsible for the A1 order (see Figure 7).

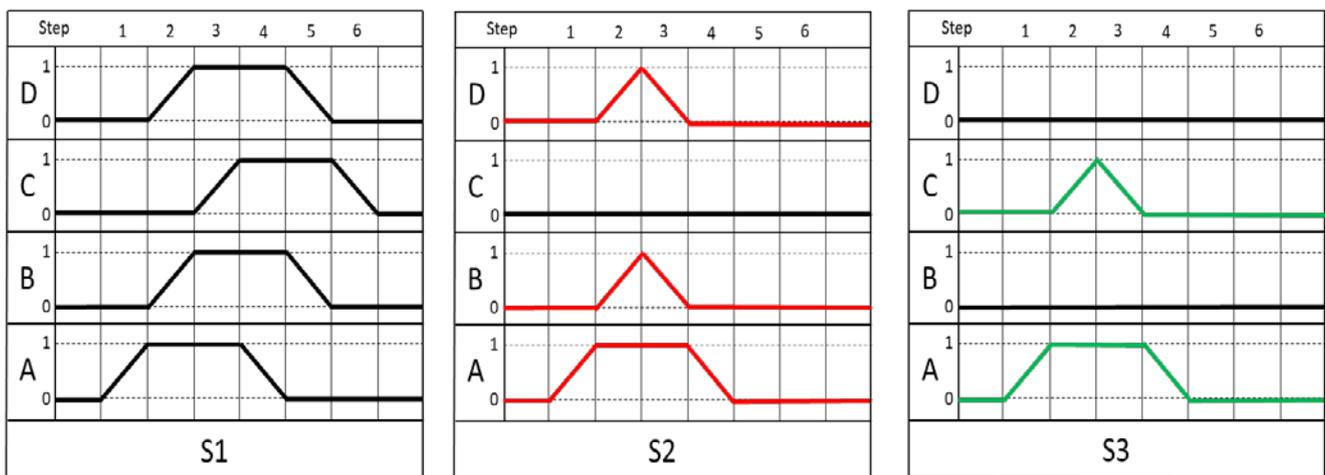


Fig. 6: Displacement diagram of the double-path sequence (S1 and S2).

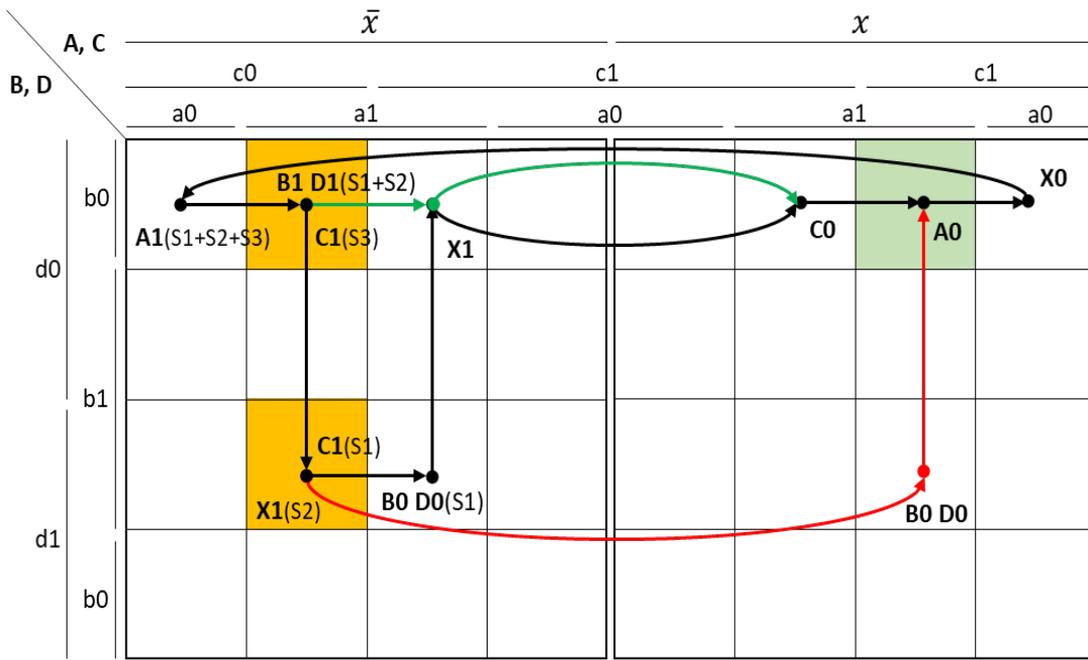


Fig. 7: Karnaugh Map for a complex sequence, three logical paths (S1, S2, and S3)

On the other hand, cells $a_1 b_0 c_0 d_0 \bar{x} / a_1 b_1 c_0 d_1 \bar{x}$ are the dividing cells of the movements of the S2 and S3 sequences, respectively (red and green path, dark yellow cells in Figure 7). Signals S1, S2, and S3 define the direction of evolution of the sequences, down, to right, and shift to x (black, red, and green path). To extract the equations, it is necessary to isolate the sequences and concurrently each of the respective orders. Then, from the analysis of the order of the initial movement (upper left corner of the map), we verify that this movement will always be performed regardless of the selection that will be made, this is the starting point, common to all sequences. However, we must consider other operating conditions since this is the starting cell of all sequences, it must also be guaranteed that all movements are completed in the same cell. So, all active variables must be present in the equation of motion associated with the A1 order. In this case, the active variables for sequence S1, S2, and S3 are \bar{x} (previous movement). Thus, the equation for controlling the advance of cylinder A (order A1, see Figure 7) will be given by:

$$A_1 = \bar{x} \cdot (S1 + S2 + S3) \quad (1)$$

Order A1, in this case, depends only on S2, So, A1 is: $A_1 = \bar{x} \cdot (S1)$. The remaining equations are obtained considering the same approach defined for the order A1. So, for the S1, black sequence, we will have:

$$A_0 = c_0 \cdot x \quad (2)$$

$$\begin{cases} B_1 = a_1 \cdot c_0 \cdot \bar{x} \cdot (S1) \\ B_0 = c_1 \end{cases} \quad (3)$$

$$\begin{cases} C_1 = b_1 \cdot d_1 \cdot (S1) \\ C_0 = x \end{cases} \quad (4)$$

$$\begin{cases} D_1 = a_1 \cdot c_0 \cdot \bar{x} \cdot (S1) \\ D_0 = c_1 \end{cases} \quad (5)$$

$$\begin{cases} X_1 = b_0 \cdot c_1 \cdot d_0 \cdot (S1) \\ X_0 = a_0 \end{cases} \quad (6)$$

Equations for B1, C1, D1 and X1, in the split cells (Figure 7), is obtained by all the previous movements (active variables) and the memorized pneumatic or electrical signal of S1, see (3-6). Figure 8 shown the implementation of the memorized pneumatic memory. This cascade representation corresponds to the signals of push bottom S1, S2, and S3, sequence selection.

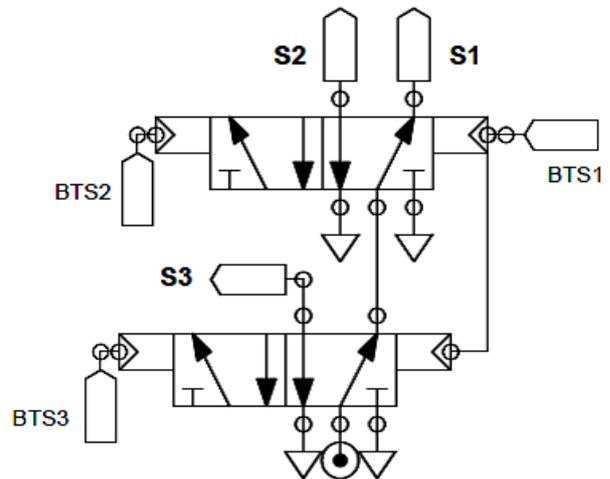


Fig. 8: Memorized pneumatic signal of S1, S2, and S3

The equations of the second sequence (S2) are also obtained from the map shown in Figure 7. The order A1 will have the same equation, already defined in (1) since this is common to the three sequences. In this case, A1 depends only on S2. So, A1 is $A_1 = \bar{x} \cdot (S2)$.

$$A_0 = b_0 \cdot d_0 \cdot x \quad (7)$$

$$\begin{cases} B_1 = a_1 \cdot \bar{x} \cdot (S2) \\ B_0 = x \end{cases} \quad (8)$$

$$\begin{cases} D_1 = a_1 \cdot \bar{x} \cdot (S2) \\ D_0 = x \end{cases} \quad (9)$$

$$\begin{cases} X_1 = b_1 \cdot d_1 \cdot (S2) \\ X_0 = a_0 \end{cases} \quad (10)$$

For the S3 sequence, the equations are also obtained from the KM (Figure 7). The equation for the order A1 is obtained by the sequence S3. In this case, A1 depends only on S3. So, A1 is $A_1 = \bar{x} \cdot (S3)$.

$$A_0 = c_0 \cdot x \quad (11)$$

$$\begin{cases} C_1 = a_1 \cdot \bar{x} \cdot (S3) \\ C_0 = x \end{cases} \quad (12)$$

$$\begin{cases} X_1 = c_1 \cdot (S3) \\ X_0 = a_0 \end{cases} \quad (13)$$

The combination of these three paths results in a set of equations that translate a combination of sequences and, as such, the repetition of movements, conditioned by the selection of the S1, S2 or S3 push button. The final set of equations will be:

$$\begin{cases} A_1 = \bar{x} \cdot (S1 + S2 + S3) \\ A_0 = c_0 \cdot b_0 \cdot d_0 \cdot x \end{cases} \quad (14)$$

$$\begin{cases} B_1 = a_1 \cdot c_0 \cdot \bar{x} \cdot (S1 + S2) \\ B_0 = c_1 + x \end{cases} \quad (15)$$

$$\begin{cases} C_1 = b_1 \cdot d_1 \cdot (S1) + a_1 \bar{x} \cdot (S3) \\ C_0 = x \end{cases} \quad (16)$$

$$\begin{cases} D_1 = a_1 \cdot c_0 \cdot \bar{x} \cdot (S1 + S2) \\ D_0 = c_1 + x \end{cases} \quad (17)$$

$$\begin{cases} X_1 = b_0 \cdot c_1 \cdot d_0 \cdot (S1) + b_1 d_1 (S2) + c_1 (S3) \\ X_0 = a_0 \end{cases} \quad (18)$$

Note that at the point of convergence (cell $b_0 \cdot c_0 \cdot d_0 \cdot x$, light green, Figure 7), the return of A (A0) must have, necessarily, all the active variables that precede it. In this case, it will be the variables related to the completion of the return movement of C (c_0) and the return variables of cylinders B and D (b_0 and d_0) as well as the memory x (active), see (14).

IV. KARNAUGH IMPLEMENTATION, PNEUMATIC AND ELECTRO-PNEUMATIC CONTROL

The implementation of pneumatic control circuits is based on two fundamental parts, the power

part (pneumatic actuation of actuators) and the control part based a pneumatic or electrical signal (directional control valves and limit switch). So, the great between these two technologies is at the control level since combinational logic is performed with pure pneumatic or electrical control.

a) Pneumatic implementation

The Implementation of pneumatic circuits is based on pneumatic action (a power part) and control performed with pneumatic signals (a mechanical part) for switching the directional and limit switch valves. So, logical control signals, binary signals (pressure or not pressure), are carried out by combining several pressure signals that perform the intended sequence. Note, however, that the control of the combined sequences is carried out with pneumatic 5/2 directional control valves (5 ways and 2 positions). Thus, and as this type of valve is used, we will have to consider that the signals of each of the selected sequences will always remain active until a new sequence is performed, that is, the sequence button pressed, S1 or S2 or S3 bottom (see "Start bottom" and "Sequence selection," see Figure 9). These signals will be present along each of the paths to validating path divergences, as can be deduced from the scheme shown in Figure 9. It is also important to remember that the initial signal of the sequence is constructed by the signal \bar{x} and S1 or S2 or S3, see (1). However, in the pneumatic scheme shown in Figure 9, in the advance o cylinder A (order A1, A+), we only show the indication of the selected button. This order will depend only on the change of the memory state, that is, on the passage to the initial state, negated state. Thus, A+ will be executed by BTS1, BTS2, or BTS3 signals that translate the signal \bar{x} .

b) Electro-pneumatic relay-base implementation

The implementation of electro-pneumatic circuits is also based on two fundamental parts, the pneumatic action (power part, performed on the actuators) and an electromechanical control part (actuation performed on the directional control valves) associated with the electrical signals of the final position of the cylinder (limit switch). These signals, also in binary or digital form, control the evolution of each of the selected sequences as a function of the signals received from the process, associating them with the signals of the present and past state. So, the minimized equations obtained by the KM will be summarized as a set of input and output signals associated, with more than one movement of the cylinders, along with the different sequences.

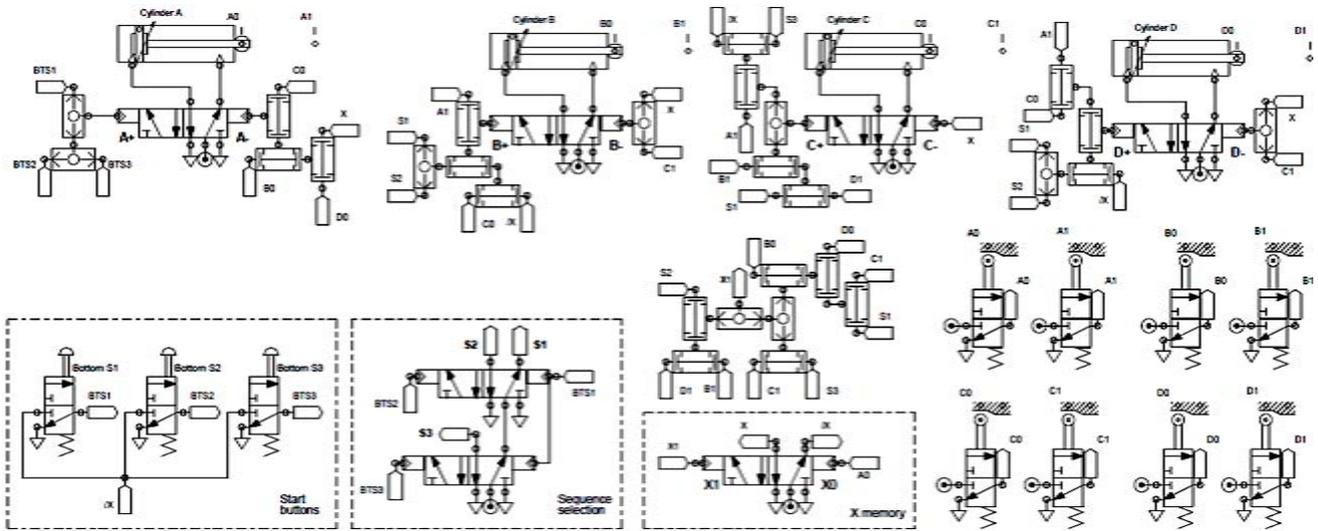


Fig. 9: Pneumatic control for the triple-path sequence (S1, S2, and S3)

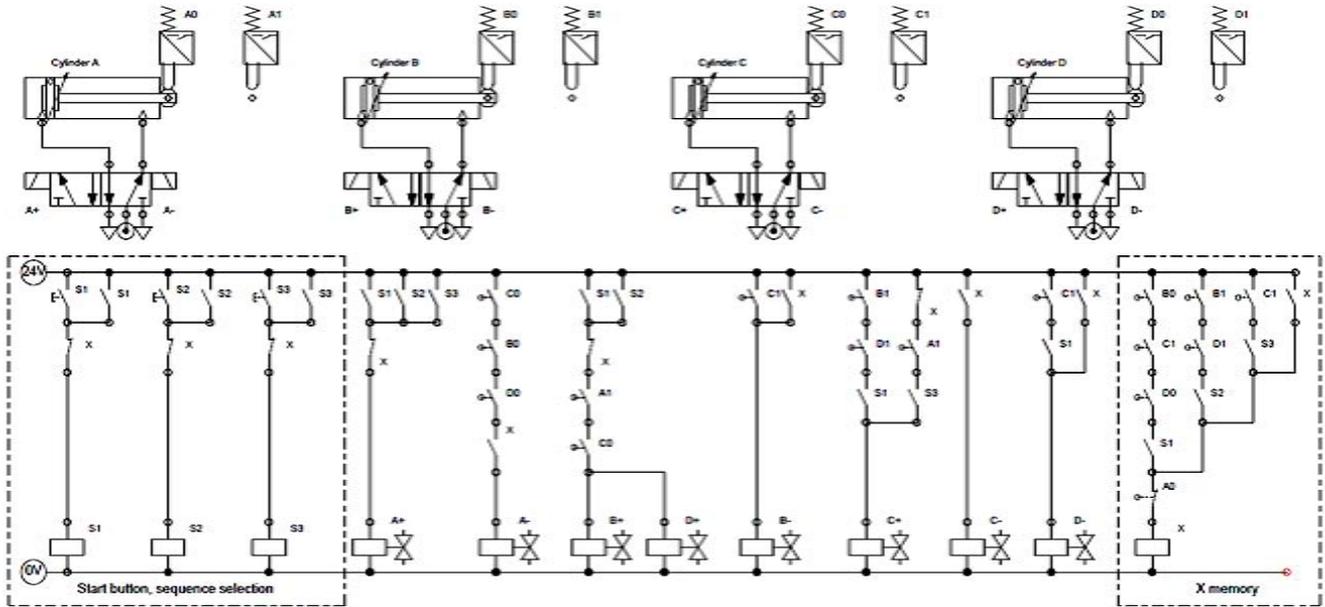


Fig. 10: Electro-pneumatic control for the triple-path sequence (S1, S2, and S3)

This set of equations forms the final equations by combining all the signs into a sum of products. Then, the electrical scheme of this sequence with triple paths, will consist of a set of components in series, parallel, and the resulting memory of the transcription to a contact diagram of the equations obtained in the KM. Figure 10 shows the electrical scheme of the implementation of the equations, as well as the memories associated with the S1, S2, and S3 buttons. Note, however, that in the implementation of the sequence selection memories (see Figure 10, "Start button, sequence selection"), a normally closed (NC) contact was used to deactivate the selection. They, the deactivation of the sequence selection memory should be performed as soon as it is no longer needed. In this case, its deactivation can be done immediately before

the map returns to state x^- , memory X deactivated. This action allows the cycle to be stopped as soon as the movements are completed, so not disabling it would lead to the continued operation of the selected sequence. Continuous cycle operation could only be interrupted by the action of an OFF button.

c) *Electro-pneumatic PLC-base implementation*

From a functional point of view, the control of electro-pneumatic systems is usually done through PLCs or computer systems, remotely or locally, using human-machine interfaces (HMI). So, implementing the electrical control of a pneumatic system, based on the KM equations, will be easy, as it will only consist of the transcription of the equations to the PLC ladder logic. The implementation of the necessary memories,

resulting from the duplication of the map, will also be an easy operation given the flexibility of the PLCs and the Ladder.

To implement the equations in a logical controller (PLC), a set of addresses needs to be defined. So, for each of the four cylinders, it is

necessary to define two actuation addresses (outputs) and two positioning addresses (inputs). For the auxiliary memory, the logic responsible for activating an internal signal, which represents its activation and deactivation, will be defined. Table 1 presents the required symbols and addresses.

Table 1: Address field of the PLC implementation

Symbol	Address	Comment
LS_A0	I0.0	Limit switch A0
LS_A1	I0.1	Limit switch A1
LS_B0	I0.2	Limit switch B0
LS_B1	I0.3	Limit switch B1
LS_C0	I0.4	Limit switch C0
LS_C1	I0.5	Limit switch C1
LS_D0	I0.6	Limit switch D0
LS_D1	I0.7	Limit switch D1
AD_A+	Q0.0	Advance A (A+)
RE_A-	Q0.1	Return A (A-)
AD_B+	Q0.2	Advance B (B+)
RE_B-	Q0.3	Return B (B-)
AD_C+	Q0.4	Advance C (C+)
RE_C-	Q0.5	Return C (C-)
AD_D+	Q0.6	Advance D (D+)
RE_D-	Q0.7	Return D (D-)
M_X	M0.0	Memory X
M_S1	M0.1	Memory S1
M_S2	M0.2	Memory S2
M_S2	M0.3	Memory S3
S1	I1.1	Sequence S1
S2	I1.2	Sequence S2
S3	I1.3	Sequence S3

The control implementation, based on a PLC, was carried out in a model way. Thus, to respect the initial conditions, choosing the sequence, controlling cylinders, and using a memory, three main function blocks were created, Start Button [FC1], Sequences [FC2], and X Memory [FC3], see Figure 11. Laboratory tests for implementation and validation of the control system were performed with SIMATIC TIA Portal V16

software, running on a 1214C AC/DC/Rly CPU, using LD language. Code validation is also performed using TIA Portal software forcing input signal (limit switches and the sequence selection buttons) to get the outputs. The main function, Organization Block [OB1], is the interface between the command operating system and the application program.

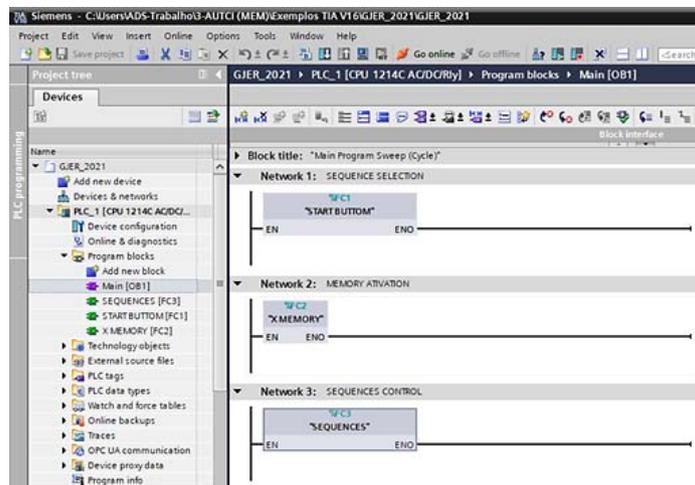


Fig. 11: Modular implementation of control for the sequences S1, S2, and S3

V. CONCLUSION

The demands of global markets demand high flexibility of production systems and, consequently, reduce equipment configuration time. These changes operated at the level of purely pneumatic systems or based on relays, present requirements that they will not be answer promptly to the need for change in the production chains. In this context, the startup and process changes will be an important factor for the company's competitiveness, credibility, and final gains. Thus, considering that purely pneumatic processes are a static system, the alteration of a simple movement in the operating sequence will imply the physical alteration of the entire control – startup times too long given the need to rebuild the entire pneumatic or electric relay-based control system.

The minimization of these startup times involves combining operational sequences capable, within limits considered acceptable, to provide immediate responses to the necessary changes. In this sense, we present a methodology that allows us to deal with different combinations of sequences from KM. They are adapted for the industrial control of pneumatic and electro-pneumatic systems (relay or PLC base), whether combinatorial or sequential. This methodology allows solving highly complex control problems, multiple sequences, for example, easily integrating them into a single command action, using selectors. The command equations obtained from KM guarantee the implementation of defined sequences (triple path, in this case) and the minimization of command variables, whether applied to pneumatics, relays, or programmable logic controllers. These control expressions were also obtained and validated using AI techniques, using PROLOG, to confirming the optimization of the equations, and possible optimal alternatives.

It is also shown that the command equations obtained by KM are easily converted into pneumatic and electrical commands. The ease of conversion into Ladder

Diagram language is also remarkable, opening possibilities for use in the industrial sector or teaching control systems.

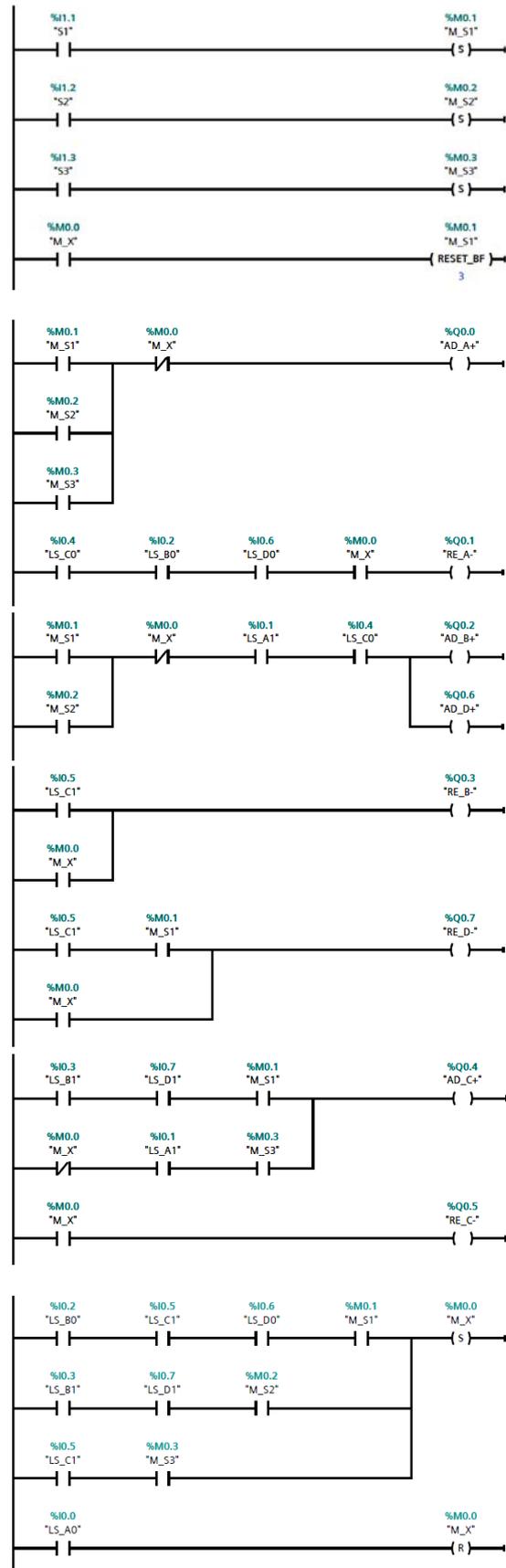


Fig. 12: Electro-pneumatic PLC-base implementation control for sequence the S1, S2 and S3

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Modeling and Applications of a Solar Dish Stirling Engine in the Perspective of Bangladesh

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Keywords: solar dish; sterling engine; solar energy; parabolic concentrator.

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Modeling and Applications of a Solar Dish Stirling Engine in the Perspective of Bangladesh

Shashwata Chakraborty

Abstract- Background: Energy is the most essential thing to ensure sustainable development and the forward ongoing approach of human civilization. For over the last three decades, the consumption of energy has doubled to the rate it was back in the last century. In our country, the scenario is even worse. In spite of being a promising country the economic development was not achieved the way it was expected just because of the lack of reliable energy source and the proper distribution of its necessary for industrialization. The amount of the total stored natural gas in the country is inadequate and tends to exhaust by the next decade. So, it is high time to find a reliable alternative source for the flawless supply of energy in this densely populated country. This paper focuses on a way to get rid of this prevalent power crisis by utilizing this solar energy using the parabolic dish solar Stirling engine which consists of a concentrator that focuses the incident solar rays to a definite point where a Stirling engine will be located to harness the heat energy and convert it to a mechanical output to be further changed to electricity with the aid of a generator coupled to it. As the fossil fuels will definitely move away soon or later, all the nations of the Earth have become concerned to find the alternatives of fossil fuel, especially a renewable source of energy so that it will never exhaust and therefore a constant assurance of the energy might be found.

Materials and Methods: Dish concentrating solar power (CSP) systems use paraboloidal mirrors which track the sun and concentrate solar energy into a recipient where it is absorbed and transferred to a heat engine/generator or else into a heat transfer fluid that is transmitted to a ground-based plant. Dish concentrators have the highest optical efficiencies, the highest concentration ratios and the highest overall conversion efficiencies of all the CSP technologies. If dish Stirling systems are installed in clusters, applications up to 10 MW can be obtained. To recognize the basic working principle and the element of a solar dish Stirling engine is of substantial importance. A dish system consists of the following elements:

- (a) A Parabolic Concentrator,
- (b) Tracking system,
- (c) Heat Exchanger,
- (d) Engine with generator and
- (e) Control unit

Results: The average annual power density of the incident solar radiation is generally in the range of 100–300 W/m². Thus, with a solar PV efficiency of 10%, an area of 3–10 km² is required to establish an average electricity production of 100 MW, which is approximately 10% of a large coal or nuclear power plant. Being different from other energy conversion technologies, solar energy technologies cause neither noise,

nor pollution; Therefore, they are often installed near consumers to cut off construction costs. As a result, we can sustain a great advantage of installing it just in places where there is just enough open land to receive enough radiations from the sun.

Keywords: solar dish; sterling engine; solar energy; parabolic concentrator.

I. INTRODUCTION

Finding out sustainable energy sources has been a prime concern throughout the world ever since the price hike in the fuel market during the post Second World War period. Since then, extensive researches have been carried out finding different scopes of utilizing renewable energy sources and developing numerous advanced energy conversion technologies, which has resulted in a number of modern and innovative ideas of finding the alternatives of fossil fuel. [1-10]. As per many researchers, the most reliable source has been the sun till now, and tremendous efforts have been made to harness this energy as this never exhaust till the world ends. Much improved and innovative schemes and mechanisms have been proposed in the last decades to produce electricity and efficiently generating it into the grid in less toiling means [11-15]. As a developing nation, the toughest challenge of Bangladesh is to touch the energy demand and thus to become supreme in power generation. It is projected that the primary energy consumption may be raised up to 37% between 2013 and 2035 [16]. Bangladesh is the 9th most densely populated country of the Earth [17]. 1203 people live in per square kilometer in this country, according to the latest statistical report by the World Bank in 2013. It is one of the least urbanized countries in the world in which 72.24% of people reside in the countryside. It is really clear that the future economic growth and economic evolution of the land will become a big challenge as she has to confront the rapid energy demand by overwhelming deficiency and additional constraints. However, with its 160 million people, Bangladesh could not ensure yet 100% accessibility of power supply [18]. Merely 20% people are now grid-connected [15] and only 42% people are associated with electricity [19] with the vast majority being deprived of a power supply. Per capita electricity use is only 146.5 kWh here in Bangladesh, whereas in India is 480.5 kWh and in Pakistan is 456.2 kWh [20]. The current literature indicates that for the developed countries, the average

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per capita electricity consumption is 8009.5 kWh but for the developing countries consumption is 1169 kWh. In addition, for any high-income country, the average per capita electricity consumption is 9789 kWh and for any low-income country, it is 392.4 kWh [20]. Then from all the points, the land has been confronting a severe power crisis for about a tenner. Known reserves (e.g., Natural gas and coal) of commercial primary energy sources in Bangladesh are limited in comparison to the development needs of the country [21]. Power generation in the country is almost entirely dependent on fossil fuels, mainly natural gas, that accounted for 81.4% of the total installed electricity generation capacity (5248 MW) in 2006 [22]. The government of Bangladesh has declared that it aims to provide electricity for all by the year 2020, although at present there is high-unsatisfied demand for energy and is growing by more

than 8% annually [23]. Demand supply gaps and load shedding have increased constantly. During the year 2012 the total electricity generation was 35,118 million-kilowatt hours (kWh) out of which 27,795 million kWh was generated from 151 billion cubic feet (BCF) of natural gas [24]. Moreover, in recent years, quick rental power plants have been established to minimize the immediate power shortage, and it simply raised the price of electricity. Also, Various numerical models have been developed to improve the performance of a solar dish by using the pre-heat method [25, 26]. Improved pyrolysis system can also increase the efficiency of the solar dish Stirling engine [27].

However, if combined heating from solar and charcoal firings is provided, it will be more efficient [28, 29].

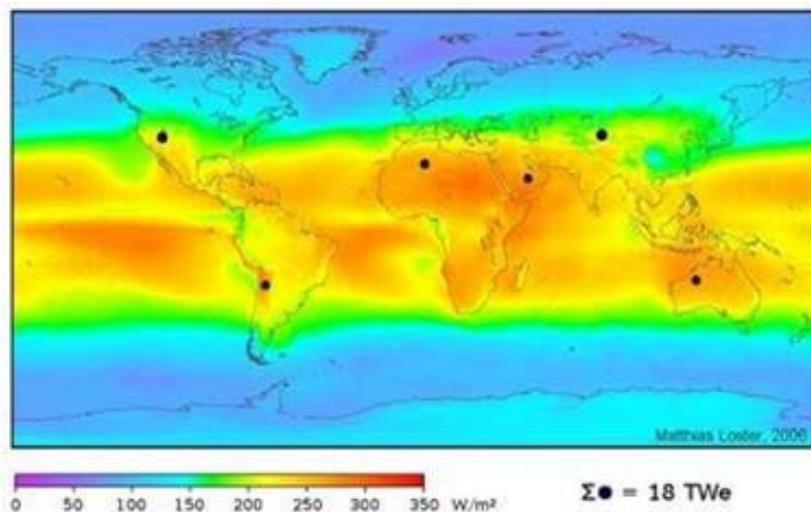


Figure 1: The Solar Irradiation throughout the World

At peak season during summer, the country experiences a severe power crisis that clearly impedances the overall progress of the country with a surprising net deficit of average 1500 megawatt (MW) [26]. Granting to the Energy and Power report of September 2015, at present total 30% of the fuels are imported from abroad for meeting the energy crisis. If this goes on, for meeting the demand of the country by 2030, we have to import 92% of the fuels from outside that will cause a gigantic sum of cost per annum of 17 billion US\$. [30]. Thus, in this crucial situation, the only means of survival for Bangladesh is to detect an alternative and reliable power source based on renewable energy. Withal, the geographical location and the climatic pattern might pave the only path out of this giant task of solving the energy crisis, if applied in good order. From all the points of view, the most common source of energy that might provide a solution to this mammoth to take task is the solar energy, according to the opinion of the specialists. The geographical location and the climatic condition of Bangladesh is very

favorable for the installment of power plants that can harness renewable energies like solar power. Bangladesh is located between $23^{\circ}34'$ N and $26^{\circ}38'$ N latitude and $88^{\circ}01'$ E and $92^{\circ}41'$ E longitudes and the climate are tropical; the very location makes the Bangladesh good recipient of solar energy [31]. Bangladesh has a total area of $1.49E+11$ m² and an average 5 kWh/m² of solar radiation goes down on this land over 300 days per annum [32]. Figure 1 clearly demonstrates that Bangladesh got, on average around 200-250 W/m² of sunlight [33]. Based on the availability of renewable energy sources, specific conditions, and the technology level in Bangladesh, many renewable energy sources for which commercial technologies exist for power generation has been experimented. Unlike the other renewable sources, this solar energy is also a dilute form of energy, and then the effectiveness and acceptance of a particular solar energy converting system solely depend on the efficiency of the mechanism in harnessing the power, side by side the minimal sum of losses during converting the harnessed

energy into usable power or more specifically, the electricity. In Bangladesh people are usually well represented with the solar photovoltaic system or the solar PV, solar cooker and so along. This report aims at introducing a safer and a newer concept that already has been shown to be a successful one in many other lands. It is more usually known as Solar Parabolic Concentrator with Stirling Engine.

II. METHODOLOGY

The Solar Dish Stirling System: Dish concentrating solar power (CSP) systems use paraboloidal mirrors which track the sun and concentrate solar energy into a recipient where it is absorbed and transferred to a heat engine/generator or else into a heat transfer fluid that is transmitted to a ground-based plant. Dish concentrators have the highest optical efficiencies, the highest concentration ratios and the highest overall conversion efficiencies of all the CSP technologies. If dish Stirling systems are installed in clusters, applications up to 10 MW can be obtained. Above this range, other solar thermal systems may be economical or more effective. Dish Stirling systems have demonstrated the highest efficiency of any solar power generation system by converting nearly 30% of direct normal incident (DNI) solar radiation into electricity after accounting for parasitic power losses [34]. These high-performance solar power systems have been in development for more than two decades, having the principal focus in recent years on reducing the capital and operating costs of systems. Dish Stirling systems currently cost about US\$10, 000 per kW installed; major cost reduction will take place with bulk production and further development of the schemes. Significant progress has been formed to improve reliability, thereby shortening the operating and maintenance (O&M) costs of the schemes. As capital costs drop to about US\$3, 000 per kW, promising market opportunities appear to be developing in green power and distributed generation markets in the southwest United States, India, the Mediterranean area, southern Europe and Africa [35]. Thus, we can be sure of the availability of this technology here in Bangladesh.

Basic Principles and components: To recognize the basic working principle and the element of a solar dish Stirling engine is of substantial importance. A dish system consists of the following elements:

- (a) A Parabolic Concentrator,
- (b) Tracking system,
- (c) Heat Exchanger,
- (d) Engine with generator and
- (e) Control unit

a) Parabolic Concentrator

The parabolic reflector functions due to the geometric properties of the paraboloidal shape: any

incoming light beam that is parallel to the bloc of the saucer will be meditated to a key point, or "focus". So parabolic reflectors can be employed to gather and concentrate energy entering the reflector at a particular angle. In comparison to spherical reflectors, which suffer from a spherical aberration that becomes stronger as the ratio of the beam diameter to the focal distance becomes larger, parabolic reflectors can be made to accommodate beams of any width. This advantage of the parabolic geometry has made it popular and reliable over the spherical concentrator.

The concentrator tracks the sun bi-axially, i.e. In the Zenith and Azimuth direction in such a manner that the optical axis of the concentrator always points to the sun. The solar radiation is concentrated by the parabolic concentrator onto the solar receiver which is located close to the focal point of the parabola. The receiver catches the high temperature thermal energy into a fluid that is either the working fluid for a receiver-mounted engine cycle, or is used to carry the energy to ground-based processes. Normally, highly reflective fabrics are used along the reflector. It might be metalized glass or plastic, thin mirrors, aluminum foils or simply could be the mirrors we use every day in our homes. It might be made fused to a one single reflector surface or can be composed of an accumulation of many smaller reflecting unit parts. Also, the highly reflective properly, they should also suffer the stress as they will be turned out throughout the daytime. [15] Making the concentrator with many smaller segments might be a better approximation for the ground that it will cut costs as we can replace only a portion of it when needs to be substituted. Another important advantage of the mirrors is that they remain almost 100% intact for over the decade just through simple maintenance of cleaning and washing. The only thing that might reduce the reflective efficiency of these glasses are the scratches.

For wide-surface concentrators, the entire concentrator surface is shaped parabolically by a molding operation. With many dish concentrators, the reflector is made up of facets mounted on a standing structure. There is a considerable variety of facet designs that have been used.

The concentrators play 2 important roles. Firstly, concentrating the total incident radiation. And secondly, convert this incident light energy as heat energy for a recipient. From the concept of the geometry and theoretical calculations, all the rays are to be centered in one individual spot. But in practical application, this is unimaginable because of the fact that no surface having 100% smoothness, so some flaws are obvious. And secondly, there are always some dispersion or irregularities. Third and most importantly, the sun is not a point source and thus the light beams are not fully parallel. That is why rather than centering the light to a point, it is rather focused on a really small area compared to the entire area of the concentrator. But it is

obvious that the flux is maximum at the central zone, and tends to decrease near the edge. The concentrators have a variety of sizes starting from an area of 20m² or a diameter of less than 1meter to 25meter. The larger the diameter the more the capacity to converge the sunlight, the more the quantity of flux. And based on the concentration ratio it varies from 1500 to 4000.

b) Tracking System

The ways to move the concentrator around the sun associates two ways. The foremost one is Azimuth-elevation tracking that lets the dish turn out in a plane parallel to the earth's surface. The other one is polar-equatorial tracking method in which the dish rotates about an axis parallel to the earth's axis of revolution. The other axis of revolution or the declination axis is perpendicular to the polar axis. The tracking system is governed by the electric motors with gearbox units, as well as hydraulic system is also examined [7].

c) Solar Heat Exchanger (Receiver)

As the proposed engine type is the Stirling engine, the receivers should be employed in a way that will help functioning the Stirling engine properly. As a fact two methods are employed in transferring the concentrated energy to the working gas while using the Stirling engine, The first type receiver, small tubes carrying the working fluid of the Stirling engine, are directly exposed by keeping with the place of direct concentrated solar flux. As in this type of receiver, the tubes carrying the fluid gets illuminated from the radiation, it has been named as Directly Illuminated Tube Receiver (DIR).

In the other instance, the receiver transfers the energy flux through an intermediate liquid metal. The liquid metal vaporizes on acceptance of the heat flux and then condenses on the tubes containing the working gas of the engine. As the vapor comes back as liquid through condensation, this particular type of receiver is likewise called a heat pipe receiver. Again, various study shows that, use of Aluminum as the receiver material results in much better efficiency and the higher temperature difference than that of copper [7].

d) The Stirling Engine with Generator

Brayton engine and Stirling engine are two different types of engines used specifically for this purpose. Stirling engines are preferred for these systems because of their favorable properties like high efficiencies (thermal to- mechanical efficiencies in excess of 40% have been reported to be found), high power density (40–70 kW/liter for solar engines), and potential for long-term, low-maintenance operation. Dish Stirling systems are modular, i.e., each system is a self-contained power generator, allowing their assembly into plants ranging a great deal of variance in size from a few kilowatts to tens of megawatts.

e) The operation of Stirling Engine

Thermal energy provided by concentrating solar radiation can be transformed into electrical energy using a Stirling engine coupled to a generator. Stirling engines are internal combustion engines and thus they use a closed thermodynamic process; i.e., always the same working gas is used within the working cycle. As because of the working fluid being different, diverse sources could be applied as the external supplier of energy, including the solar heat energy in contrast to Otto or Diesel engines where the working fluid is the fuel itself, i.e., petroleum gas or oil. That is why Stirling motors are also suited for solar operation. The basic principle of a Stirling engine is based on the cyclic compression and expansion of gas at different temperature levels to create a net conversion of heat energy to mechanical work. One of the greatest advantages found in such type of engine is that it works on comparatively lower temperature than the rest of the available technologies. And as because it is an external combustion engine, that means a definite working fluid remains throughout the system. Referable to the low thermal inertia, a dish Stirling System reacts very quickly to changes in solar thermal input. Hence steady state operation is achieved within a few minutes after system start.

f) Extraction and Supply of the Harnessed Energy

The generator coupled to the Stirling engine converts the mechanical energy to electrical energy which then can be used individually or can be provided through a dedicated grid system.

g) Solar Home System (SHS)

The system with a larger concentrator and a more powerful engine can be used for supplying electricity in 2-5 houses depending on the size. With appropriate sunlight conditions, the system has proven to be competitive for remote household applications. Such system will run good for the remote zones, marshlands and small islands of Bangladesh like the Saint Martin, Bandarbans, Rangamati and the remotest parts of the Srimongol and the rest of Sylhet where the national grid electricity supply has not reached yet. Installing it on a mass scale might turn the houses to be self-dependent on the field of the daily electricity supply.

h) The Grid System

Variety of grid interactive systems are being tested in countries where extensive utility grid lines are available. A series of these units can be connected and synchronized to the grid using an appropriate power conditioning sub-arrangement that converts the DC energy to alternating current (AC) energy synchronized to the grid energy [36]. Thus, no additional energy storage is necessary. The grid itself is the storage medium for this kind of grid- interactive system, which

delivers energy to the grid as long as enough sunshine is available out there.

III. RESULT & DISCUSSION

a) *Technical potential of Solar Dish Stirling System*

Schematic comparison with the available Solar PV Technology

The average annual power density of the incident solar radiation is generally in the range of 100–300 W/m². Thus, with a solar PV efficiency of 10%, an area of 3–10 km² is required to establish an average electricity production of 100 MW, which is approximately 10% of a large coal or nuclear power plant [42]. Being different from other energy conversion technologies, solar energy technologies cause neither noise, nor pollution; Therefore, they are often installed near consumers to cut off construction costs. As a result, we can sustain a great advantage of installing it just in places where there is just enough open land to receive enough radiations from the sun. Thus, identification of suitable locations for the application of solar energy is practically the search for suitable rooftops and unused ground. A study suggested that 6.8% (10,000 km²) of Bangladesh's total land are necessary for power generation through the operation of solar PV to meet electricity demand of 3000 kWh/capita/year [37]. Another study found that total household roof area is about 4670 km² [39] which is roughly 3.2% of total land area of the country. In urban area (Dhaka city) 7.86% of total land are suitable for electricity generations through solar PV systems. [38]. Looking at the grid availability, only 1.7% of the land in Bangladesh is assumed technically suitable for generating electricity from solar PV [38]. The capacity of grid- connected solar PV is found out using the annual mean value of solar radiation (200 W/m²) and a 10% efficiency of the solar PV system. Thus, the technical potential of grid-connected solar PV in the perspective of Bangladesh is calculated as about 50,174 MW. Whereas the potential market for grid-connected PV systems is in the highly populated urban and electrified areas, the potential market for SHSs is households without access to the national grid network, especially those in remote and hilly areas. Agreeing to a survey report, a market of SHSs of approximately 0.5 million households, expected of reaching 4 million in the future is envisioned in Bangladesh [40]. If an average standard 50-Wp solar panel is considered for each household [41], the technical total capacity will be equivalent to 200 MW.

Now, seeing a crude estimation of the cost of the Dish Stirling CSP, it is even far more efficient than that of the Solar PV systems. Granting to the information provided by Ripasso Energy, they have minimized the usage of land at a great extent, which means we have to cover even lesser land than that of all the present popular photovoltaic (PV) technology along with an

increased efficiency of concentration to about 95% spectral reflectivity. It results in a stunning ratio of usage of only an area of 2 hectares of land for one megawatt of energy production [43]. When arrives to the term of Stirling Engine, the same 100 MW electricity output could be found utilizing only 2 km² of land. Besides, some innovative thinking might result in the minimal usage of land as for using a floating platform or building the modules individually on the rooftops which has been discussed later. From the previously mentioned estimation, for meeting the demand of this same 3000 kWh/capita electricity demand every year, if we consider that a Stirling Engine of the Ripasso Energy remains active for 10 hours daily, it will produce at least 10,000 kWh of energy using every 2 hector of land space. Which means, it will be needed to provide only a land space of 2630 km² of land compared to the 10000 km² needed for the solar PV system. It is only 1.78% of the total land area of Bangladesh. And it will apparently use no space if it is possible to utilize just half of the rooftops throughout the country.

Some other advantages are that, when a PV module gets damaged, it will be highly costly to replace it. But if the concentrator damages, it will same as be replacing a household mirror. It uses no toxic materials, whereas though PV panels are eco-friendly, their manufacturing causes huge environmental hazards as they use toxic and expensive materials like Bismuth Telluride.

b) *Further Proposition for Modification*

Bangladesh is rich in shallow water bodies and the marshlands which remain under water almost the entire year. The haor, baor, canals, large reservoirs are seen almost everywhere in Bangladesh. Whatever might be their source of water, but they usually have no current flow or tide and ebb. These stagnant water bodies might be a useful solution to the problem of the landmass necessary for establishing the solar dish Stirling engine modules. For this purpose, only a small modification of the entire setup could be of great help. Building one or two of these structures on the floating platforms and letting them float near the banks and edges of the water bodies will serve two purposes. Such a setup has been illustrated in the following figure.

It will not only be a source of the required land area, but at the same time it will be a reliable solution to the household power crisis of these regions as because the grid connections are still out of reach to these remote areas. That is, some of these families and villages will be self-dependent in their power supply. As a result, the government will have a one less task to solve regarding the prevailing power crisis.

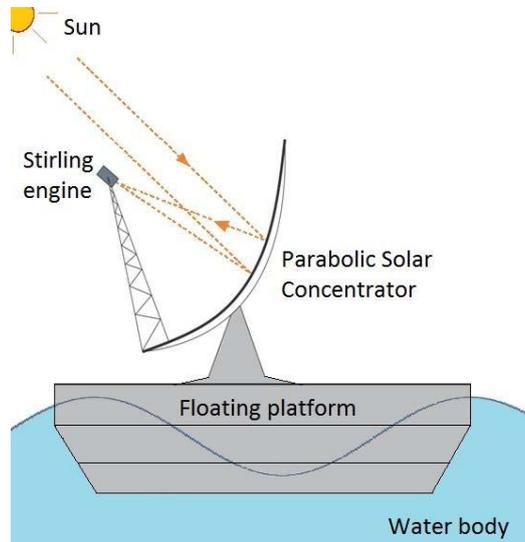


Figure 3: Establishing the Solar Dish Stirling System on a floating Platform in Still Water Body

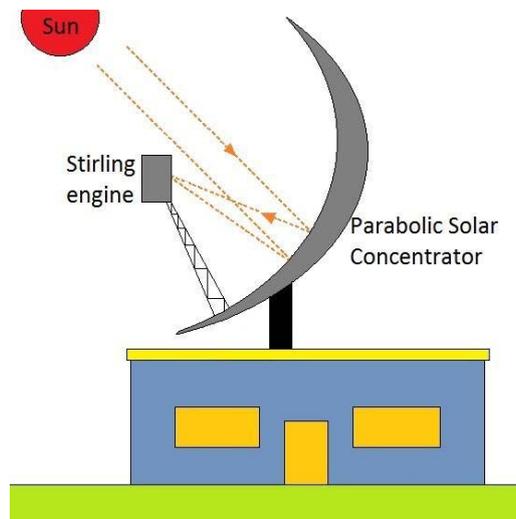


Figure 4: Establishing a Solar Dish Stirling System on a roof top

Nowadays, along with the people getting employed, the villages are developing economically. And it is reflected on the gesture of the homes. Newer houses are built using the modern materials like steel rod, cement which have a good strength and load bearing capacity. So, a highly reinforced rooftop is enough for setting up this system that will help solving the problem related to the place of installation. Being analogous to the dish antenna or mobile tower, the base of the system takes a lot lesser space than that of the disk. So, it will be indeed an excellent idea to set the module on the ceiling or rooftop of the house rather than on the ground to save space.

IV. CONCLUSION

Among all types of the available solar power harnessing system, this has been proved to be more promising and eco-friendlier. The installed cost might be higher because of the less acquaintance among the

people. However, mass scale production might be a solution to this, and further research will surely bring some fruitful result to make it both more efficient and cost effective. When the world has been looking for an alternative source of energy, we should not lag behind as because soon or later, even after paying adequate money, these fossil fuels will not be available. So, in order to avoid this inevitable situation, it is high time to plan carefully for solving these energy related problems in a simple but sustainable mean. Solar powered plants are beyond doubt will lead the world energy source one day. But the earlier introduction to these technologies not only ensures the cost savings of the nation, but also will help to save the environment from the disasters caused by the GHGs, all types of exhaust gases, and side by side the nuclear hazards. The sun is the cleanest source of renewable energy. As all the data and methodology has been described here are now in use, so these technologies are easily available and if

necessary care is taken, the modules can easily be produced in our country. Initially the installation cost is high, though it is far minimized by the effective use of it as the modules are robust in design and they are usually built in a way to last for more than two decades with the fully functional conditions [44]. It needs the least maintenance. Simply the regular cleaning of the mirror surfaces can keep it in the original state when it was installed. Lastly, if all things work out and the Government helps to introduce this efficient technology in our country, the long-dreamt self-dependence in the field of energy will soon come true.

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INTRODUCTION



FERC/AERC is the most prestigious membership of Global Journals accredited by Open Association of Research Society, U.S.A (OARS). The credentials of Fellow and Associate designations signify that the researcher has gained the knowledge of the fundamental and high-level concepts, and is a subject matter expert, proficient in an expertise course covering the professional code of conduct, and follows recognized standards of practice. The credentials are designated only to the researchers, scientists, and professionals that have been selected by a rigorous process by our Editorial Board and Management Board.

Associates of FERC/AERC are scientists and researchers from around the world are working on projects/researches that have huge potentials. Members support Global Journals' mission to advance technology for humanity and the profession.

FERC

FELLOW OF ENGINEERING RESEARCH COUNCIL

FELLOW OF ENGINEERING RESEARCH COUNCIL is the most prestigious membership of Global Journals. It is an award and membership granted to individuals that the Open Association of Research Society judges to have made a 'substantial contribution to the improvement of computer science, technology, and electronics engineering.

The primary objective is to recognize the leaders in research and scientific fields of the current era with a global perspective and to create a channel between them and other researchers for better exposure and knowledge sharing. Members are most eminent scientists, engineers, and technologists from all across the world. Fellows are elected for life through a peer review process on the basis of excellence in the respective domain. There is no limit on the number of new nominations made in any year. Each year, the Open Association of Research Society elect up to 12 new Fellow Members.



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Global Journals sends a letter of appreciation of author to the Dean or CEO of the University or Company of which author is a part, signed by editor in chief or chief author.



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A FERC member gets access to a closed network of Tier 1 researchers and scientists with direct communication channel through our website. Fellows can reach out to other members or researchers directly. They should also be open to reaching out by other.

Career

Credibility

Exclusive

Reputation



CERTIFICATE

CERTIFICATE, LOR AND LASER-MOMENTO

Fellows receive a printed copy of a certificate signed by our Chief Author that may be used for academic purposes and a personal recommendation letter to the dean of member's university.

Career

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DESIGNATION

GET HONORED TITLE OF MEMBERSHIP

Fellows can use the honored title of membership. The "FERC" is an honored title which is accorded to a person's name viz. Dr. John E. Hall, Ph.D., FERC or William Walldroff, M.S., FERC.

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BETTER VISIBILITY AND CITATION

All the Fellow members of FERC get a badge of "Leading Member of Global Journals" on the Research Community that distinguishes them from others. Additionally, the profile is also partially maintained by our team for better visibility and citation. All fellows get a dedicated page on the website with their biography.

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Credibility

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Fellows receive discounts on the future publications with Global Journals up to 60%. Through our recommendation programs, members also receive discounts on publications made with OARS affiliated organizations.

Career

Financial



GJ ACCOUNT

UNLIMITED FORWARD OF EMAILS

Fellows get secure and fast GJ work emails with unlimited storage of emails that they may use them as their primary email. For example, john [AT] globaljournals [DOT] org.

Career

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To take future researches to the zenith, fellows receive access to all the premium tools that Global Journals have to offer along with the partnership with some of the best marketing leading tools out there.

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Career

Credibility

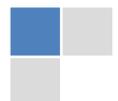
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All fellows receive the early invitations to all the symposiums, seminars, conferences and webinars hosted by Global Journals in their subject.

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Fellows can publish articles (limited) without any fees. Also, they can earn up to 70% of sales proceeds from the sale of reference/review books/literature/publishing of research paper. The FERC member can decide its price and we can help in making the right decision.

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AND MUCH MORE

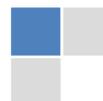
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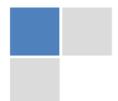
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<p>\$4800 lifetime designation</p> <hr/> <p>Certificate, LoR and Momento 2 discounted publishing/year Gradation of Research 10 research contacts/day 1 GB Cloud Storage GJ Community Access</p>	<p>\$6800 lifetime designation</p> <hr/> <p>Certificate, LoR and Momento Unlimited discounted publishing/year Gradation of Research Unlimited research contacts/day 5 GB Cloud Storage Online Presense Assistance GJ Community Access</p>	<p>\$12500.00 organizational</p> <hr/> <p>Certificates, LoRs and Momentos Unlimited free publishing/year Gradation of Research Unlimited research contacts/day Unlimited Cloud Storage Online Presense Assistance GJ Community Access</p>	<p>APC per article</p> <hr/> <p>GJ Community Access</p>



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3. Ensure corresponding author's email address and postal address are accurate and reachable.
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- Writings
- Diagrams
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2. Drafting the paper and revising it critically regarding important academic content.
3. Final approval of the version of the paper to be published.

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The corresponding author should mention the name and complete details of all co-authors during submission and in manuscript. We support addition, rearrangement, manipulation, and deletions in authors list till the early view publication of the journal. We expect that corresponding author will notify all co-authors of submission. We follow COPE guidelines for changes in authorship.

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Unless specified in the notification, the Editorial Board's decision on publication of the paper is final and cannot be appealed before making the major change in the manuscript.

Acknowledgments

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The following is the official style and template developed for publication of a research paper. Authors are not required to follow this style during the submission of the paper. It is just for reference purposes.



Manuscript Style Instruction (Optional)

- Microsoft Word Document Setting Instructions.
- Font type of all text should be Swis721 Lt BT.
- Page size: 8.27" x 11", left margin: 0.65, right margin: 0.65, bottom margin: 0.75.
- Paper title should be in one column of font size 24.
- Author name in font size of 11 in one column.
- Abstract: font size 9 with the word "Abstract" in bold italics.
- Main text: font size 10 with two justified columns.
- Two columns with equal column width of 3.38 and spacing of 0.2.
- First character must be three lines drop-capped.
- The paragraph before spacing of 1 pt and after of 0 pt.
- Line spacing of 1 pt.
- Large images must be in one column.
- The names of first main headings (Heading 1) must be in Roman font, capital letters, and font size of 10.
- The names of second main headings (Heading 2) must not include numbers and must be in italics with a font size of 10.

Structure and Format of Manuscript

The recommended size of an original research paper is under 15,000 words and review papers under 7,000 words. Research articles should be less than 10,000 words. Research papers are usually longer than review papers. Review papers are reports of significant research (typically less than 7,000 words, including tables, figures, and references)

A research paper must include:

- a) A title which should be relevant to the theme of the paper.
- b) A summary, known as an abstract (less than 150 words), containing the major results and conclusions.
- c) Up to 10 keywords that precisely identify the paper's subject, purpose, and focus.
- d) An introduction, giving fundamental background objectives.
- e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition, sources of information must be given, and numerical methods must be specified by reference.
- f) Results which should be presented concisely by well-designed tables and figures.
- g) Suitable statistical data should also be given.
- h) All data must have been gathered with attention to numerical detail in the planning stage.

Design has been recognized to be essential to experiments for a considerable time, and the editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned unrefereed.

- i) Discussion should cover implications and consequences and not just recapitulate the results; conclusions should also be summarized.
- j) There should be brief acknowledgments.
- k) There ought to be references in the conventional format. Global Journals recommends APA format.

Authors should carefully consider the preparation of papers to ensure that they communicate effectively. Papers are much more likely to be accepted if they are carefully designed and laid out, contain few or no errors, are summarizing, and follow instructions. They will also be published with much fewer delays than those that require much technical and editorial correction.

The Editorial Board reserves the right to make literary corrections and suggestions to improve brevity.



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It is necessary that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.

All manuscripts submitted to Global Journals should include:

Title

The title page must carry an informative title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) where the work was carried out.

Author details

The full postal address of any related author(s) must be specified.

Abstract

The abstract is the foundation of the research paper. It should be clear and concise and must contain the objective of the paper and inferences drawn. It is advised to not include big mathematical equations or complicated jargon.

Many researchers searching for information online will use search engines such as Google, Yahoo or others. By optimizing your paper for search engines, you will amplify the chance of someone finding it. In turn, this will make it more likely to be viewed and cited in further works. Global Journals has compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Keywords

A major lynchpin of research work for the writing of research papers is the keyword search, which one will employ to find both library and internet resources. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining, and indexing.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy: planning of a list of possible keywords and phrases to try.

Choice of the main keywords is the first tool of writing a research paper. Research paper writing is an art. Keyword search should be as strategic as possible.

One should start brainstorming lists of potential keywords before even beginning searching. Think about the most important concepts related to research work. Ask, "What words would a source have to include to be truly valuable in a research paper?" Then consider synonyms for the important words.

It may take the discovery of only one important paper to steer in the right keyword direction because, in most databases, the keywords under which a research paper is abstracted are listed with the paper.

Numerical Methods

Numerical methods used should be transparent and, where appropriate, supported by references.

Abbreviations

Authors must list all the abbreviations used in the paper at the end of the paper or in a separate table before using them.

Formulas and equations

Authors are advised to submit any mathematical equation using either MathJax, KaTeX, or LaTeX, or in a very high-quality image.

Tables, Figures, and Figure Legends

Tables: Tables should be cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g., Table 4, a self-explanatory caption, and be on a separate sheet. Authors must submit tables in an editable format and not as images. References to these tables (if any) must be mentioned accurately.



Figures

Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

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Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution at final image size ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs): >350 dpi; figures containing both halftone and line images: >650 dpi.

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1. Choosing the topic: In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

2. Think like evaluators: If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

3. Ask your guides: If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

4. Use of computer is recommended: As you are doing research in the field of research engineering then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

5. Use the internet for help: An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow [here](#).



6. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

7. Revise what you wrote: When you write anything, always read it, summarize it, and then finalize it.

8. Make every effort: Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

9. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

10. Use proper verb tense: Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

11. Pick a good study spot: Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

12. Know what you know: Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

13. Use good grammar: Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

14. Arrangement of information: Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

15. Never start at the last minute: Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

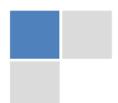
16. Multitasking in research is not good: Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

17. Never copy others' work: Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

18. Go to seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

19. Refresh your mind after intervals: Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

20. Think technically: Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.



21. Adding unnecessary information: Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.

22. Report concluded results: Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.

23. Upon conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium through which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

INFORMAL GUIDELINES OF RESEARCH PAPER WRITING

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

Final points:

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

The introduction: This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

The discussion section:

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear: Adhere to recommended page limits.

Mistakes to avoid:

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.



- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

Title page:

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

Abstract: This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

Reason for writing the article—theory, overall issue, purpose.

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

Approach:

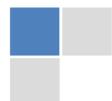
- Single section and succinct.
- An outline of the job done is always written in past tense.
- Concentrate on shortening results—limit background information to a verdict or two.
- Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

Introduction:

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

The following approach can create a valuable beginning:

- Explain the value (significance) of the study.
- Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- Briefly explain the study's tentative purpose and how it meets the declared objectives.



Approach:

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

Procedures (methods and materials):

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

Materials may be reported in part of a section or else they may be recognized along with your measures.

Methods:

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

Approach:

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

What to keep away from:

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.



Content:

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

What to stay away from:

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

Approach:

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

Figures and tables:

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

Discussion:

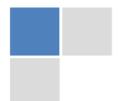
The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.



Approach:

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

THE ADMINISTRATION RULES

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Topics	Grades		
	A-B	C-D	E-F
<i>Abstract</i>	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
<i>Introduction</i>	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
<i>Methods and Procedures</i>	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
<i>Result</i>	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
<i>Discussion</i>	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
<i>References</i>	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring



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