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Mechanical & Mechanics Engineering

Highlights

- Boundary Element Model
- Machinability of Nickel Chromium
- Simulation of Journal Bearings
- Chromium Case Hardened Steel

Discovering Thoughts, Inventing Future

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By Boris Menin

Abstract- This paper proposes a new framework for calculating the discrepancy of a model and the observed technological process or physical phenomenon. It offers powerful tools for all measurement methods applied in technology, engineering and experimental physics. Since the studies that validate and verificate the models of the phenomenon are still complex, they need to be combined into one total measure. Existing methods used in almost all literature up to the present time implicitly suggest that the use of supercomputers and the latest mathematical statistical methods allows achieving high accuracy very close to the boundaries of Heisenberg principle. To compare methodologies for improving models, we propose a new metric called comparative uncertainty. This allows us to prove that there is a limit to the achievable discrepancy between the model and the object under study.

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Abstract- This paper proposes a new framework for calculating the discrepancy of a model and the observed technological process or physical phenomenon. It offers powerful tools for all measurement methods applied in technology, engineering and experimental physics. Since the studies that validate and verificate the models of the phenomenon are still complex, they need to be combined into one total measure. Existing methods used in almost all literature up to the present time implicitly suggest that the use of supercomputers and the latest mathematical statistical methods allows achieving high accuracy very close to the boundaries of Heisenberg principle. To compare methodologies for improving models, we propose a new metric called comparative uncertainty. This allows us to prove that there is a limit to the achievable discrepancy between the model and the object under study. Our results have wide implications for known climate forecasts, spacecraft missions, measurement of fundamental constants, and other measurements during any technological processes. In this paper, the use of the information approach is illustrated by several examples: measurement of fundamental constants and calculation of the amount of information received by the Maxwell demon during modelling. In addition, we apply the Landauer limit to calculate the amount of information corresponding to the energy contained in the universe, with a known radius.

Keywords: bekenstein bound; fundamental physical constants; information theory; landauer limit; mathematical modeling; maxwell demon, similarity theory.

I. Introduction

Physical laws express in mathematical form a quantitative relationship between different physical quantities. They are based on the generalization of the experimental data obtained and reflect the objective laws that exist in nature. It is so fundamentally important that all physical laws are an approximation to reality, since the construction of theories is formulated by certain models of phenomena and processes. Beyond these models, laws do not work or work poorly. Therefore, laws have certain limits of applicability. In other words, physical laws give good predictions in a specific area of experimental conditions, and the corresponding theory explains them. A more accurate or more correct theory has a wider range of applications. Scientists believe that physical laws, at least, allow us to predict the results with arbitrary accuracy. For example, classical mechanics, based on the three laws of Newton and the law of universal gravitation, is valid only for the motion of bodies with velocities much less than the speed of light. If the velocities of bodies are comparable with the speed of light, the predictions of classical mechanics are erroneous. The special theory of relativity has successfully coped with these problems. In fact, all physical theories are limited. The principle of correspondence requires that the new theory with a wider scope of applicability be limited to the old theory within its applicability. An appeal to the theory of new concepts creates important prerequisites for further development.

Among the various explanations for the admissibility of possible limits of applicability of physical laws, the following are most often used. The first is the assumption that there is a limited destabilization of phenomena for which the Heisenberg inequality gives a quantitative expression. Secondly, the limitations are determined by the real nature of the macroscopic instrument or measuring system. Most of the devices are finally presented as a solid one. In principle, it can be argued that any device has an educational effect only in the realm of reality, what it is. Thus, the results of research should be expressed in terms of macroscopic. In other words, concepts and images can be identified and associated only with ordinary macroscopic representations. The last argument is the point of view of the principle of the electromagnetic nature of all modern means of measurement and their role in determining the limits of experimental and measurement capabilities and harmonizing data with theoretical postulates. Thus, explanations are possible, but any quantitative approaches to quantifying the difference between the model (formulated by the physical law) and the existing reality have not been proposed to date.

Concerning the fundamental physical constants, it should be noted that their values are the accuracy of our knowledge of the fundamental

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properties of matter. On the one hand, very often the verification of physical theories is determined by the accuracy of the measured physical constant. On the other hand, firmly established experimental data form the basis of new physical theories.

When studying physical constants, it should be noted that they are measured with very high accuracy, which is steadily increasing. In itself it is evidence of the development and improvement of methods of physical experiment. Nowadays, exact research is carried out to measure and refine the values of physical constants and to work diligently to harmonize data obtained by different methods and different groups of researchers. However, there is an urgent need to further improve the accuracy of measuring fundamental physical constants. This is explained by the desire to improve the axiomatic basis of the International System of Units (SI).

To estimate the accuracy achieved in various nature and technological processes, including measurements of fundamental physical constants, the concept of relative uncertainty is used. It should be noted that this method of determining the measurement accuracy does not indicate the direction in which the true value of the fundamental physical constant can be found. In addition, it includes an element of subjective judgment [1].

In [2], the authors proposed to simplify the method for estimating the uncertainties of the measurement results: provided that the indirectly measured physical quantity depends only on the directly measured physical quantities directly or indirectly, the evaluation of the measurement accuracy using the maximum uncertainty can be interpreted as having a much a higher informative value than the value provided by a simple orientation estimate.

On the contrary, we propose a new method for estimating the reliability of the obtained measurement results by achieving the least relative uncertainty.

Taking into account the aforesaid, the use of information theory for the modelling of physical processes takes on a special place. Information-oriented theoretical calculations of models of physical phenomena are based on the analogy between measurement systems and communication systems. In a simple communication system, the message (input) is encoded into a signal at the end of the transmitter, sent to the end of the receiver, and then decoded back (output). The accuracy of the transmission depends on the characteristics of the communication system, as well as on the characteristics of the medium, that is, on the background noise level. Similarly, measuring instruments can be considered as "information machines" [3], which interact with the object in this state (input), code this state into an internal signal and convert this signal into readout (output). The accuracy of the measurement is similarly dependent on the instrument, as well as on the noise level in its environment. Conceived as a special type of information transfer, the dimension is analysed from the point of view of the conceptual apparatus of information theory [4].

Bas van Fraassen [5] recently proposed a measurement concept in which information plays a key role. He considers measurements as consisting of two levels: at the physical level, the measuring device interacts with the object and reads, for example, the position of the pointer. At the abstract level, this theory represents the possible states of the object in the parameter space. Measurement finds an object in the sub-region of this space of abstract parameters, thereby reducing the range of possible states. This reduction in capabilities is reduced to collecting information about the measured object.

Since the studies that confirm and test the phenomenon models are still complex, they need to be combined into one general measure. The methods used in almost all literature up to the present time implicitly suggest that the use of supercomputers and the latest mathematical statistical methods makes it possible to achieve a high arbitrary accuracy very close to the boundaries of the Heisenberg principle. To compare the methodologies for improving models, we propose a new metric called comparative uncertainty. This metric is a novel one. This allows us to prove that there is a limit to the achievable discrepancy between the model and the object under study. In another words, the state of an object cannot be known with arbitrary precision independently of its measurement [6].

Here we investigate the information cost of measurements in the modelling. Starting with the framework set in ref. [7], we introduce the metric of dignity, the comparative uncertainty of the measurement, which is realized in a real experiment. We believe in the importance of this work because of the following points. Thanks to the introduction of this quantitative tool, we obtain the lower limit of the achieved absolute and relative uncertainties associated with the act of observation, which is characteristic and inherent in measurement. The flexibility of our experimental setup allows us to calculate the amount of information retrieved from the system. Our method allows us to determine how much the developed model (before carrying out the experiment or computer calculations) can extract information in order to achieve the lowest threshold inconsistency in comparison with the object under study. Moreover, there was showed that the information amount inherent in the model can be calculated and how it proscribes the required number of quantities which should be taken into account. It was thus concluded that in most physically relevant cases (micro- and macro-physics), the comparative uncertainty can be realized by field tests or computer simulations within the prearranged variation of the main recorded quantity.

The information-oriented approach was applied for design of thermal energy storage systems [8], technological processes of slurry ice production [9], climate models and spacecraft heating [10]. Since the information approach provides a theoretically grounded value of relative uncertainty, with great certainty, one can estimate the admissibility of a particular measurement result. It can also be easily updated when new measurements come out. The approach can also be used for the measurements of the fundamental physical constants and will greatly shorten the duration of the studies and the design stage, thereby reducing the cost of the projects. This moment, it will be revised for a very controversial, at the current level of understanding nature by scientists, measurements of Hubble constant and concept of the Maxwell's demon.

Our work is organized as follows. In the next section, we introduce an information-oriented approach and a methodology for calculating relative and comparative uncertainties. In Section III, we use the information method to analyze the relative uncertainties of the Hubble, Boltzmann, Planck, fine structure, and gravitational constants. In addition, we analyze the paradox of Maxwell's demon and we apply the Landauer limit to calculate the amount of information corresponding to energy contained in the universe, with a known radius. We discuss in Section 4 and conclude in Section 5.

II. Key Concepts from Information-Oriented Approach

In seminal paper [7] the approach, called μ_{SI} – hypothesis, for calculating the lowest comparative uncertainty of the researched quantity based on principles of information and similarity theories with the usage of the International system of units (SI), is formulated. Following it, the certain uncertainty exists before starting experiment due only the known recorded number of quantities. In turn, the dimensionless comparative uncertainty ε of the dimensionless quantity u, which varies in a predetermined dimensionless interval S, for a given number of selected physical dimensional quantities z'', and β'' (the number of the recorded base quantities) can be determined from the relation:

$$\varepsilon = \Delta u / S \leq [(z' - \beta')/(\Psi - \xi) + (z'' - \beta'')/(z' - \beta')] \quad (1)$$

where Δu is the dimensionless uncertainty of physical-mathematical model describing the experiment of measurement of the dimensionless quantity u;

ξ is a number of the base quantities with independent dimension; SI includes the following seven (ξ =7) base primary quantities: L is the length, M is weight, T is time, I is electric current, Θ is thermodynamic temperature, J is force of light, F is a number of substances. The dimension of any derived quantity q can only express a unique combination of dimensions of base quantities in different degrees [11]:

$$q \supset L^l M^m T^t I^i \Theta^{\Theta} J^j F^f. \quad (2)$$

l, m... f are exponents of quantities, the range of each has maximum and minimum value; according to [12], integers are the following:

$$-3 \leq l \leq +3,\ -1 \leq m \leq +1, -4 \leq t \leq +4, -2 \leq i \leq +2, \quad (3)$$

$$-4 \leq \Theta \leq +4,\ -1 \leq j \leq +1, -1 \leq f \leq +1;$$

The exponents of quantities take only integer values [12], so the number of choices of dimensions for each quantity e_k, k = {l, m... f} according to (3) is the following:

$$e_l = 7;\ e_m = 3;\ e_t = 9;\ e_i = 5;\ e_\theta = 9;\ e_j = 3;\ e_f = 3; \quad (4)$$

where, for example, L^{-3} is used in a formula of density, and Θ^4 in the Stefan-Boltzmann law.

The total number of dimension options of physical quantities equals $\Psi^* = \prod_l^f e_k - 1$

$$\Psi^* = e_l\, e_m\, e_t\, e_i\, e_\theta\, e_j\, e_f - 1 = 7.3.9.5.9.3.3 - 1 = 76{,}544, \quad (5)$$

where "-1" corresponds to the occasion when all exponents of base quantities in the formula (2) are treated to zero dimension; Π is a product of e_k;

The value Ψ^* includes both required, and inverse quantities (for example, L^1 – length, L^{-1} – running length). The object can be judged knowing only one of its symmetrical parts, while others structurally duplicating this part may be regarded as information empty [13]. Therefore, the number of options of dimensions may be reduced in 2 times. It means that the total number of dimensional physical quantities without inverse quantities for SI equals.

$$\Psi = \Psi^* / 2 = 38{,}272; \quad (6)$$

z' is a total number of dimensional physical quantities in the chosen class of phenomena (COP); in SI frames, every researcher selects a particular COP to study material object. COP is a set of physical phenomena and processes described by a finite number of base and derived quantities that characterize certain features of material object from the position with qualitative and quantitative aspects [14]. In studying mechanics, for example, which widely applied for the Newtonian gravitational constant measurements with a torsion balance, the base units of SI are typically used: L, M, T (LMT). In publications relating to the measurement, for example, of the Boltzmann constant, the model corresponds to $COP_{SI} \equiv LMT\theta$;

β' is the number of base physical quantities in the chosen COP; taking into account π –theorem [11], a total number of dimensionless criteria $\mu_{SI} = \Psi - \xi$ inherent in SI equals.

$$\mu_{SI} = \Psi - \xi = 38{,}265. \quad (7)$$

Equation (1) quantifies $\Delta u/S$ caused by the limited number of quantities taken into account in the theoretical or experimental analysis of researched quantity. On the other hand, it also sets a limit on the expedient increasing of the measurement accuracy in conducting experimental studies. In turn, $\Delta u/S$ is not a purely mathematical abstraction. It has a physical meaning, consisting in the witness that in nature there is a fundamental limit to the accuracy of displaying any observed material object, which cannot be surpassed by any improvement of instruments and methods of measurement. The reality of the environment is the obvious a *priori* condition for the modeling of the investigated material object. By allocating the interested process or phenomenon, the unknown relationships between the content of object and the environment are "broken". In this context it is obvious that an overall uncertainty of the model including inaccurate input data, physical assumptions, the approximate solution of the integral-differential equations, etc., will be larger than Δu. Thus, Δu is only one lowest component of a possible mismatch of real object and its modeling results.

In fact, equation (1) can be regarded as the conformity principle (uncertainty relation) for the process of model development. No model can produce results that contradict the relation (1). That is, any change in the level of the detailed description of the observed object (z''-β''; z'-β') causes a change in the minimum comparative uncertainty value Δ_{pmm}/S of the model of a specific COP and in the achieved accuracy of each main quantity, characterizing the internal structure of the object. In other words, the *conformity principle* fundamentally establishes the accuracy limit (for a given class of phenomena) of simultaneously defining a pair of quantities, observed by a conscious researcher, particularly, the absolute uncertainty in the measurement of the investigated quantity and the interval of its changes.

Equating the derivative of $\Delta u/S$ (1) with respect to z'-β', to zero, we obtain the condition for achieving the minimum comparative uncertainty for a particular COP:

$$(z'-\beta')^2/(\Psi-\xi) = (z''-\beta'') \qquad (8)$$

It should be noted that, for example, for the electromagnetism processes ($COP_{SI} \equiv LMTI$), which are used usually for the Rydberg constant measurements, the lowest comparative uncertainty ε_{LMTI} can be reached at the following conditions:

$$(z'-\beta') = (e_l\, e_m\, e_t\, e_i - 1)/2 - 4 = (7\cdot3\cdot9\cdot5-1)/2-4 = 468 \qquad (9)$$

$$(z''-\beta'') = (z'-\beta')^2/(\Psi-\xi) = 468^2/38{,}265 \approx 6 \qquad (10)$$

Then one can calculate an achievable comparative uncertainty ε_{LMTI}

$$\varepsilon_{LMTI} = (\Delta u/S)_{LMTI} = 468/38{,}265 + 6/468 \approx 0.0244 \qquad (11)$$

Below is Table 1 introducing different class of phenomena and the corresponding achievable comparative uncertainties and recommended number of quantities.

Let to apply the above-mentioned method to determine the minimum possible measurement uncertainty of several fundamental physical constants.

Table 1: Comparative uncertainties and recommended number of dimensionless criteria

COP_{SI}	Comparative uncertainty	Number of criteria
LMT	0.0048	0.2 < 1
LMTF	0.0146	≅ 2
LMTI	0.0244	≅ 6
LMTθ	0.0442	≅ 19
LMTIF	0.0738	≅ 52
LMTθF	0.1331	≅ 169
LMTθI	0.2220	≅ 471
LMTθFI	0.6665	≅ 4,249

For these purposes the reader needs to remember that if the range of observation S is not defined, the information obtained during the observation or measurement cannot be determined, and the entropic price becomes infinitely large [15]. In the framework of the information-oriented approach, it seems that the theoretical limit of the absolute and relative uncertainties depends on the empirical value, that is, possible interval of placing (the observed range of variations) S of the measured physical constant. In other words, the results will be completely different if a larger interval of changes is considered in the measured fundamental physical constant. It is right, however, if S is not declared, the information obtained in the measurement cannot be determined. Any specific measurement requires certain (finite) a priori information about the components of the measurement and interval of observation of the measured quantity. These requirements are so universal that it acts as a postulate of metrology [16]. This, the observed range of variations, depends on the knowledge of the developer before undertaking the study. "If nothing is known about the system studied, then S is determined by the limits of the measuring devices used" [15].

That is why, taking into account Brillouin's suggestions, there are two options of applying the conformity principle to analyze the measurement data of the fundamental physical constants.

First, this principle dictates, factually, analyzing the data of the magnitude of the achievable relative uncertainty at the moment taking into account the latest results of measurements. The extended range of changes in the quantity under study S indicates an imperfection of the measuring devices, which leads to a large value of the relative uncertainty. The development of measuring technology, the increase in the accuracy of measuring instruments, and the improvement in the existing and newly created measurement methods

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together lead to an increase in the knowledge of the object under study and, consequently, the magnitude of the achievable relative uncertainty decreases. However, this process is not infinite and is limited by the conformity principle. The reader should bear in mind that this conformity principle is not a shortcoming of the measurement equipment or engineering device, but of the way the human brains work. When predicting behavior of any physical process, physicists are, in fact, predicting the perceivable output of instrumentation. It is true that, according to the *μ*-hypothesis, observation is not a measurement, but a process that creates a unique physical world with respect to each particular observer. Thus, in this case, the range of observation (possible interval of placing) of the fundamental physical constant *S* is chosen as the difference between the maximum and minimum values of the physical constant measured by different scientific groups during a certain period of recent years. Only in the presence of the results of various experiments one can speak about the possible appearance of a measured value in a certain range. Thus, using the smallest attainable comparative uncertainty inherent in the selected class of phenomena during measuring the fundamental constant, it is possible to calculate the recommended minimum relative uncertainty that is compared with the relative uncertainty of each published study. In what follows, this method is denoted as IARU and includes the following steps:

1. From the published data of each experiment, the value z, relative uncertainty r_z and standard uncertainty u_z (possible interval of u placing) of the fundamental physical constant are chosen.
2. The experimental absolute uncertainty Δ_z is calculated by multiplying the fundamental physical constant value z and its relative uncertainty r_z attained during the experiment, $\Delta_z = z \cdot r_z$.
3. The maximum z_{max} and minimum z_{min} values of the measured physical constant are selected from the list of measured values z_i of the fundamental physical constant mentioned in different studies.
4. As a possible interval for placing the observed fundamental constant S_z, the difference between the maximum and minimum values is calculated, $S_z = z_{max} - z_{min}$.
5. The selected comparative uncertainty ε_T (Table 1) inherent in the model describing the measurement of the fundamental constant is multiplied by the possible interval of placement of the observed fundamental constant S_z to obtain the absolute experimental uncertainty value ΔIARU in accordance with the IARU, $\Delta_{IARU} = \varepsilon_T \cdot S_z$.
6. To calculate the relative uncertainty r_{IARU} in accordance with the IARU, this absolute uncertainty Δ_{IARU} is divided by the arithmetic mean of the selected maximum and minimum values, $r_{IARU} = \Delta_{IARU} / ((z_{max} + z_{min})/2)$.
7. The relative uncertainty obtained r_{IARU} is compared with the experimental relative uncertainties r_i achieved in various studies.
8. According to *IARU*, a comparative experimental uncertainty of each study, ε_{IARUi} is calculated by dividing the experimental absolute uncertainty of each study Δ_z on the difference between the maximum and minimum values of the measured fundamental constant S_z, $\varepsilon_{IARUi} = \Delta_z / S_z$. These calculated comparative uncertainties are also compared with the selected comparative uncertainty ε_T (Table 1).

Second, *S* is determined by the limits of the measuring devices used [15]. This means that as the observation interval in which the expected true value of the measured fundamental physical constant is located, a standard uncertainty is selected when measuring the physical constant in each particular experiment. Compared with various fields of technology, experimental physics is better for the fact that in all the researches, the experimenters introduce the output data of the measurement with uncertainty bars. At the same time, it should be remembered that the standard uncertainty of a particular measurement is subjective, because the conscious observer probably did not take into account this or that uncertainty. The experimenters calculate the standard uncertainty, taking into account all possibilities, they noticed the measured uncertainties. Then, one calculates ratio between the absolute uncertainty reached in an experiment and standard uncertainty, acting as a possible interval for allocating a fundamental physical constant. So, in the framework of the information approach, the comparative uncertainties achieved in the studies are calculated, which in turn are compared with the theoretically achievable comparative uncertainty inherent in the chosen class of phenomena. Standard uncertainty can be calculated also for quantities that are not normally distributed. Transformation of different types of uncertainty sources into standard uncertainty is very important. In what follows, this method is denoted as IACU and includes the following steps:

1. From the published data of each experiment, the value z, relative uncertainty r_z and standard uncertainty u_z (possible interval of placing) of the fundamental physical constant are chosen.
2. The experimental absolute uncertainty Δ_z is calculated by multiplying the fundamental physical constant value z and its relative uncertainty r_z attained during the experiment, $\Delta_z = z \cdot r_z$.
3. The achieved experimental comparative uncertainty of each published research ε_{IACUi} is calculated by dividing the experimental absolute uncertainty Δ_z on the standard uncertainty u_z, $\varepsilon_{IACUi} = \Delta_z / u_z$.

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4. The experimental calculated comparative uncertainty ε_{IACUi} is compared with the selected comparative uncertainty ε_T (Table 1) inherent in the model, which describes the measurement of the fundamental constant.

III. Applications

On the one hand, equation (1) requires the use of an experimental stand with the number of variables corresponding to the chosen class of phenomena. On the other hand, equation (1) clearly indicates the impossibility to develop an experimental device that allows to achieve the exact value of the selected comparative uncertainty for a given measurement result. Its introduction emphasizes the need for the development of new experimental stands suitable for quantifying the quantity under study. The μ_{SI}-hypothesis given in equation (1) makes the lower bound of the change in the entropy of the chosen model inaccessible from theoretical considerations. Our experiment allows us to estimate the comparative uncertainty Δu / S from the published results, although this is not equivalent to measuring the actual changes in the fundamental constant. This trend is reflected in the spread of the value of comparative uncertainty in comparison with its theoretical-informational lower limit, depending on the chosen class of phenomena.

a) Hubble constant H_0

The current state of Hubble's constant H_0 definitions gives the scale of the length of the universe, connecting the speed of expansion of objects with their distance. There are two broad categories of measurements. In the first case (Λ Cold Dark Matter model - ΛCDM), individual astrophysical objects are used that have some property that allows them to determine their internal brightness or size or allows them to determine their distance geometrically. The second category includes the use of a cosmic microwave background (CMB) in the sky, or the correlation between large samples of galaxies, to determine information about the geometry of the universe and, consequently, the Hubble constant, usually in combination with other cosmological parameters. The current results give a range of the Hubble constant changes from 67 km·s^{-1}· Mpc^{-1} to 74.3 km·s^{-1}· Mpc^{-1}. Whether there is a discrepancy and whether a new physics is needed to solve it depends on details of the systematic of object-oriented methods, as well as on assumptions about other cosmological parameters and on what data sets are combined in the case of sky methods. Maybe the Hubble constant discrepancy is just due unaccounted uncertainties.

Of course, all these measurements have uncertainty. Each research team first produces unprocessed measurements, then attempts to explain the vagaries of individual telescopes, astrophysical unknowns and countless other sources of uncertainty that can hold astronomers all day. Then, all the individual published studies are combined into a single number for the rate of expansion, as well as a measure of how vague this number is.

Several research publications made during 2009-2018 [17-25] were analysed from the position of the introduction of clear achieved values of the relative uncertainty with a published possible interval of H0 placing. Comparative uncertainties in the measurement of the Hubble constant are calculated. The reader must bear in mind that measurements closed to ΛCDM belong $COP_{SI} \equiv LMT\theta$ and the Hubble constant measurements closed to CMB belong to $COP_{SI} \equiv LMT$. In the framework of the information-oriented approach it is impossible not only to achieve, but also to approach the smallest relative uncertainty when using $COP_{SI} \equiv LMT$ (see Table 1): the optimal number of the dimensionless criteria is less 1.That is why, further calculations will be carried out only for $COP_{SI} \equiv LMT\theta$.

In order to apply the stated approach (*IARU*), as the possible measurement interval H_0, there was chosen the difference in its values obtained in two projects: H_{0min}= 67.0 km·c-1·Mpc^{-1} [25] and H_{0max} = 72.5 km·c^{-1}·Mpc^{-1} [21].

Then the possible observable range S_H of changes H_0 and the average value H_{0aver} are equal:

$$\boldsymbol{S}_{\rm H} = {\rm H}_{0\max} - {\rm H}_{0\min} = 5.5\ ({\rm km}\cdot{\rm c}^{-1}\cdot{\rm Mpc}^{-1}) \tag{12}$$

$$({\rm H}_0)_{\rm aver} = ({\rm H}_{0\max} + {\rm H}_{0\min})/2 = 69.75({\rm km}\cdot{\rm c}^{-1}\cdot{\rm Mpc}^{-1}). \tag{13}$$

Applying the *IARU* approach, one can calculate the desired value of the relative uncertainty $(r_H)_{LMT\theta}$, by which the researchers in the future are going to measure the true value of H_0. Measuring equipment, test bench and a measurement model of H_0 correspond to $COP_{SI} \equiv LMT\theta$ (Table 1)

$$(\varepsilon_{\rm H})_{LMT\theta} = 0.0442. \tag{14}$$

Then an absolute uncertainty $(\Delta_H)_{LMT\theta}$ for $COP_{SI} \equiv LMT\theta$.

$$(\Delta_{\rm H})_{LMT\theta} = (\varepsilon_{\rm H})_{LMT\theta} \cdot S_{\rm H} = 0.0442 \cdot 5.5 = 0.243199\ ({\rm m}^{-1}). \tag{15}$$

Table 2: Hubble constant determinations and relative and comparative uncertainties achieved

Year	Hubble constant H_0 km·c^{-1}·Mpc^{-1}	Achieved relative uncertainty r_H	Absolute uncertainty Δ_H km·c^{-1}·Mpc^{-1}	H_0 possible interval of placing u_H km·c^{-1}·Mpc^{-1}	Calculated comparative uncertainty $\varepsilon_H{'} = \Delta_H / u_H$ *IACU*	Calculated comparative uncertainty $\varepsilon_H{''} = \Delta_H / S_H$ *IARU*	Ref.
2009	71.9	0.038	2.7	5.2**	0.5192	0.49	[17]
2011	72.0	0.042	3.0	4.7*	0.6383	0.55	[18]
2011	71.0	0.035	2.5	6.0**	0.4167	0.45	[19]
2013	69.32	0.012	0.8	4.3**	0.1860	0.15	[20]
2014	72.5	0.034	2.5	6.5*	0.3846	0.45	[21]
2014	69.6	0.010	0.7	1.4*	0.5000	0.13	[22]
2015	68.11	0.013	0.86	1.4*	0.6143	0.16	[23]
2016	67.8	0.013	0.9	2.2**	0.4091	0.16	[24]
2018	67.0	0.013	0.9	1.0**	0.9000	0.16	[25]

** Data are introduced in [23];*
*** Data are introduced in [26]*

In this case, the lowest relative uncertainty $r_{LMT\theta}$ for COP$_{SI}$ ≡*LMTθ* is as follows:

$$r_{LMT\theta} = \Delta_{LMT\theta} / ((H_{max} + H_{min})/2) = 0.0035. \quad (16)$$

An analysis of the data given in Table 2 [17-25], shows that during the last decade there has been sharp increase in the accuracy of measuring H_0 from the point of view of reducing the relative uncertainty.

Following the method *IARU*, it is seen from the data given in Table 2 that there was too a significant improving the accuracy of the measurement of the Hubble constant during last decade. It is authorized true when based on calculation of the relative and comparative uncertainties. Judging the data by the comparative uncertainty following to *IACU*, one can see that the measurement accuracy was not improved. At the same time, there is yet a large gap between the comparative uncertainty calculated according to the information-oriented approach $\varepsilon_{LMT\theta}$ =0.0442 and the experimental magnitudes achieved during measuring H_0. It must be mentioned that, most likely, the exactness of Hubble constant as other fundamental physical constants, cannot be infinite. Therefore, the development of a larger number of designs and improvement of the various experimental facilities for the measurement of Hubble constant is an absolute must. In addition, the difference may be explained by the fact that experimenters take into account a very contrast number of quantities in comparison with the formulated number according to the information-oriented approach (Table 1).

Despite the very depressing situation revealed by using the information-oriented method to estimate the accuracy of the Hubble constant measurement, being optimistic, we can hope that in the near future scientists will be able to improve the measurement technique. On the other hand, as the analysis presented in the next chapter will show, measurements of other fundamental constants are performed with much higher accuracy, and the results of experimental studies coincide with the values recommended in the framework of the information approach.

b) *Analysing publications of measurements of k_b, h, N_A, α^{-1} and G*

Taking into account the methodology mentioned in Key concepts from information-oriented approach, there were analysed the measurement results of Boltzmann constant, Planck constant, Avogadro constant, inverse fine structure constant and gravitational constant published in different journals and CODATA recommendations. Data inherent in only relative uncertainties calculated according to *IARU* are introduced in Table 3[27].

Table 3: Fundamental physical constants: recommended and calculated relative uncertainties

Fundamental constant	Designation	Dimension	Class of phenomena	The analyzed interval of publications	Published, recommended relative uncertainty	Calculated relative uncertainty (*IARU*)
Boltzmann constant	k_b	m²· кg·c^{-2}·K^{-1}	*LMTθF*	2015 - 2018	$3.7 \cdot 10^{-7}$[28]	$2.8 \cdot 10^{-7}$
Plank constant	h	m²·кg·c²	*LMTI*	2007 - 2014	$9.1 \cdot 10^{-9}$[29]	$8.7 \cdot 10^{-9}$
Avogadro constant	N_A	mol^{-1}	*LMTF*	2001 - 2015	$2 \cdot 10^{-8}$[30]	$1.7 \cdot 10^{-8}$
Inverse fine structure constant	α^{-1}		*LMT*	2006 - 2014	$2.9 \cdot 10^{-11}$[31]	$2.9 \cdot 10^{-11}$
Gravitational constant	G	m³· кg^{-1}·c^{-2}	*LMTI*	2000-2016	$4.7 \cdot 10^{-5}$[32]	$1.35 \cdot 10^{-5}$

It is seen from Table 3 that published recommended values of relative uncertainties are consistent with the same calculated according to *IARU*. This fact confirms that the theoretically grounded information approach allows for crafting of a meaningful picture of future results. However, the quantity that need to be predicted is generally not experimentally observable before the prediction, since otherwise no prediction would be needed. Assessing the credibility of such extrapolative predictions is challenging. In validation CODATA's approach, the model outputs for observed quantities are constructed, using modern advanced Bayesian statistical methods and powerful computers to determine if they are consistent. By itself, this consistency only ensures that the model can predict the measured physical constants under the conditions of the observations [33]. This limitation dramatically reduces the utility of the CODATA's effort for decision making because it implies nothing about predictions for scenarios outside of the range of observations. So, these remarks define the main principal difference between CODATA's approach and the information-based and theoretically grounded method.

It should be noted that the proposed method is not considered universal, since it does not answer the question of choosing specific physical quantities for better representation of the surrounding world. The information-oriented approach for estimating the model's uncertainty does not involve a spatio-temporal or causal relationship between the quantities involved. Instead, it takes into account only the differences between their numbers. However, this method can be firmly asserted that this method reveals an inconsistency between the various methods of measuring a particular fundamental constant H_0.

c) Maxwell demon

Over the past twenty years, both information in the form of a certain substance, and methods of information theory are the subject of special attention of scientists, engineers and philosophers. A great number of studies are devoted not only to clarifying the internal content of the concept of INFORMATION, but also to the application of this unique substance in all fields of human activity: physics, chemistry, biology, psychology, business, etc. The number of theories offered is uncountable. Impressive practical results were obtained using information theory in the field of quantum mechanics, telecommunications, medicine, marketing and the development of non-lethal weapons. At the same time, in theoretical and experimental physics, the number of research papers (with a specific *quantitative* result) using information theory is catastrophically small; they can be counted on the fingers. The author, being a convinced practitioner, took the liberty and did not delve into the endless and unconvincing theoretical discussions in order to realize the usual calculations (in the sense that all known and generally accepted formulas are used) to quantify the amount of information for several examples.

What do the measurements of the fundamental constants and the Maxwell's demon have in common? In fact, a little. Adapting the μ_{SI}-hypothesis, which was used in recent years to test the achievable relative uncertainty in measuring fundamental constants, we are developing a way to better understand specific problems that are closed to the Maxwell problem.

In one of his versions, the standard Maxwell's demon is a very small intellectual being endowed with free will, and a fairly subtle tactile and perceptive organization to enable him to observe and influence individual molecules of matter. In Maxwell's thought experiment, two gas chambers, maintained at equal temperatures, are separated by an adiabatic wall with a small hole and a gate that the demon opens and closes. Observing the speed of individual molecules, the demon selectively opens and closes the gate to quickly detach from slow molecules, creating a clean temperature difference between the two chambers. Thus, as the collisions with the shutter are elastic, and moving the shutter is frictionless, no work is performed by the demon. The temperature difference that develops could be exploited by a conventional heat engine to extract work, in violation of second law of thermodynamics.

Various researchers suggested different ways by which a demon could select particles in a reversible manner. Leó Szilárd in 1929 [34] argued that the demon must consume energy in the act of measuring the particle speeds and that this consumption will lead to a net increase in the system's entropy. In fact, Szilárd formulated an equivalence between energy and information, and calculated that $k_b \cdot \theta \cdot \ln 2$ is both the minimum amount of work needed to store one bit of binary information and the maximum that is liberated when this bit is erased, where θ is the temperature of the storage medium. Through latest publications [35, 36, 37, 38], one must remember [39], in which there was finally clarified that the demon's role does not contradict the second law of thermodynamics, implying that we can, in principle, convert information to free energy. Toyabe et al in [40] showed that since the energy transformed from the information is compensated by the cost of the demon's energy for manipulating information, the second law of thermodynamics is not violated when a general system involving both a particle and a demon is considered. In the proposed research system, the demon consists of macroscopic devices, such as computers. The microscopic device receives energy due to the energy consumption of the macroscopic device. In other words, using information as an energy transfer medium, this transformation of information into energy can be used to transfer energy to nano machines, even if they cannot be directly controlled. In [41] there was declared that the

Maxwell's demon can be converted into free energy by one bit of information obtained by measurement. The authors implemented an electronic Maxwell's demon based on a one-electron unit operating as a Szilard engine, where $k_b \cdot \theta \cdot \ln 2$ heat is extracted from the reservoir at a temperature θ by one bit of generated information. The information was encoded in the position of an additional electron in the box. The authors provided, to their knowledge, the first demonstration of extracting nearly $k_b \cdot \theta \cdot \ln 2$ of work for one bit of information.

After 150 years a satisfactory additional solution of this paradox can be given [7]. In order to prevent the violation of the second law, one must assume that the demon is a conscious observer with knowledge, experience and intuition. Then, before performing any actions, in order to know the velocity of every molecule in the box, he must compose a mental model of the experiment, with no disturbances being brought into the box. In turn, the demon for the development of the model will take advantage of the already well-known International system of units (SI). When modeling a particle movement, the demon may choose quantities, for example, velocity, mass, angle of motion of the particle with respect to the shutter, temperature that may substantially differ from those chosen by another demon, as happened, for example, during the study of electrons that behave like particles or waves. That is why SI can be characterized by equally probable accounting of any quantity chosen by the demon. In this case, the total number of possible dimensionless criteria μ_{SI} of SI with the seven base quantities L, M, T, I, Θ, J and F could be calculated (7)

$$\mu_{SI} = 38,265,$$

Then μ_{SI} corresponds to a certain value of entropy and may be calculated by the following formula [7]:

$$\mathbf{H} = k_b \cdot \ln \mu_{SI} \tag{17}$$

where H is entropy of SI including μ_{SI}, equally probable accounted quantities, k_b is the Boltzmann's constant.

When a demon chooses the influencing factors (the conscious limitation of the number of quantities that describe an object, in comparison with the total number μ_{SI}), entropy of the mathematical model changes a priori. The entropy change is generally measured as follows:

$$\Delta\mathbf{H} = \mathbf{H}_{pr} - \mathbf{H}_{ps} \tag{18}$$

where ΔH is the entropy difference between two cases, *pr* – "a priori" and *ps* - "a posteriori".

"The efficiency Q of the experimental observation method can be defined as the ratio of the information obtained to the entropy change accompanying the observation" [15]. During a thought demon's experiment, no distortion is brought into the real system, that is why Q=1. Then one can write it according to [15]:

$$\Delta\mathbf{A} = \mathbf{Q} \cdot \Delta\mathbf{H} = \mathbf{H}_{pr} - \mathbf{H}_{ps} \tag{19}$$

where ΔA is the a *priori* information quantity pertaining to the observed object.

Using Equations (17)-(19) and imposing symbols–where z' is the number of physical dimensional quantities in the selected COP and β' is the number of base quantities in the selected COP – lead to the following equation:

$$\Delta\mathbf{A}' = \mathbf{Q} \cdot \left(\mathbf{H}'_{pr} - \mathbf{H}'_{ps}\right) = 1 \cdot [k_b \cdot \ln \mu_{SI} - k_b \cdot \ln(z' - \beta')] = = k_b \cdot \ln[\mu_{SI} / (z' - \beta')] \tag{20}$$

where ΔA' is the a priori amount of information pertaining to the observed object due to the choice of the COP.

Following the same reasoning, one can calculate the a priori amount of information ΔA", caused by the number of recorded dimensionless criteria chosen in the model. ΔA" takes the following form:

$$\Delta\mathbf{A}'' = k_b \cdot \ln[(z' - \beta') / (z'' - \beta'')] \tag{21}$$

where ΔA" cannot be defined without declaring the chosen COP (ΔA'); z'' is the number of physical dimensional quantities recorded in a mathematical model and β'' is the number of the base quantities recorded in a model of box.

A minimal amount of information ΔA_E about the observed modeled box is calculated according to the following:

$$\Delta\mathbf{A}_E = \Delta\mathbf{A}' + \Delta\mathbf{A}'' = \kappa_b \cdot \ln[\mu_{SI} / (z'' - \beta'')] \tag{22}$$

where ΔA_E is measured in units of entropy [42], z'' is the number of physical dimensional quantities recorded in the mathematical model, β'' is the number of the base dimensional quantities recorded in a model.

In order to transform ΔA_E to bits ΔA_b, one should divide it by the following abstract number $\kappa_b \cdot \ln 2 = 9.569926 \cdot 10^{-24} kg \cdot m^2 \cdot s^{-2} \cdot K^{-1}$ [15, 43]. Then

$$\Delta\mathbf{A}_b = \ln[\mu_{SI} / (z'' - \beta'')] / \ln 2 (\text{bits}). \tag{23}$$

Taking into account that μ_{SI}=38,265 and suppose z''-β''=1 (one can choose a larger number of dimensionless criteria, but this does not affect the course of further reasoning and conclusions, see Table 1), one can calculate the minimum boundary of the motion blur of a particle in the eyes of a demon

$$\Delta \mathbf{A}_{\mathrm{b}} = \ln [38,265/1]/0.6931472 \approx 11(\mathrm{bits}). \quad (24)$$

Thus, equation (24) contains a very strong hint that the demon is not able to clearly distinguish the exact state of a large number of particles. There are no glasses that could correct the sight of the demon. This closes the possibility of developing a device that could distinguish between fluctuations in individual particle velocities. Hence it is clear that any material physical device, in comparison with a mental thought experiment (conscious, without a material shell by a demon), will require much more information and energy for the release of any gate movement.

Let us apply ΔA_b (24) corresponding to the insurmountable threshold mismatch ("cloud" of blurring) between the vision of the demon and the actual situation in the box with the particles, i.e. amount of information inherent in a particle. As an example, consider that the radius of the particle is determined by the region, in which it can produce some effect. According to [44], a radius of single photon r_p in energy region of Ep =2.1 GeV equals $2.8{\cdot}10^{-15}$ metres. In this case, the amount of information contained in one photon is [45]:

$$\Upsilon_{\mathrm{bp}} \leq \left(2{\cdot}\pi{\cdot}\mathrm{r_p}{\cdot}\mathrm{E_p}\right)/(\hbar{\cdot}c{\cdot}\ln 2) = 270(\mathrm{bit}). \quad (25)$$

where Υ_{bp} is the information amount expressed in bits and corresponding to the photon's sphere; r_p is the radius of photon expressed in meters, $2.8{\cdot}10^{-15}$ m [44]; c is the light speed, c = 299,792,458 m/s, ħ is the reduced Plank constant, ħ = $1.054572{\cdot}10^{-34}$ $m^2{\cdot}kg{\cdot}s^{-1}$, ln2 = 0.693147, π = 3.141593.

Thus, the minimum boundary of the motion blur of the particle in the eyes of the demon (in bits) is much less than the information contained in the photon (270 bit » 11 bit). However, this fact does not in any way allow us to state that the demon, after preliminary modeling, will be able to carry in one direction particles moving at high speed, and in the other way - particles having a low speed, thereby violating the second law of thermodynamics. On the contrary, the demon will need information through a measuring device that is comparable in magnitude to the information inherent in the particle. This, in turn, will require the performance of work, which will lead to an increase in entropy in the total volume of the casket.

The proposed approach provides only a hint of how much information a demon and the observed particle have before starting any action with a system box-demon or about "uncertainty" in the mind of someone about to receive a message [46].

d) Universe information associated with energy

In connection with the foregoing, there is an amazing possibility (and for the readers maybe a very controversial one) of applying the results obtained in analyzing the status of the miniature demon Maxwell to the problems associated with clarifying the energy of the observed universe.

Experiments and theories developed in theoretical physics over the past decades have demonstrated the significant role of information, the amount of which physicists usually identify with entropy, but which can be more general when used to explain the emerging complexity of the universe. One of the most attractive features of the Bekenstein formula [47] is that it allows us to compose an idea of the possible connection between energy and information contained in the universe.

For this purpose, let us recall [47], in which it was proved that the amount of information of any physical system must be finite if the space of object and its energy are finite. In informational terms, this boundis given by

$$\Upsilon_b \leq (2{\cdot}\pi{\cdot}R{\cdot}E)/(\hbar{\cdot}c{\cdot}\ln 2), \quad (26)$$

where Υ_b is the information expressed in the number of bits contained in the quantum states of the chosen object sphere. The ln2 factor (approximately 0.693149) comes from defining the information as the natural logarithm of the number of quantum states, R is the radius of an object sphere that can enclose the given system, E is the total mass-energy, including rest masses, ħ is the reduced Planck constant, and c is the speed of light.

Further, the Landauer principle [39], which is applicable to all systems in nature, asserts that the minimum amount of energy required to destroy one bit of information is:

$$k_b{\cdot}\,\boldsymbol{\theta}\cdot \ln 2, \quad (27)$$

where $\boldsymbol{\theta}$ is the temperature in kelvins of environment.

It is important to note that the equivalent bit energy depends on the temperature of the described system. The average temperature of the universe today is approximately $\boldsymbol{\theta}$=2.73K [48], based on measurements of cosmic microwave background radiation. Therefore, with a bit of imagination and an essential assumption, in order to transform Υ_b to termsof the ordinary energy Υ_E, one should multiple it by $k_b{\cdot}\boldsymbol{\theta}{\cdot}\ln 2$.

$$\Upsilon_E = \Upsilon_b \cdot k_b \cdot \theta \cdot \ln 2 \leq ((2 \cdot \pi \cdot R \cdot E) / (\hbar \cdot c \cdot \ln 2)) \cdot k_b \cdot \theta \cdot \ln 2, \quad (28)$$

or

$$\Upsilon_E / E \leq (2 \cdot \pi \cdot R \cdot \kappa_b \cdot \theta) / (\hbar \cdot c) \quad (29)$$

Using the dimensional analysis, we verify the achieved dimension of equation (29).

$$\dim R \ni m;\ \dim \kappa_b \ni kg \cdot m^2 \cdot s^{-2} \cdot K^{-1};\ \dim \theta \ni K;\ \dim \hbar \ni m^2 \cdot kg \cdot s^{-1};\ \dim c \ni m \cdot s^{-1}; \quad (30)$$

$$\dim (\Upsilon_E / E) \ni m \cdot kg \cdot m^2 \cdot s^{-2} \cdot K^{-1} \cdot K / (m^2 \cdot kg \cdot s^{-1} \cdot m \cdot s^{-1}) = 1$$

So, at least, from the point of view of the dimensional analysis there is not a fatal mistake.

Further, the age of universe T_{univ} is about 13.7 $\pm$ 0.13 billion years or 4.308595×10^{17} s [49]. Then, taking into account c = 299,792,458 m/s, the imaginary spherical shell of the Universe has a radius:

$$R_{univ} = T_{univ} \cdot c = 1.291684 \cdot 10^{26} (m). \quad (31)$$

It should be noted that there is no known boundary, that is, R_{univ} is an approximate value. When people talk about the size of observable universe, this means the estimated distance to the most distant objects that we can see here. This does not mean that there is nothing further; it simply means that we do not see it.

In this case, one can get the numerical relationship between energy corresponding to amount of information and the energy associated with matter, which contained in a universe sphere:

$$\Upsilon_E / E \leq (2 \cdot \pi \cdot R_{univ} \cdot \kappa_b \cdot \theta) / (\hbar \cdot c) =$$
$$= (2 \cdot 3.141593 \cdot 1.291684 \cdot 10^{26} \cdot 1.38064852 \cdot 10^{-23} \cdot 2.73) / (1.054572 \bullet 10^{-34} \cdot 299{,}792{,}458) = \quad (32)$$
$$= 30.590185 \cdot 10^{3} / 3.161527 \cdot 10^{-26} = 9.6 \cdot 10^{29} \approx 10^{30}$$

Thus, we have shown that the energy associated with information makes a significant contribution to the total energy of the universe. Of course, this (32) is a rough estimate. It is interesting to note that 10^{30} is much less than 10^{122}. According to the holographic principle, the last huge number represents an upper bound on the information content of the universe[50]. Since information energy can make a significant contribution to the dark energy and dark matter of the universe, scientists need to study it more closely. Maybe this value (10^{30}) can also be a signal of some kind of new interaction of matter and information.

Therefore, more is unknown than known. Besides this, it is a complete secret. But this is an important secret. The rest is everything on the Earth, everything that has ever been observed with all our instruments, all normal energy, is a meager part of the universe. Think about it, perhaps it is not a "normal" at all, since it is such a small part of the universe. But what kind of information is this? Perhaps information itself is a fundamental entity of the physical universe. Is it "ontological" - the real substance from which space, time and matter emerge? Or is it "epistemic" - something that only represents our state of knowledge about reality? Ultimately, information can be a key element in the constitution of physical reality and it is a decisive content in physical systems and technological processes. The explicit relationship between entropy and information, using the concept of objective quantitative information of Shannon, was formalized in [51], and this can be regarded as irrefutable confirmation of information as a physical entity.

Such a dramatic gap of 10^{30} between the amounts of energy associated with the ordinary matter and the energy due to information can be conditioned with the assumptions originally assumed: the universe is not a sphere; the average temperature of the universe can be much lower than the observed temperature; for the giant distance scale, the Landauer's limit is not satisfied.

The presented results (24), (25), (32) are simply a routine calculation by formulas known in the scientific literature. At the same time, only experts of quantum electrodynamics or the theory of gravity can "separate wheat from chaff". However, if the Bekenstein formula and the Landauer's limit have a physical explanation, perhaps the result (32) can be used to study the universe.

Additional explanation of how information acquires energy comes from the quantum theory of matter. In this theory, "empty space" is actually full of temporal ("virtual") particles that are constantly being formed, possessing certain information, and then disappear. But when we tried to calculate how much energy this information gives to the empty space, the answer turned out to be erroneous - wrong by a lot. The number of 10^{30} is too large. It is difficult to get such an answer. So, the mystery exists.

Another explanation of the significant magnitude of the energy corresponding to the information contained in the universe is that it is a new kind of field energy that fills the whole space. But if the information itself is the answer, we still do not know what it is, what it interacts with or how it exists in the universe. Thus, the mystery continues.

More speculatively, a last possibility is that Einstein's theory of gravity is not correct. That would affect the way that normal matter in galaxies behaved. This fact would provide a way to decide if the solution of the amount of information is a possible and inadmissible part of the new gravity theory or not. Thus, there are many questions, no answers. *That is why; things are still not so bad as to expect improvement.*

As an alternative to dark energy and dark matter, the energy due to information contained in the universe can serve as a fundamental component [52-55]. The giant difference between the two types of energy (32) makes it possible to assert that the universe is isotropic-the same in all directions-and homogeneous, without the regions of the cosmos, which have special, peculiar characteristics. Equation (32) cannot be an illusion caused by mathematics. It does not just come out by accident. Does this mean that our universe consists of information, and the associated energy is responsible for the inhibition of space and time and the accelerating expansion that we observe? It is difficult for the matter-of-fact physicist to agree with this point of view. Maybe there are better ideas? It is tempting to look for links and analogies, even if they are at first considered bad for discussion. Perhaps in the future these two problems are not as fragmented as they might seem. Formulating a problem that at first glance seems completely extravagant can sometimes, with further reflection, acquire real meaning and become very meaningful for the further development of science.

IV. Discussion

Apparently, the application of information theory to calculate measurement uncertainty will be unnatural for some readers. If you ask why such cases are generally considered, then instead of the answer it is useful to recall the English anecdote about the doctor-pathologist. One of his students said that he does not see the benefits of pathological physiology, because it is so unnatural. The doctor called him a fool and added: Only by studying pathology, it is possible to establish true health conditions.

At present, the term "comparative uncertainty", as well as "information contained in the model", "change in entropy in a mental experiment," obtained the rights of citizenship. Physical systems, which include such elements, are systems used both in experimental physics and in any technological processes. In this paper, various applications of the information-oriented method are presented. The μ_{SI} hypothesis made it possible to establish the fact that scientists may approach, but never reach, the comparative uncertainty corresponding to the chosen COP. Regardless of the implementation of super power computers, brilliant modern data processing methods and unique test benches, comparative uncertainty, even with the required number of dimensionless criteria, will be unattainable. In addition, the μ_{SI} hypothesis made it possible to judge the appropriate limit of the accuracy of measurements in each individual case.

Under the proposed approach, for each mathematical model of physical law there is an uncertainty, which initially, before the full-scale experimental studies, or computer simulations, describes its proximity to the examined physical phenomenon or process. This value is called the comparative uncertainty. It depends only on the number of selected quantities and the observation interval of the selected primary quantity. One of the interesting features of the proposed hypothesis is that the minimum achievable comparative uncertainty is not constant and varies depending on the class of phenomena choice. Moreover, theory can predict its value. In particular, this means that when switching from a mechanistic model (*LMT*) to COP with a larger number of the base quantities, this uncertainty grows. This change is due to the potential effects of the interaction between the increased number of quantities that can be taken into account or not taken into account by the researcher.

On the one hand, well-known physical laws are valid in a certain area and served as a reliable tool in everyday life. At the same time, taking into account the experience of the creation of special relativity theory, we know that the achieved accuracy of the description of the world is not satisfactory. On the other hand, fundamental physical constants currently measured with high accuracy. However, it is not sufficient to be able to modify the International system of units (SI). The proposed approach allows us to estimate the limits of our knowledge and to reveal an insurmountable barrier for identifying compliance of model and the object studied. A clear evidence of this is a possibility to estimate the minimum attainable value of the relative uncertainty for the gravitational constant, Planck's constant, the fine structure constant, Boltzmann's constant, Avogadro's constant, especially considering that the predictions do not contain quantities that can be chosen intuitively or based on statistical methods.

V. Conclusions

In addition to the relative uncertainty analysis, the introduced approach could enable new methodology that will help the additional monitoring the measurement accuracy of fundamental physical constants. The use of the μ-hypothesis only limits the domain of applicability of measurement theory for uncertainties that are much larger than the uncertainty of the physical-mathematical model due to its finiteness.

By introducing the comparative uncertainty concept along with known physical laws, we can verify required relative uncertainties values of fundamental physical constants that must be recommended for identifying concrete ways in perfecting SI. The suggested approach is a mathematical tool that allows describing a physical system with the lowest uncertainty, which is a surprisingly simple relation.

If the measure of the beauty of the theory is the ratio of the number of things that it explains, how many assumptions it makes for their explanation, then the information-oriented approach seems very promising. μ_{SI} hypothesis does refer to a real place of the surrounding world. It might be applicable to experimental verification. In general, it is available when the researcher has all the information about the uncertainty interval of the main quantity. Moreover, μ_{SI} hypothesis provides new functionalities useful for micro- and macro-physics including engineering, astronomy, and quantum electrodynamics. The comparative uncertainty can be a peculiar metric for the assessing the measurement accuracy of physical laws and fundamental physical constants.

The information-oriented approach, in particular, *IARU*, makes it possible to calculate with high accuracy the relative uncertainty, which is in a good agreement with the recommendations of CODATA. The principal difference of this method, in comparison with the existing statistical and expert methodology of CODATA (actually all statistical methods are unreliable - some more and some less [56]), is the fact that the information method is theoretically justified.

There is a weak tension between some (but not all) astrophysical measurements and cosmological conclusions. There are several ways to look at it. First, one or more methods are now limited to systematic; in other words, the subject is limited to accuracy, not precision, and that close attention to the underestimated systematic will lead to a convergence of values in the next few years. Secondly, it is possible that the new physics is involved outside the change in the index of dark energy. New physical experiments will require a relative uncertainty of 1% or less of the definitions of H_0, given the current state of play in cosmology.

Significant differences in the values of the comparative uncertainties achieved in the experiments of measuring H_0 and calculated in accordance with the *IACU* can be explained as follows. The very concept of comparative uncertainty, within the framework of the information approach, assumes an equally probable account of various quantities, regardless of their specific choice by scientists when formulating a model for measuring a particular fundamental constant. Based on their experience, intuition and knowledge, the researchers build a model containing a small number of quantities, and which, in their opinion, reflects the fundamental essence of the process under investigation. In this case, many phenomena, perhaps not significant, secondary, which characterized by specific quantities, are not taken into account.

For example, when measuring the value of the Hubble constant by CMB ($CoP_{SI} \equiv LMT$), some assumptions are advanced: dynamic dark energy is modeled as an ideal fluid; flat universe; a fixed cosmological model. Thus, the developers do not take into account that: the recognition of dark energy in the form of an ideal fluid is physically inconsistent and does not adequately approach the evolution of dark energy; in the real world the universe is not flat; the expected model may differ slightly from the models taken for analysis, etc. In this case, we get a paradoxical situation. On one side, different groups of scientists dealing with the problem of measuring a certain fundamental constant and using the same method of measurement "learn" from each other and improve the test stand to reduce uncertainties known to them. This is clearly seen using the *IARU* method: when measuring, for example, h, k_b, N_A, **α**, G, all the relative uncertainties are very consistent, especially for measurements made in recent years. However, ignoring a large number of secondary factors, which are neglected by experimenters, leads to a significant variance in the comparative uncertainties calculated by the *IACU* method.

Obviously, the coordination of a probabilistic subatomic world with a macroscopic everyday world is one of the greatest unsolved problems in physics. The use of the μ_{SI} hypothesis opens the possibility of combining these two worlds: from Maxwell's demon to cosmology and astrophysics.

μ_{SI} hypothesis allows to obtain the entropy cost associated with the acquisition of the demon information. Any demon, no matter how smart it is, must perform measurements. Certainly, when creating a model for the separation of particles, it is necessary to consider in detail the constitution of a rational being. The possession of information can indeed be regarded as a decrease in entropy. However, in the case of mental modeling, obtaining information does not require the dissipation of heat, and there is no threat to the generalized form of the second law.

Mental modeling requires us to say something about the demon itself as a physical being. A demon can perform a modelling without energy dissipation. This fully corresponds to the position of the Brillouin. He characterized the information as "connected" if it was embodied in states of the physical device, but he bluntly

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stated that information contained only in the mind is "free", and not "connected".

Now the connection between entropy and information becomes more understandable. When the demon leaves the system, he can be viewed as an agent that has information about the system. Uncertainty in the description of the system can be considered as a lack of knowledge of the demon about the exact state of the system. If the demon has more information, the system's entropy is smaller. However, once the demon can obtain information without dissipation, the system's entropy decreases, and the only compensation appears to be an increase in the uncertainty of the state of the demon itself.

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A Boundary Element Model Applied to the Simulation of Journal Bearings

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Abstract- The Boundary Element Method presents difficulties for solving certain problems that include sources, body and inertia forces or other cases whose mathematical model includes non self-adjoint terms. This avoids the desired representation of the problem solely in terms of boundary integrals. In this work, a new strategy is presented to overcome that problem through the use of Radial basis functions. Two formulations of this kind are used for solving the distribution of the pressure field generated in a hydrodynamic journal bearing. The partial differential equation of this problem has variable coefficients and cannot be rewritten directly as boundary integrals. Numerical solutions for the 1D and 2D problems are presented and their results are compared with the available analytical solutions or then obtained with the application of the finite element method.

Keywords: *journal bearings, boundary element method, radial basis interpolation.*

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ABOUNDARYELEMENTMODELAPPLIEDTOTHESIMULATIONOFJOURNALBEARINGS

Strictly as per the compliance and regulations of:

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Abstract- The Boundary Element Method presents difficulties for solving certain problems that include sources, body and inertia forces or other cases whose mathematical model includes non self-adjoint terms. This avoids the desired representation of the problem solely in terms of boundary integrals. In this work, a new strategy is presented to overcome that problem through the use of Radial basis functions. Two formulations of this kind are used for solving the distribution of the pressure field generated in a hydrodynamic journal bearing. The partial differential equation of this problem has variable coefficients and cannot be rewritten directly as boundary integrals. Numerical solutions for the 1D and 2D problems are presented and their results are compared with the available analytical solutions or then obtained with the application of the finite element method.

Keywords: journal bearings, boundary element method, radial basis interpolation.

I. Hydrodynamic Model for the Journal Bearing

The journal bearings are sliding bearings which use the flow of a lubricating fluid around a pair of non concentric circular surfaces given by the shaft and the bearing that generate a pressure field. Under high rotations this pressure field supports the shaft, eliminating its contact with the surface of the bearing. The pressure field arises due to the variation of the clearance between these surfaces, as shown in Fig. 1:

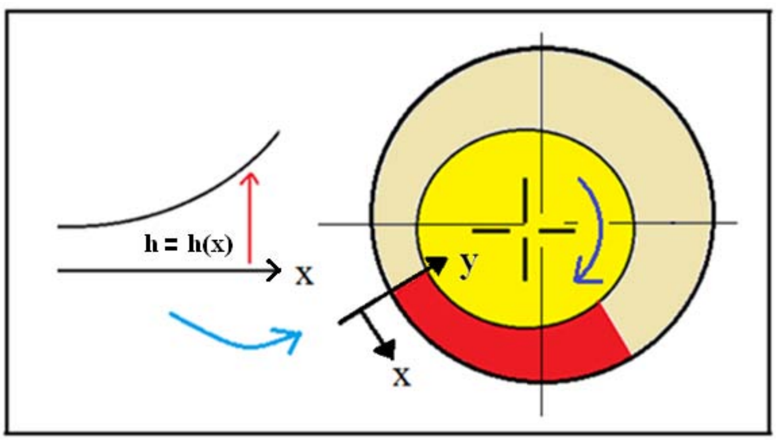

Figure 1: A schematic model for the journal bearing highlighting the meaning of the clearance h(x).

The most common mathematical model to approach this type of problem, usually proposed in the design of machine elements, is deduced from the Navier-Stokes Equation assuming several simplifying hypotheses. The following features are neglected: the curvature of bearing, the inertia of the lubricant, the external field forces, the gradient of pressure and the velocity of the fluid in the radial direction and their variation in this direction as well. Newtonian lubricant with constant viscosity is also assumed, as well is supposed laminar and incompressible flow. Thus, under conditions of one-dimensionality, the following differential equilibrium equation is given by (Shigley et. al, 2003):

$$\frac{d}{dx}\left[\frac{\rho h(x)^3}{\mu}\frac{dp(x)}{dx}\right] = \frac{\rho h^3(x)}{\mu}\frac{d^2p(x)}{dx^2} + \frac{3\rho h^2(x)}{\mu}\frac{dp(x)}{dx} = -6V\frac{dh(x)}{dx} \tag{1}$$

In Eq. (1) p(x) is the overpressure with respect to the initial oil injection pressure, V is a mean flow velocity and μ is the viscosity. The clearance h(x) depends on both the curvature and the eccentricity between the surfaces of the components, but it is known, see figure 1. Essential conditions are imposed in terms of the pressure p(x) and natural conditions in terms of the flow q(x), as follows:

$$q(x) = \rho h(x) v(x) \tag{2}$$

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In the previous equation, ρ is the density, assumed to be constant. The lubricant velocity v(x) is given by:

$$v(x) = V - \frac{h(x)^2}{\mu}\frac{dh(x)}{dx}\frac{dp(x)}{dx} \quad (3)$$

Equation (1) is a particular case of the Reynolds Equation in fluid motion. Despite in many journal bearings, the fluid flow in the z direction does not exist, the pressure can vary axially as a consequence oil output system. In this case, a source term W(z) can be assumed, resulting in a more general governing equation (Panday et. al, 2012):

$$\frac{\partial}{\partial x}[\frac{h^3(x)}{\mu}\frac{\partial p(x,z)}{\partial x}] + \frac{\partial}{\partial z}[\frac{h^3(x)}{\mu}\frac{\partial p(x,z)}{\partial z}] = -V\frac{d[h(x)]}{dx} - W(z) \quad (4)$$

Thus, in this assumed model the lubricant can have a similar magnitude in both directions x and z. Concerning the source terms in the right hand side of Eq. (4), both result due to the simplifications imposed in the mathematical model, especially related to the integration along y-direction. Another kind of sources or sinks can be idealized, as those that concentrate in a specific region. It must be highlighted that the height h(x) does not change axially, what allows an easier numerical approach.

Equation (4) it is a partial scalar differential equation in which the physical property continuously varies only the position x in the domain Ω. It can be verified that this governing equation is similar to that which describe the following cases: torsion in bars with uniformly variable sections; potential flow in tanks with variable depth; and heat transfer in heterogeneous media.

II. Integral Governing Equation

For convenience, henceforth the indicial notation is used for easiness in subsequent mathematical manipulations. Therefore, the governing equation (Eq. (4)) can be adequately written in indicial notation, as shown below:

$$[K(X)p(X),_i],_i = s(X) \quad (5)$$

In this last expression it was considered the following definitions:

$$K(x) = \frac{h^3(x)}{\mu}; \quad s(X) = -V\frac{d[h(x)]}{dx} - W(z); \quad X = X(x,z) \quad (6)$$

The starting integral form (Brebbia, 1978) is obtained by integrating Eq. (5) over the physical domain Ω(X), using as an auxiliary function the fundamental solution u*(ξ; X). This function is the solution of a Poisson´s problem which is assumed a homogenous infinite medium, submitted to a unitary concentrate source applied to an arbitrary point ξ, that is (Brebbia et al., 1980):

$$u,_{ii}{}^*(\xi;X) = -\Delta(\xi;X) \quad (7)$$

Thus, the integral equation associated with the Eq. (5) is given by:

$$\int_\Omega [K(X)p(X),_i],_i u^*(\xi;X)d\Omega = \int_\Omega s(X)u^*(\xi;X)d\Omega \quad (8)$$

The inverse integral form of the left hand side of Eq. (8) can be deduced by performing two integrations by parts, as shown below, where the Divergence Theorem has been properly applied:

$$\int_\Omega [K(X)p(X),_i],_i u^*(\xi;X)d\Omega = \int_\Gamma [K(X)p(X),_i u^*(\xi;X)]n_i d\Gamma - \int_\Gamma [p(X)K(X)u^*(\xi;X),_i]n_i d\Gamma + \int_\Omega [p(X)[K(X)u^*(\xi;X),_i],_i d\Omega \quad (9)$$

Developing the product of two functions in the last term to the right hand side of the previous equation can be rewritten:

$$\int_\Omega [p(X)[K(X)u^*(\xi;X),_i],_i d\Omega = \int_\Omega [p(X)K,_i(X)u^*(\xi;X),_i]d\Omega + \int_\Omega [p(X)K(X)u^*(\xi;X),_{ii}]d\Omega \quad (10)$$

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Using the properties of the Dirac Delta function (Raisinghania, 2011), one has:

$$\int_{\Omega}[K(X)p(X),_i],_i u^*(\xi;X)d\Omega = \int_{\Gamma}\{[K(X)q(X)u^*(\xi;X)] - \int_{\Gamma}[p(X)K(X)q^*(\xi;X)]d\Gamma + \int_{\Omega}[p(X)K,_i(X)u^*(\xi;X),_i]d\Omega + c(\xi)K(\xi)p(\xi) \tag{11}$$

In the previous expression, $q^*(\xi;X)$ is the normal derivative of the fundamental solution and $q(X)$ is the normal derivative of the pressure $p(X)$. The coefficient $c(\xi)$ depends on the positioning of the source points ξ with respect to the physical domain Ω (X) and, in the case of being located on the boundary $\Gamma(X)$, also of the smoothness of this one (Brebbia and Walker, 1980). It is verified the presence of a domain integral in Eq. (11), which is treated in the following item, like the approach of the term source s(X), referring to the right side of Eq. (6). It should also be noted that in this case K(X) is treated as a nodal quantity, linearly interpolated on each boundary element.

III. Quasi-Dual Procedure

Focusing the elimination of the domain integrals that still persist in the right hand side of Eq. (11) the direct integration procedure (DIBEM) could be used. However, in this case, the Quasi-dual Reciprocity model (Loeffler and Mansur, 2003) is the most suitable and accurate procedure. Quasi-dual (QDR) is a technique similar to Dual Reciprocity (Partridge et al., 1992), but it was developed to approximate first order derivatives in diffusive-advective problems. The QDR approximation uses linear combinations of primitive radial basis functions ψ^j, which are multiplied by coefficients α^j in the following form:

$$p(X)K,_i(X) \approx \alpha^j \psi,_i^j(X^j;X) \tag{12}$$

In Eq. (12) X^j is the coordinates of interpolation basis points. Considering two-dimensional cases the QDR approach is just suitable for potential fields. However, since the height h does not vary in the z direction of journal bearings (see eq. (6)), the differential given by the left hand side of Eq. (12) is always exact and can be treated accurately using the QDR. Thus, replacing Eq. (12) in the domain integral that persists in Eq. (11), one has:

$$\int_{\Omega}[p(X)K,_i(X)u^*(\xi;X),_i]d\Omega \approx \alpha^j\int_{\Omega}[\psi,_i^j(X^j;X)\,u^*(\xi;X),_i]d\Omega = \alpha^j\int_{\Omega}[\psi^j(X^j;X)u^*(\xi;X),_i],_i\,d\Omega - \alpha^j\int_{\Omega}[\psi^j(X^j;X)u^*(\xi;X),_{ii}]d\Omega = \alpha^j\int_{\Gamma}[\psi^j(X^j;X)q^*(\xi;X)]d\Gamma - c(\xi)\alpha^j\psi^j(X^j;\xi) \tag{13}$$

As a last remark, it is important to highlight that unlike other models that use radial basis functions, the inclusion of poles did not improve the results in QDR approach; in fact, the inclusion of poles only increased the round of errors.

IV. Dibem Procedure

When the body force term is given by the simple mathematical function, the Galerkin Tensor is the most effective way to deal with its domain integral, transforming it in a boundary integral. Considering more elaborate functions, a solution of Poisson's problems can be more effectively by global functions in the Goldberg's sense (Goldberg,1994) or then, using the Radial Integration Method (RIM) (Gao, 2002), despite the huge computational time of this later.

Here, the DIBEM procedure is applied in association with the QDR for convenience. DIBEM is also a similar technique to the Dual Reciprocity but the entire kernel of the domain integral is interpolated, aiming to transform it in a boundary integral. The technique already successfully applied to scalar problems governed by the Poisson equation (Loeffler et al., 2015) and Helmholtz (Loeffler et al., 2015). DIBEM substitute advantageously standard procedures as the domain integration by cells and the DRBEM. Comparatively, it shows superior performance and mathematical suitableness, since it is more similar to a simple interpolation procedure.

First DIBEM tests for performance are done solving Poisson's Equation, where domain integral is just comprised by known functions. Thus, different coordinates can be used to distinguish the interpolation points to the field points on the boundary, avoiding the singularity in the fundamental solution. Concerning the internal interpolation points, these points do not appear in the final matrix system. A different situation occurs in other more elaborate problems as Helmholtz and diffusive-Advective, in which the regularization procedure is required to avoid singularity since the interpolation points also are taken as source points (Loeffler and Mansur, 2017).

Provided internal interpolation points are not necessary for the QDR, the application of DIBEM is easier. Thus, the complete kernel of the domain integral is interpolated directly, according to the following expression:

$$s(X)u^*(\xi;X)={}^{\xi}\beta^j F^j(X^j;X) \tag{14}$$

Similarly to the DRBEM, the proposed method also uses a primitive function ϕ, such as:

$$\int_\Omega z(\xi;X)d\Omega = \int_\Omega ({}^{\xi}\beta^j F^j(X))d\Omega = \int_\Omega ({}^{\xi}\beta^j \phi^j_{,ii}(X))d\Omega = \int_\Gamma ({}^{\xi}\beta^j \phi^j_{,i}(X)n_i(X))d\Gamma = {}^{\xi}\beta^j \int_\Gamma \eta^j(X)d\Gamma = {}^{\xi}\beta^j z^j(X) \tag{15}$$

V. Discretization

Using radial basis functions, for each source point ξ, the interpolation given by Eq. (6) corresponds to scanning all points X^j in relation to domain points X. For the QDR, a similar procedure to the DRBEM is followed, in which the matrix H already calculated by the discretization of the integrals related to the Laplacian is used (Partridge, 1992). Double points X^j located in the corners should be departed to avoid singularity in the inversion of the interpolation matrix. Thus, one can write:

$$\mathbf{[H]p-[G]q+[H][\Psi]\alpha=[H][\Psi][\Psi,_i]^{-1}[K,_i]p=[\overline{H}]p} \tag{17}$$

In the last equation the α vector was eliminated based on Eq. (12), that is:

$$\boldsymbol{\alpha}=\mathbf{[\Psi,_i]^{-1}[K,_i]p} \tag{18}$$

The governing equation is a scalar one, but the source term $K_{,i}$ in Eq. (18) taken separately is vectorial. So, it is necessary also to put the interpolation function ψ in the dyadic form. Among other options, one such a class of functions is given by:

$$\Psi^j_{p,i}=3RR_iR_p+R^3\delta_{ip} \tag{19}$$

In Eq. (18), $R=R(X;X^j)$ is the Euclidian distance between the interpolation point X^j and the field point X, δ_{ip} is the Kronecker Delta operator, and:

$$R_p = [x_p(X^j)-x_p(X)] \tag{20}$$

It is easily demonstrated that:

$$\Psi^j_p=R^3R_p \tag{21}$$

Considering now the source term analyzed in Eq. (13) by the DIBEM approach, the complete governing matrix equation take the following form:

$$\mathbf{[H]p-[G]q+[\overline{H}]p=[A]z=b} \tag{22}$$

In Eq. (8), the lines of matrix A are comprised of vectors ${}^{\xi}\beta$, which may be obtained from following the basic interpolation equation:

$$\mathbf{[{}^{\xi}\beta]=[F]^{-1}[{}^{\xi}\Lambda][F]\beta=[F]^{-1}[{}^{\xi}\Lambda][s]} \tag{23}$$

The radial basis function used in the DIBEM approach is the well know thin plate function, given by:

$$F^j=R^2[\ln R] \tag{24}$$

VI. Numerical Simulations

a) First example: one-dimensional flow

Aiming to evaluate the robustness of the proposed model, in the following tests the function that characterizes the variation of the clearance h(x) between the bearing and shaft surfaces is changed. Actually, this distance is defined by the gap between two circular surfaces; here, it will be successively approximated by polynomials with crescent order, that is, by linear, quadratic and cubic functions. The clearance h(x), the geometry and the boundary conditions are shown in Figure 2.

In these simulations, the pressure values are prescribed zero at the input and output, since internally the fluid flow imposes the overpressure values, while the null values of the flow along the x direction impose the mathematical one-dimensionality of the model. The average velocity V (see Eq. (1)) is assumed to be equal 1/12 and the density ρ and viscosity μ are unitary.

The difference between analytical and numerical values, divided by the highest analytical value, was chosen as a measure of errors. For the one dimensional cases, the analytical solution is available for comparison. Three meshes with 40, 80, 160 and 320 linear boundary elements with double nodes at the corners were used to simulate the pressure field and velocities, while the thin-plate radial function is employed to the DIBEM interpolation. Improving the approximation of the source term according required by the DIBEM approach, a different number of internal interpolation points also is used. The quantity of these points is indicated in each simulation.

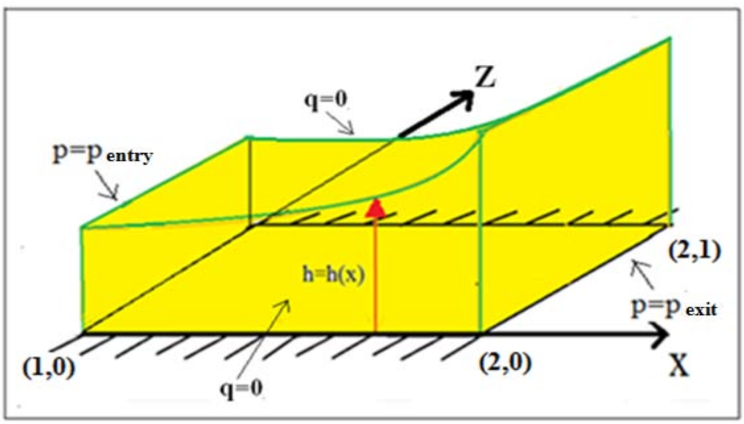

Figure 2: Geometry of the domain with the applied boundary conditions.

i. *Linear variation of the h(x)*

This simplest and hypothetical case appears as an example solved in most of the classic books dealing with the hydrodynamics of the bearings, serving to show how the height differential - in this case, a linear variation of clearance h(x) - implies a pressure value that throughout the domain examined.

Figure 3 shows the profile obtained by the MEC for the two meshes, with 44 and 84 nodes, and respectively 49 and 81 interpolating internal points, in comparison with the corresponding analytical value. The results presented an excellent concordance, as can be observed.

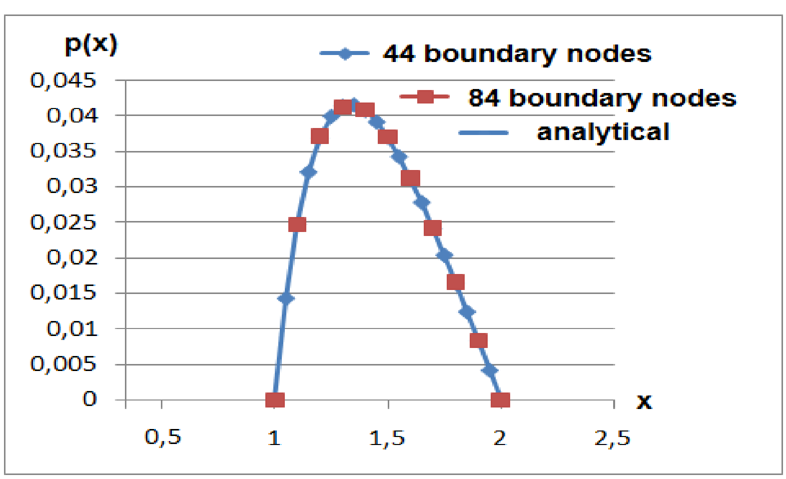

Figure 3: Numerical and analytical solutions of pressure along the fluid flow for a linear variation of h(x).

For better detailing of the effect of internal interpolation points and boundary mesh refinement, a convergence curve is presented in Fig. 3, in which the average percentage error is expressed as a function of the increasing number of nodal points and interpolation points. It is verified that the values of the percentage errors in each mesh are very small and are mainly reduced with the boundary refinement. It can also be seen that only the introduction of many interpolating points without the proper refinement of the boundary is not very effective. It occurs because only the DIBEM procedure requires such points.

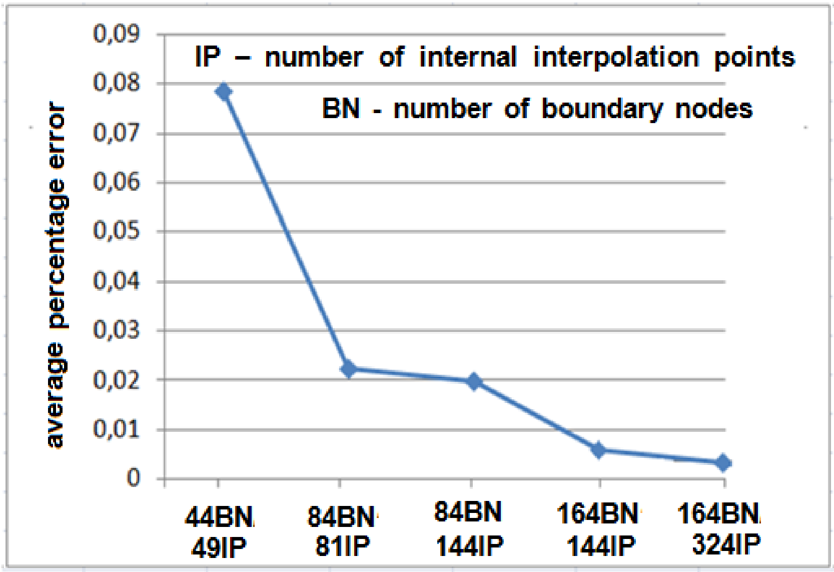

Figure 4: Average percentage error as a function of mesh refinement and insertion of internal interpolating points for a linear variation of h(x).

ii. *Quadratic variation of the h(x)*

Now the effect of height variation amplifies exponentially comparatively to the previous example so that a significant reduction in the precision of the numerical model employed is expected. Indeed, numerical errors have grown, but the results of this simulation continued with very good accuracy, as shown in Fig. 5.

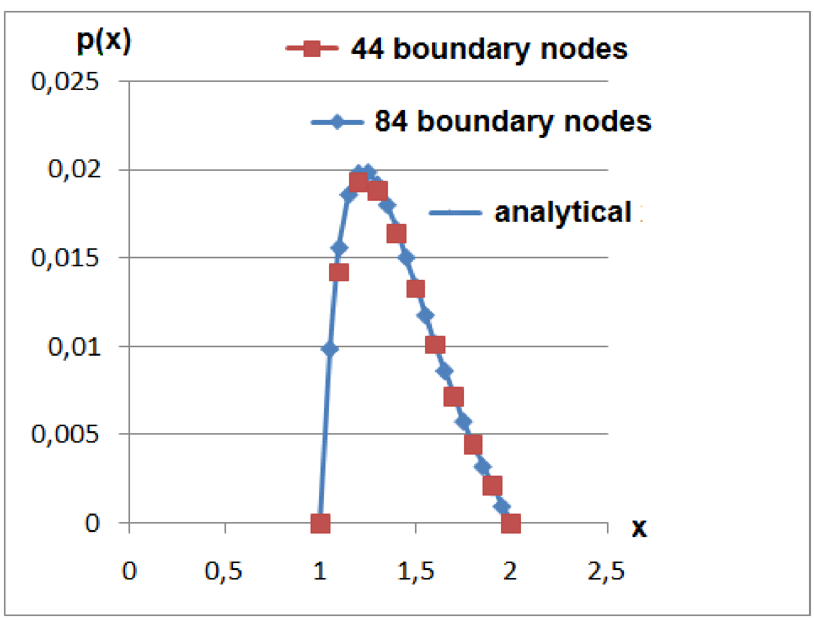

Figure 5: Numerical and analytical solutions of pressure along the fluid flow for quadratic variation of h(x).

As shown in the previous case, Fig. 6 shows an error curve as a function of the boundary mesh refinement and insertion of internal interpolation points.

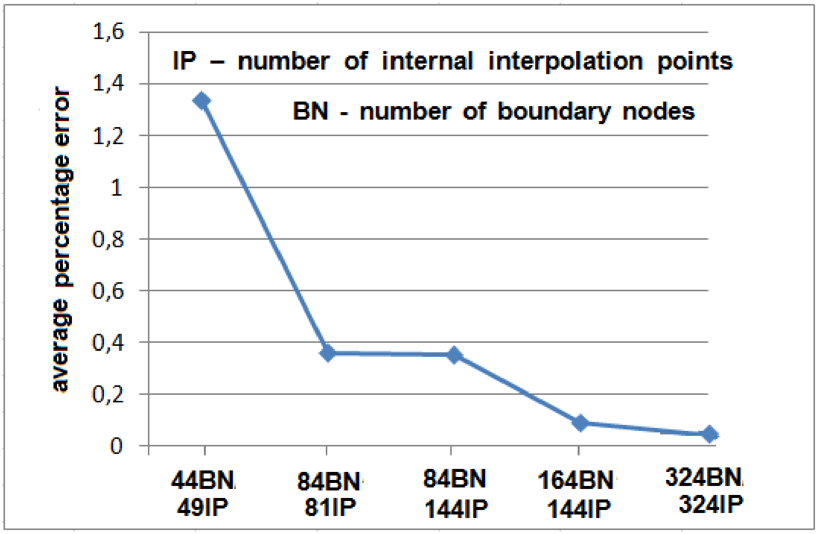

Figure 6: Average percentage error as a function of mesh refinement and pole insertion for quadratic variation of h(x).

iii. *Cubic variation of the h(x)*

Considering a cubic variation for h(x), the pressure gradients at the inlet are strongly accentuated and the less refined mesh already presents errors above 2%. It must be highlighted that the function that describes the height h(x) appears to the third power. However, the results are shown in Fig. 7 are still reasonable and reach a very satisfactory precision if more refined meshes are used, accompanied by a regular number of poles to represent the term proactive source or term of the governing equation, which is composed of the mean inlet velocity versus the derivative of the function h(x).

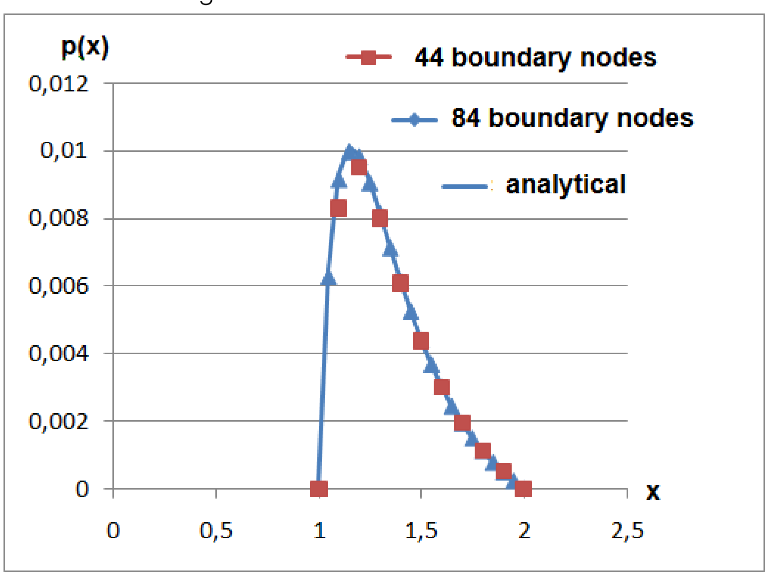

Figure 7: Numerical and analytical solutions of pressure along the fluid flow for cubic variation of h(x).

b) *Second example: two-dimensional flow*

Many journal bearings have an oil feedback system, as well as many other functional upgrades that cannot be described here. The representation of a squeeze lubricant flow in the axial direction is done hypothetically through a source W(z) (see Eq. (4)). This source should be located in a restricted region but for simplicity, it will be assumed distributed throughout the domain. The purpose here is only to show that the model can solve suitably two-dimensional cases pertinent to the hydrodynamic theory of the journal bearings.

In order to compare the results, a model generated from the Finite Element Method (FEM) (Reddy, 2005) using triangular elements with 20000 nodal points was taken as reference solution, since no analytical solution is available. The sources adopted have the following form:

$$V = 1; \qquad W(z) = 10(z^2 - z) \tag{25}$$

In this example the clearance h(x) is assumed to have quadratic variation. The values of pressure along the x direction calculated using BEM formulation with 84 boundary nodes and 81 internal interpolation points are compared with FEM results. This comparison is shown in Fig.8. It can be observed that the results obtained by both techniques have an excellent agreement.

It must be highlighted that the insertion of the source W(z) not only alters the profile of velocities such as also change the values of pressure. For clarity, in Fig. 9 one three-dimensional view of the pressures on the domain is shown.

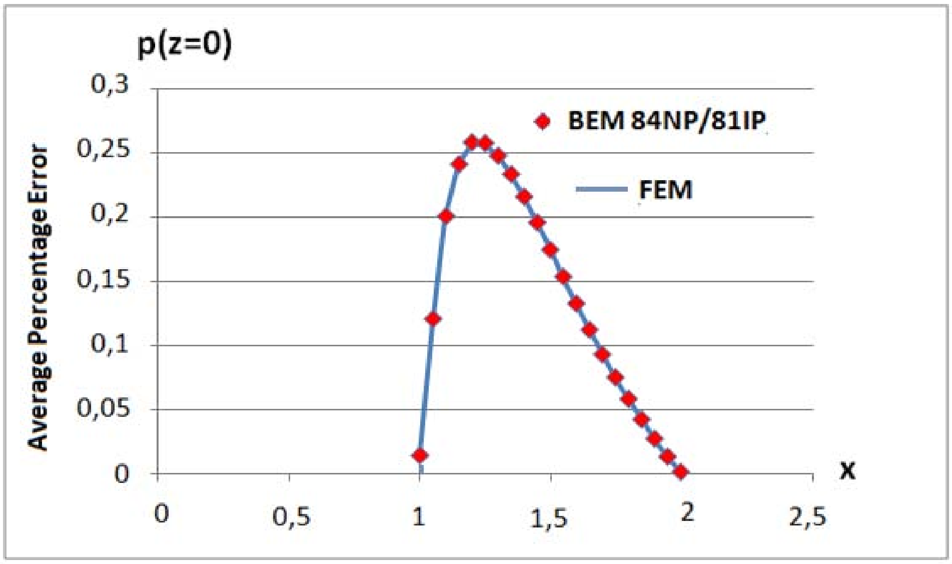

Figure 8: Comparison between BEM and FEM pressure results along the fluid flow for quadratic variation of h(x).

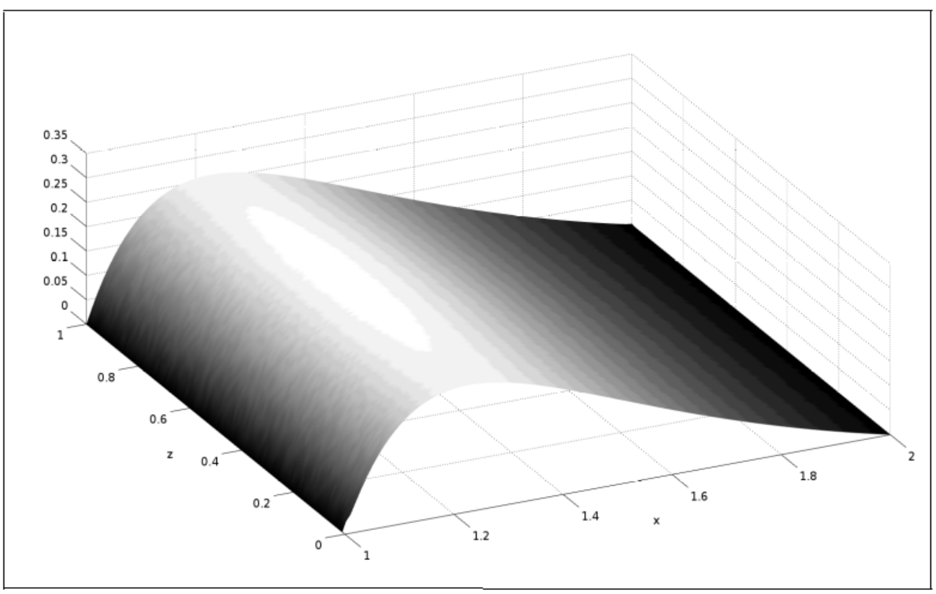

Figure 9: Three-dimensional view of the pressures on the domain for the second example.

VII. Conclusions

The boundary element model developed here was successfully implemented to study the hydrodynamic of the journal bearing problem, a case of great industrial interest. The rotating shaft and the slider bearing are given by two non-concentric circumferences whose clearance defines the lubricant fluid flow and the pressure field. Regarding the numerical model, this variable distance can be computed directly at the nodal level using the simplicity of the BEM discretization.

Mathematically, this problem is expressed in terms of a non-homogeneous scalar field equation, composed of three terms with different physical meaning: the variable diffusivity, the advective effect, and the body force. The diffusive term has been well represented, although the cube of the function h(x) is approximated by linear boundary elements. The advective term was suitably approached by the Quasi-dual model through radial functions, as well as the body force term, related here to the source.

The Quasi-dual solves accurately one-dimensional cases in general or then two-dimensional cases that can be expressed by a potential function, which is the case of the hydrodynamic bearing. It does not require the internal inclusion of interpolating points, which are necessary only to the source representation. Regarding this term, in this case, the application of the DIBEM procedure did not require numerous poles, due to its relative mathematical simplicity.

Unlike to the DRBEM, using the DIBEM approach the insertion of an excessive number of interpolating points does not produce disturbance effects in the numerical solution, commonly reported in the literature as due to ill conditioning matrix problems. Despite the necessary matrix inversion, the computational cost of this model is comparatively lower than that spent using alternative formulations such as DRBEM and RIM.

The successful association between the two techniques based on the approach with radial basis functions opens new options for the BEM application, due to the similarity of the problem addressed and the modeling of other cases in which the properties of the constitutive medium vary gradually along the domain, common in geophysics and soil mechanics problems.

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Machinability of Nickel Chromium Case Hardened Steel (EN36C)

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Abstract- Nickel Chromium Case Hardened Steel (EN36C) is surface hardened low carbon steel provided with a strong core prepared by the thermo-mechanical process. Owing to high strength, corrosion resistance, shock resistance, and good fracture toughness properties this kind of steel is used. Heavy duty crane shafts, airplane gears, cam, rollers, truck construction, some structural members and other more are the applications of this steel. It is compatible with dynamic conditions where the load is fluctuating with time, but the rigorous amount of temperature develops due to friction. The paper presents the experimental study on machinability of the EN36C steel. Experimentation was carried out by Chemical vapor deposition (CVD) coated carbide tool. Speed, feed and depth of cuts are the input parameters and chip reduction coefficient, material removal rate (MRR) and Von Mises stress are the output responses. The input parameters were assigned with code and arranged in 3^3 factorial design forms according to the Design of Experiment (DOE).

Keywords: machinability; chip thickness; strain hardening; von mises stress.

GJRE-A Classification: FOR Code: 091399p

MACHINABILITYOFNICKELCHROMIUMCASEHARDENEDSTEELEN36C

Strictly as per the compliance and regulations of:

Machinability of Nickel Chromium Case Hardened Steel (EN36C)

Vishal Mishra [α] & Dr. Kalyan Chakraborty [σ]

Abstract- Nickel Chromium Case Hardened Steel (EN36C) is surface hardened low carbon steel provided with a strong core prepared by the thermo-mechanical process. Owing to high strength, corrosion resistance, shock resistance, and good fracture toughness properties this kind of steel is used. Heavy duty crane shafts, airplane gears, cam, rollers, truck construction, some structural members and other more are the applications of this steel. It is compatible with dynamic conditions where the load is fluctuating with time, but the rigorous amount of temperature develops due to friction. The paper presents the experimental study on machinability of the EN36C steel. Experimentation was carried out by Chemical vapor deposition (CVD) coated carbide tool. Speed, feed and depth of cuts are the input parameters and chip reduction coefficient, material removal rate (MRR) and Von Mises stress are the output responses. The input parameters were assigned with code and arranged in 3^3 factorial design forms according to the Design of Experiment (DOE). The true stress-true strain curve helped to evaluate the material properties such as strain hardening exponent and strength coefficient. Von Mises stress evaluated owns the function of strain hardening exponent and strength of coefficient of the material. The study showed that low and moderate cutting speeds are the favorable conditions for machining on EN36C steel.

Keywords: machinability; chip thickness; strain hardening; von mises stress.

I. Introduction

Steel has a vital role in the manufacturing industries. As per manufacturing is concerned, the material should be deformable but so far as functioning is related material must not deform during its application. For designing any mechanical component made out of steel, it is necessary to know about the working environment of the component. For maintaining the required conditions, the steel needs to be alloying, and heat treated followed by some other processes.

Case hardening of steel is used to improve the mechanical property of steel such as wear resistance without affecting the inner core. The alloying elements take care the strength of the inner core and the thermo-mechanical processes hardens the outer surface. There are many methods by which case hardening can be achieved; some among them are surface coatings, diffusion methods, carburising methods, applied energy methods, etc. Energy applied method which includes flame hardening, induction heating, laser surface heat treatment, and laser transformation hardening is the case hardening process used for EN36C steel.

The work presented aimed at experimental investigation of the Von Mises stresses generated during dry turning of EN36C steel. The work focuses on the chip formation process which was the result of the input process parameters applied during machining. Chip formation and its thickness showed the extent of the rigorous plastic deformation of the material. The plastic deformation of material causes the generation of the Von Mises stress during machining. The generated Von Mises stress lies in the flow zone during the process of chip formation. There are many experimental ways to determine the stresses generated in the material during machining which requires some extra setup such as dynamometer installation, the force measuring sensors and many more which makes the whole machining process complex. Considering the material properties such as Strength coefficient ‘K’ and strain hardening exponent ‘n’ and the chip reduction coefficient ‘ξ’ evaluation of Von Mises stress has been carried. The chips formed during machining of EN36C steel are sometimes twisted and curl with an irregular surface which creates a problem of direct measurement of its length and width. Therefore we considered the length and weight of a chip to evaluate the cut chip thickness. The weight of the chip takes care of the inaccuracies occurred for the determination of the cut chip thickness. Chips are further subjected to SEM examination and analysis continues.

II. Literature Review

Kaushal Pratap Singh et al. [1] used Taguchi optimization technique to optimize input process parameters so to improve surface finish and material removal rate (MRR) during turning operation of EN36 steel. In the experiment, researchers adopted three levels (wet, dry, neutral) of the cutting environment with different spindle speed, feed, depth of cut, and nose radius. After performing the experiment and analysis, researchers concluded that cutting parameters effects MRR by 0.33%, 0.276%, 0.222%, 0.503% and 0.840% respectively and surface roughness by 0.105%, 0.412%, 0.261%, 0.703% and 0.447% respectively.

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Manan Kulshreshtha [2] studied the effect of machining parameters over the surface roughness of EN36 steel shafts by the use of carbide and cobalt-based tool insert using CNC lathe. Types of tool insert used, spindle speed, feed rate and depth of cut are the input process parameters used. The sequence of the input parameters was generated and considered according to Central Composite Design (CCD). As a result of the experiment, feed rate contributes most and cutting speed contributes least as an input factor affecting the surface roughness. By the use of Tungsten carbide tool, 2.1 micron was the optimum surface roughness value recorded at 0.2mm DOC, 10mm/min feed rate and 1200 rpm cutting speed.

However, by machining with cobalt insert, it was observed that 2.3 micron was the optimum surface roughness value recorded at 0.2mm DOC, 15mm/min feed rate and 1200rpm cutting speed.

A.Venkata Vishnu et al. [3] used Taguchi approach to optimize the turning process parameters of EN36 alloy. By using a Taguchi robust design approach, the optimum value of the selected control parameters was found to improve the material removal rate. EN36 steel in annealed condition was the work material, CNC machine with three types of tool inserts (Uncoated, PVD coated (TiAlN), CVD coated (CVD Al_2O_3 film MT-TiCN + TiC + Al_2O_3) was used for turning the work material. Researchers removed a ring-shaped layer of material, measured difference in the initial and final weight of the workpiece to calculate the MRR Number of the experiments conducted are nine. The work shows the Taguchi method application.

The result obtained that MRR increases with increase in cutting speed and feed rate respectively and also MRR increases till the moderate depth of cut and then decreases on increasing the depth of cut and at last MRR was maximum for the Uncoated tooltip, moderate for CVD tool and minimum for PVD coated tool.

They concluded that 100m/min cutting speed, 0.4mm/rev feed, 1 mm depth of cut were the optimum values and the uncoated tool was good for MRR.

III. Experimental Analysis

For the assessment on machinability of EN36C steel, Von Mises stress and the chip formation mechanism are two primary factors considered. The work material is of 110 mm diameter and 400 mm length dimension. The work material is Nickel Chromium case hardened steel prepared by the thermo-mechanical process. For turning of the work material, the present work employed Tungaloy made CVD (Chemical Vapour Deposition) coated (3 to 16 μm thick) carbide grades consisting of cemented carbide substrate TiCN tool insert. The coating over the tool insert improves the hot hardness and oxidation resistance property of the tool, thus making the tool chemically stable which increases the tool life and efficiency of machining.

Table 1: Chemical composition of EN36C steel

%Fe	%C	%Mn	%Si	%P	%Cr	%Mo	%Ni	%Al	%S
Balanced	0.159	0.386	0.182	0.0164	0.820	0.131	3.10	0.0182	0.0199

The present work employed gear driven central lathe for turning the workpiece. Spindle speed range of 45 rpm to 1000 rpm, and feed a range of 0.06mm/rev to 1.72 mm/rev are values available in the central lathe.

a) Tool Used

Holder specification: ASBNR 25*25 M12-A

Carbide inserts Specification: SNMG 120404 TM T9125

b) Selection of process parameters

The input process parameters were selected based on the values available on the lathe.

Table 2: Input Process Parameters used for machining

Factors	Level 1	Level 2	Level 3
Coding	-1	0	1
Speed (m/min)	36	60	100
Feed (mm/rev)	0.49	0.63	0.86
DOC (mm)	0.67	1	1.5

Table 2 describes the codes for each input process parameters. As per 3^3 factorial design, 27 experiments are available in the present work.

Table 3: 3^3 factorial design showing the input for machining

S. No.	Velocity Code	Feed Code	DOC Code	V (m/min.)	f (mm/rev)	d (mm)
1	-1	-1	-1	36	0.49	0.67
2	-1	-1	0	36	0.49	1
3	-1	-1	1	36	0.49	1.5
4	-1	0	-1	36	0.63	0.67
5	-1	0	0	36	0.63	1
6	-1	0	1	36	0.63	1.5
7	-1	1	-1	36	0.86	0.67
8	-1	1	0	36	0.86	1
9	-1	1	1	36	0.86	1.5
10	0	-1	-1	60	0.49	0.67
11	0	-1	0	60	0.49	1
12	0	-1	1	60	0.49	1.5
13	0	0	-1	60	0.63	0.67
14	0	0	0	60	0.63	1
15	0	0	1	60	0.63	1.5
16	0	1	-1	60	0.86	0.67
17	0	1	0	60	0.86	1
18	0	1	1	60	0.86	1.5
19	1	-1	-1	100	0.49	0.67
20	1	-1	0	100	0.49	1
21	1	-1	1	100	0.49	1.5
22	1	0	-1	100	0.63	0.67
23	1	0	0	100	0.63	1
24	1	0	1	100	0.63	1.5
25	1	1	-1	100	0.86	0.67
26	1	1	0	100	0.86	1
27	1	1	1	100	0.86	1.5

After mounting the work material on the lathe, turning operation was carried out for 30 seconds for each experiment. The experiment performed results in the formation of 27 different types of chips.

Fig. 1: (a). EN36C Steel mounted on the lathe. (b). EN36C Steel after machining.

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IV. Theory and Result

After the machining operation from 27 different experiments, the weight and the length of 27 experimental chips are available in the present study. Chip thickness and Von Mises stress values are available as subsequent machining response from the present work material. The below given formaulations are considered for the calculations:

Uncut Chip Thickness $t_1 = f * \sin \Phi$

Where,
f = Feed (mm/rev)
Φ = Principle Cutting edge angle (in degree)

$$Cut\ chip\ thickness\ t_2 = \frac{W}{\rho w l}$$

Where,
W = Weight of a chip (gm)
ρ = Density of the steel (0.008 gm/mm^3)
l = Length of a chip (mm)
w = width of a chip (mm)

$$width\ of\ a\ chip\ w = \frac{d}{\cos(90 - \theta)}$$

Where,
d = Depth of cut (mm)
θ = Principle approach angle (in degree)

Chip reduction coefficient $\xi = \frac{t_2}{t_1}$

$$Shear\ angle\ \hat{Y} = \frac{\cos\alpha}{\xi - \sin\alpha}$$

Where, α = Rake Angle (in degree)

Von Mises stress $\sigma_v = 1.74 * K * (\ln\xi)^n$ (MPa)

Where,
K = Strength coefficient (MPa)
n = strain hardening exponent

The above mentioned ‘K’ and ‘n’ values were calculated by selecting the points from true stress-true strain curve and plotting them on log-log graph paper. INSTRON 1195 UTM machine shows tensile test data of ASTM-E8 specimen prepared from the work material.

Fig. 2(a): ASTM-E8 EN36C steel Specimen before the tensile test.

Fig. 2(b): ASTM-E8 EN36C steel Specimen (Broken) after the tensile test.

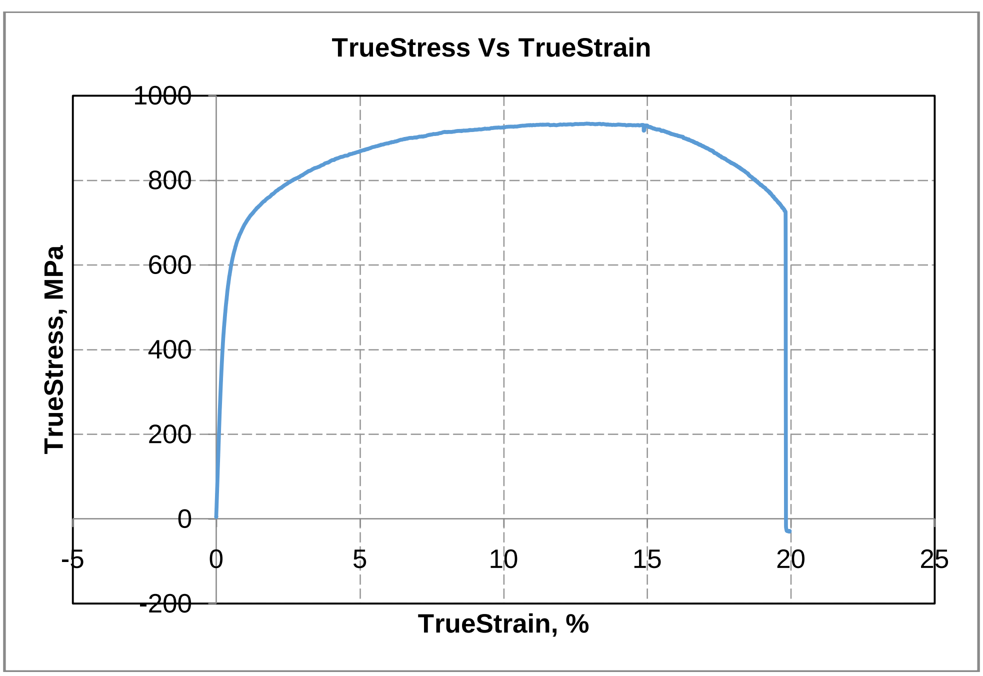

Fig. 3: True stress - True strain curve.

From the true stress-true strain curve points were selected which lies between the yield stress point and the ultimate stress point. Strain hardening exponent 'n' and strength coefficient 'k' values are available in the present work obtained from plotting the points of true stress-true strain curve on log-log graph paper and extrapolating the line to strain value 1. Value of 'K' is the value of true stress at true strain equals to 1 on the log-log graph (Fig. 4).

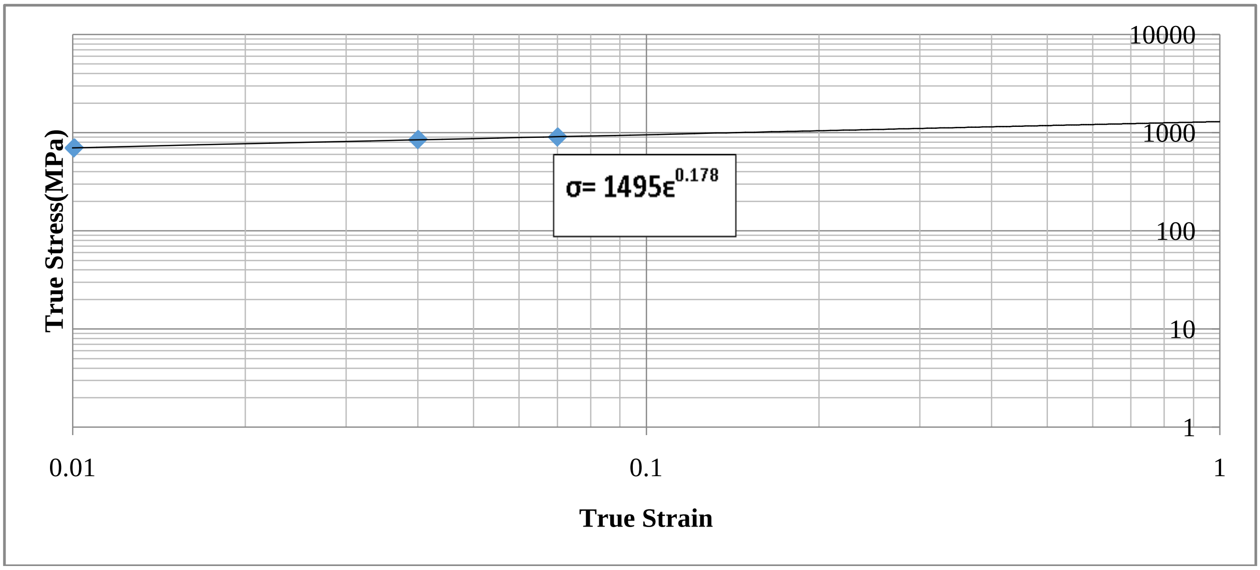

Fig. 4: True stress v/s True strain log-log graph.

So by getting the value of 'K' and 'n' power equation $\sigma = K\varepsilon^n$ was obtained as:

$$\sigma = 1495\varepsilon^{0.178}$$

Where,

σ = True Stress (MPa)

ε = True Strain

For total work done, elemental work done was to be evaluated first as shown below:

Elemental work done W_e,

$$W_e = \frac{K(1.15 ln \xi)^{n+1}}{n+1}$$

Total Work done T_W,

$$T_w = W_e * V * f * d * t \text{ (Nm)}$$

Where,

V = Cutting speed (m/min)

f = feed (mm/rev)

d = depth of cut (mm)

t = time (minutes)

The regression coefficients were obtained through Minitab software. The second order equations for the chip reduction coefficient (b_{CRC}) and Von Mises Stress (b_{VMS}) are obtained as:

$$b_{CRC} = 1.3334 - 0.0561x_1 - 0.0322x_2 - 0.0163x_3 - 0.2708x_1^2 + 0.1474x_2^2 + 0.0563x_3^2 + 0.0366x_1x_2 + 0.0183x_1x_3 - 0.0093x_2x_3 \quad \text{(eq. i)}$$

$$b_{VMS} = 1810.7 - 76.2x_1 - 25.1x_2 - 7x_3 \text{ . } 324x_1^2 + 265.7x_2^2 + 157.9x_3^2 + 101.5x_1x_2 + 129.5x_1x_3 - 374x_2x_3 \quad \text{(eq. ii)}$$

Where,

x_1 = Speed.

x_2 = Feed.

x_3 = Depth of cut.

Design of experiment equations helped us to obtain 3D graphs for chip reduction coefficient 'CRC', and Von Mises stress for various cutting parameters.

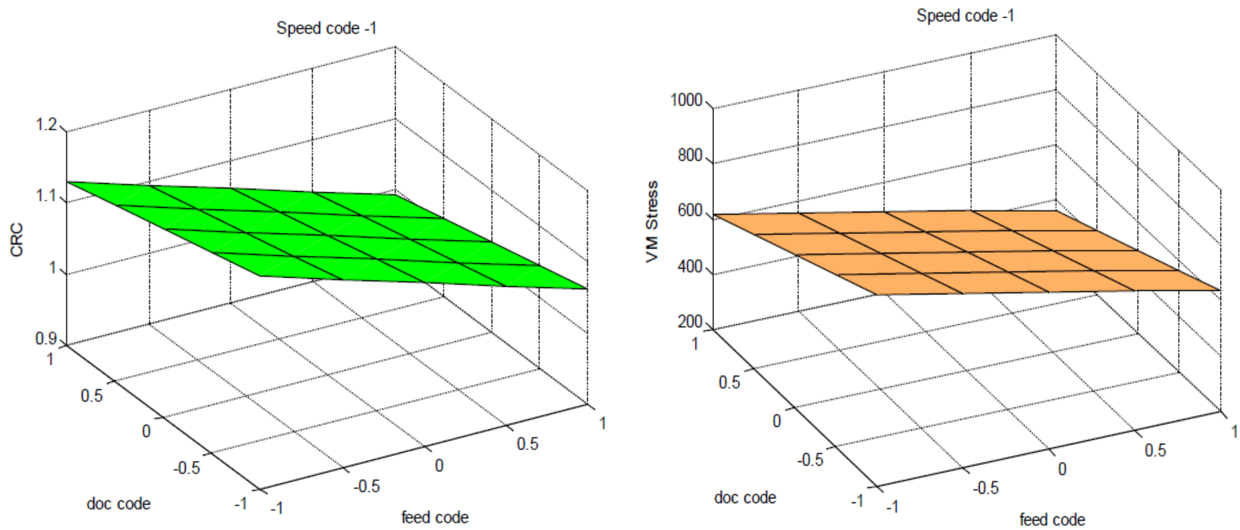

Fig. 5: (a). Variation of CRC concerning to the feed and depth of cut code for the speed code -1.
(b). Variation of Von Mises Stress concerning the feed and depth of cut code for the speed code -1.

The fig. 5 (a) and 5 (b) shows that at the lowest speed (speed code -1), both CRC and Von Mises stress decrease with an increase in the feed. Strain hardening of the work material and brittleness transition becomes effective with increased feed to reduce the value of CRC and Von Mises stress.

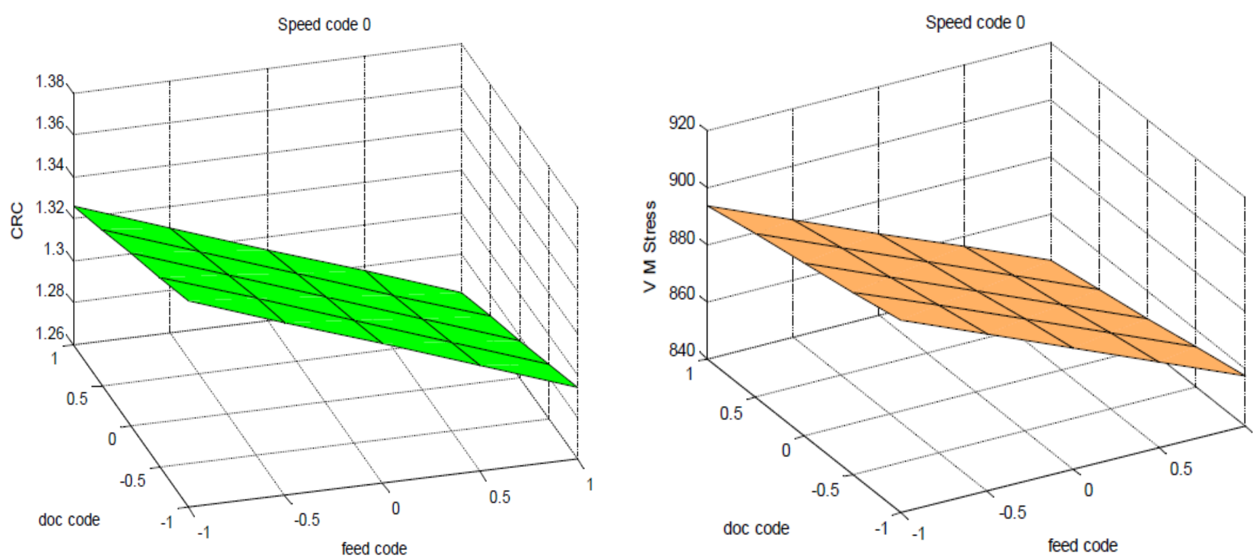

Fig. 6: (a). Variation of CRC concerning to the feed and depth of cut code for the speed code 0.
(b). Variation of Von Mises Stress concerning to the feed and depth of cut code for the speed code 0.

From fig. 6 (a) and 6 (b) shows that both CRC and Von Mises stress decreases with an increase in feed. At increased feed, material hardening and brittleness transition become more effective to reduce the value of CRC and Von Mises stress during the process of chip formation. Variation of the depth of cut at this cutting condition is found to be less effective to vary both CRC and Von Mises stress.

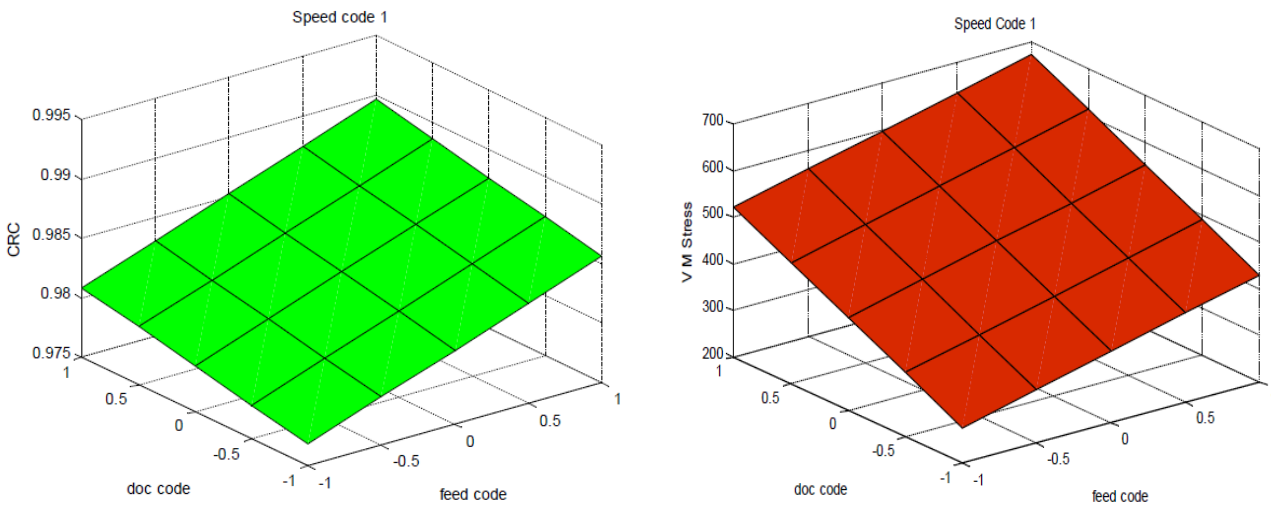

Fig. 7: (a). Variation of CRC concerning to the feed and depth of cut code for the speed code 1.
(b). Variation of Von Mises Stress concerning the feed and depth of cut code for the speed code 1.

From fig. 7 (a) and 7 (b) shows that both CRC and Von Mises stress are increasing with the feed and depth of cut. In the present work, code 1 is the highest code value for each input parameters. At maximum speed, feed and depth of cut condition, the thermal effect becomes pronounced causing the thermal softening to raise the CRC value for the produced chip at this specific cutting condition. A ductile transition of the work material occurs at the cutting zone during the process of chip formation causing pronounced cohesive energy in the flow zone due to thermal effect and Von Mises stress increases enormously owing to the ductile separation of the chip material during the process of chip formation.

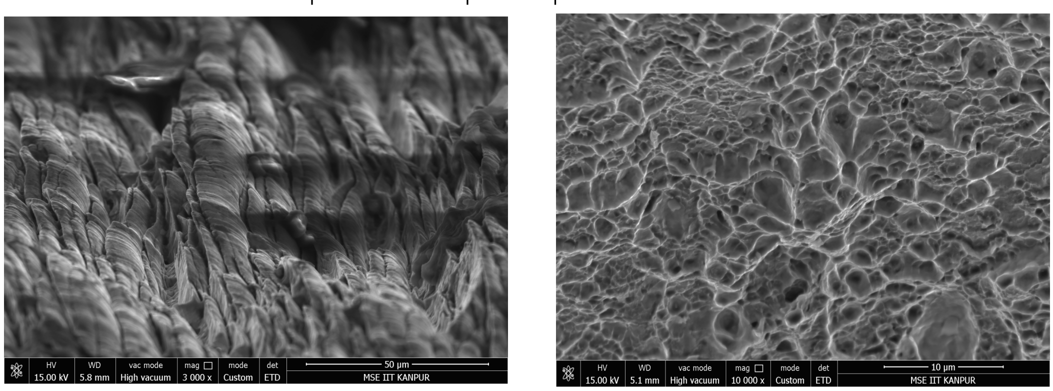

Fig. 8: (a). SEM image of the side edge of a chip at 3000X magnification.
(b). SEM image of the fractured tip surface of a chip at 10000X magnification.

Chip specimen obtained at maximum speed, feed and depth of cut (v = 100 m/min, f = 0.86 mm/rev and d = 1.5 mm) condition was examined under the Scanning Electron Microscope (SEM). Chip image for the chip side edge along with chip top surface was viewed under the Scanning Electron Microscope (Fig. 8 (a)). Enormous ductile separation of the material occurs during the process of chip formation. SEM examination of chip fractures surface shows ductile fracturing (fig. 8 (b)). Numerous dimples are available at the fractured surface. The fig. 8 (b) showed that ductile tearing mode took place during the process of chip formation. This finding clearly illustrates the dominating effect of temperature causing ductile transition at the flow zone during the process of chip formation.

V. Conclusion

1. Property transition of the work material occurs at the cutting zone during the process of chip formation.
2. Machining of EN36C steel should be in respective to the lower speed and moderate speed at variable feed and depth of cut.
3. High-speed machining is not good for machining EN36C steel.

Acknowledgement

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Automatic Street Light Control System using Light Dependent Resistor and Motion Sensor

By Md. Sazol Ahmmed, Tanzima Zoha Chowdhury & Sourav Kumar Ghosh
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Abstract- Automatic street light control system is used in modern world for energy savings by using Light dependent Resistor (LDR).Nowadays the human has not enough time, and he/she is unable to find time even to switch the lights on or off. This new system can be used more effectively in case of street lights. In proposed system, the street lights will be switched on just before the sun sets and are switched off the next day morning when there is sufficient light on the road. The proposed model also uses motion sensor to control the intensity of light. Huge power is consumed when most the vehicles don't move during the late. This paper shows that the proposed System is relatively low cost, efficiency is better than the existing system.

Keywords: automation, LDR, motion sensor, relay switch.

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AUTOMATICSTREETLIGHTCONTROLSYSTEM USINGLIGHTDEPENDENTRESISTORANDMOTONSENSOR

Strictly as per the compliance and regulations of:

Automatic Street Light Control System using Light Dependent Resistor and Motion Sensor

Md. Sazol Ahmmed [α], Tanzima Zoha Chowdhury [σ] & Sourav Kumar Ghosh [ρ]

Abstract- Automatic street light control system is used in modern world for energy savings by using Light dependent Resistor (LDR).Nowadays the human has not enough time, and he/she is unable to find time even to switch the lights on or off. This new system can be used more effectively in case of street lights. In proposed system, the street lights will be switched on just before the sun sets and are switched off the next day morning when there is sufficient light on the road. The proposed model also uses motion sensor to control the intensity of light. Huge power is consumed when most the vehicles don't move during the late. This paper shows that the proposed System is relatively low cost, efficiency is better than the existing system.

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I. Introduction

In 21[st] century it is quite impossible to avoid accident during night without lights. So street light is the essential part in our busy life for safety purposes. But the manpower required for controlling the light cuts a huge cost .So in this situation this project helps to reduce the cost of man power and reducing power Consumption. During day time there is no essence of street light so the LDR keeps the street light off. As soon as the light intensity is low then the LDR is started working and the light is switched on. Motion sensor has a huge indoor and outdoor application. Very common application of motion sensor is activation of automatic door opening. Motion sensor also used instead of convention sensor because of its accuracy. Motion sensor also used as an alarm when it detects the motion of a possible intruder.

II. Literature Review

Bangladesh faces major problem regarding electricity i.e. its rate of generation of electricity is less than rate of consumption. Even small implementations can make large contributions on large scale. We know in this area of development more and more numbers of highways, expressways etc. thus an automation is needed to improve this condition [1].In the prior automation system i.e. only using LDR the system could only reduce the manual switching, but power saving could not be handled[2].Itcan control (on/off) distribution line of a specific region based on the intensity of the daylight was implemented by [3]. The circuit was built by providing some special features so that it can withstand or adjustable if the intensity of light varies with some others factor. The microcontroller based control systems are more reliable, accurate and easily programmable to perform data transfer, data security, design the control system and tracking the changes in the system.[4].Street lights are controlled by photocells. These have only one function, which is switching lights on and off according to factory-fixed, light-level thresholds. Telensa's proposed system operates by replacing the traditional photocell with an 'outstation'. This performs the lamp switching and monitoring functions [5].

III. System Components

It consists of nine main components. These are LDR, LM 358, Diode, BC 547, Relay, Voltageregulator, Bulb, Motion sensor, Resistor, Adapter.

a) Design of system components

i. Automatic switch on off control system components

Light-dependent resistor (LDR): Photo resistor or light-dependent resistor (LDR) or photocell is a light-controlled variable resistor. The resistance of photo resistor decreases with increasing incident light intensity; in other words, it exhibits photoconductivity. Photo resistor can be applied in light-sensitive detector circuits, and light- and dark-activated switching circuits.

The electrons are liberated when the light falls on the sensor. The photons absorbed when the light intensity exceeds a certain limit. For these reason lots of free electrons and hole are released and resistance is decreased dramatically. The equation to show the relation between resistance and illumination can be written as

$$R = A*E^{a}$$

The value of 'a' depends on the CdS used and on the manufacturing process. Values are usually in between 0.7 and 0.9.

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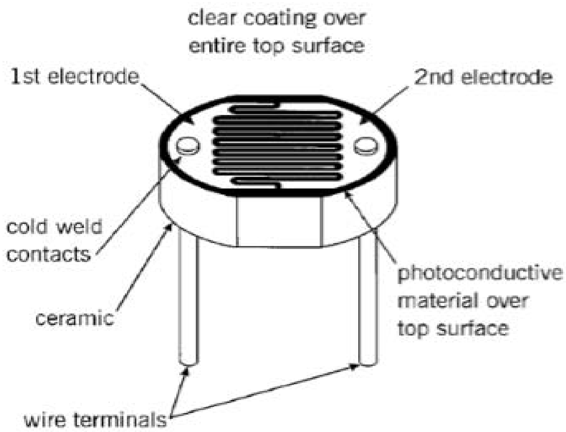

Fig. 1: Light Dependent Resistor

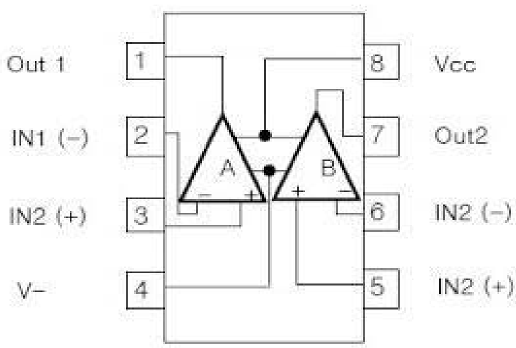

Fig. 2: Pin configuration of IC

LM 358: LM358 consists of two independent and high gain operational amplifiers. It is not require independent power supply for each comparator for wide range of power supply. LM358 may be used as transducer amplifier, DC gain block etc. It consists of dc voltage gain of 100dB. The power supply requires from 3V to 32V for single power supply or from ±1.5V to ±16V for dual power supply.

ii. *Light intensity control system components*

Motion sensor:

Motion sensor has an optical, microwave, or acoustic sensor. However, a *passive* sensor only senses a signal emitted by the moving object itself. Changes in the optical, microwave, or acoustic field in the device's proximity are interpreted by the electronics based on one of the technologies listed below. Motion detectors can detect in variable distances depends on their cost. In this project we use passive inferred ray motion sensor to detect the arrival of vehicle.

Fig. 3: PIR Sensor

Relay switch:

A relay is an electromagnetic switch operated by a relatively small electric current that can turn on or off a much larger electric current. Many relays use an electromagnet, but other operating principles are also used such as solid-state relays.

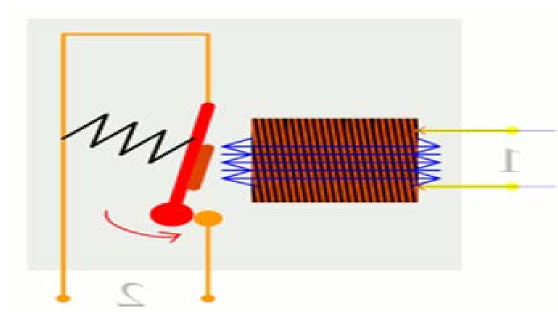

Fig. 4: Relay

IV. Working Procedure

This circuit uses divider circuits connected as comparator; the output goes high when the trigger pin 2 is at lower then 1/3rd level of the supply voltage. Conversely, the output goes low increasing its power supply. So small change in the voltage of pin-2 is enough to change the level of output (pin-3) from high to low and high to low. The output has only two states high and low and cannot remain in any intermediate stage. It is powered by a 6V battery for portable use. The circuit is economic in power consumption. Pin 4, 6 and 8 is connected to the positive supply and pin 1 is grounded. To detect the present of an object we have used LDR and a source of light.

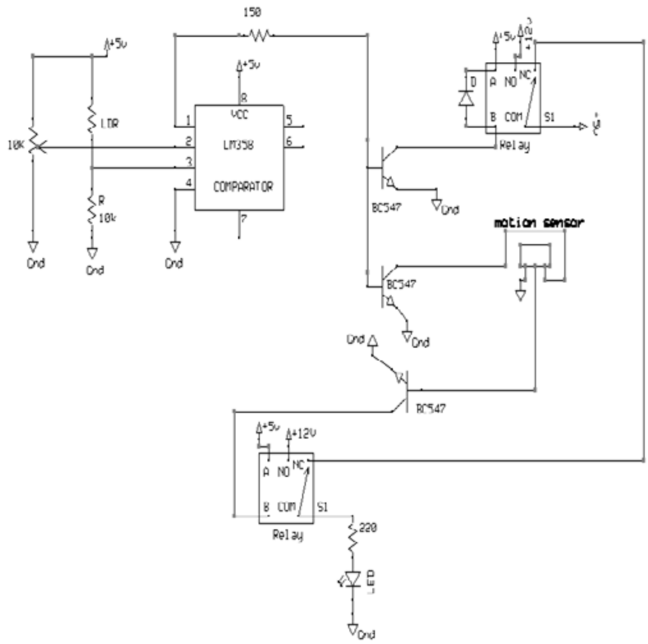

Fig. 5: Main circuit diagram of automatic light on–off and light intensity control.

LDR is a special resistance whose value depends on the intensity of the light which is falling on it. It has resistance of about 1 mega ohm in case of total darkness, but a resistance of only about 5k ohms when brightness illuminated. It responds to a large part of light spectrum. We have built divider circuit with LDR and 100K variable resistance connected in series. It is well known that that voltage is directly proportional to conductance. This divided voltage is given to pin 2 of IC 555. Sensitiveness can be adjusted by using variable resistance. As soon as LDR gets dark the voltage of pin 2 drops 1/3rd of the supply voltage and pin 3 gets high and LED which is connected to the output gets activated. When the switching circuit is activated, the motion sensor circuit will not work, so when light is fall in the LDR that means in day-night motion sensor will not work.

V. Design Analysis

The lamp power rating was 3 WATT and its working voltage is 12v.

The current rating of the lamps is calculated as follows:

I (amp) = POWER/VOLTAGE
=3 /12 A
= 0.25A

Therefore, the current rating used in lamps is 0.25A. The bulb number used is 20.Therefore, the current consumption of the lamps used = (0.25 x 20)A. I(amps) = 5.Since the current consumption used is 5A. A Relay of 10A contact current is used for the control circuit of the lamps.

Proper Selection of transistor for the Relay:

Since the voltage rating of the D.C. power supply used for the lamp is 12v. A. 12v D.C. Relay is selected for automatic switching ON/OFF. The coil resistance of the relay used is 82Ω.Relay working voltage = 12v, Resistance of the Relay = 82Ω
Therefore, I(relay) = 12/82 A = 0.15 A

Since the current consumption used is 0.15A, a BC 547 transistor with collector current rating of 0.8A, collector to base voltage of 11v, collector to emitter voltage of 7v and emitter to base voltage of 4v is considered suitable to drive the relay used in the output of the control circuit.

VI. Cost Analysis

The present situation if the night time is 12 hours and the 300 lights are working under 220 volts, and the power of the light is 60 watts .the road distance consider 1 kilometer, the unit is calculated below

Unit =p*T/1000
=60*12/1000
=0.72Units per day per lamp

Let the cost of electricity per unit is5.50 taka then the total cost per month =0.72*5.5*30=118.8 taka per month per light The Total amount for all light is=118.8*300=35640 Taka Using automatic intensity control circuit The vehicle moves late night small number, so the lamps do not get voltage 220 volt all time .In small-town For the automated system lets consider 2 cases heavy traffic and very light traffic.

Case 1: Heavy traffic, the road is continuously having vehicles; power consumption will be,

Total=0.72Watts per month per vehicle
=216 watt per month
Total cost =35640 taka

Case 2: Light traffic, a very few vehicles pass by this road, For a highway minimum speed can be considered as 30 kilometer per hour, So it will take 2 min to cover the stretch of 1km for light traffic of 100 vehicles it would take 200 minutes i.e.3 hours 20 minutes

Unit =30*p*T/1000
=30*60*4/1000
=7.2Units per month per lamp
=2100 unit per month for all lights

Total cost=7.2*300*5.5=11800 taka

For Thus in any of the cases, the system in this paper is capable of saving electricity.

VII. Conclusion

This project is automatic street light control system. It is very economical because it is a very cheap budget project. So it can play an important rule to save energy consumption. As a product design engineer we are trying to analyze the product in such a way that it will

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be less costly, good appearance, user-friendly, economical improved performance & after all satisfy customer's requirements. But our effort will be successful if the customers satisfy to get this project benefit. We think post survey is required among the customers to find out further improvement in design.

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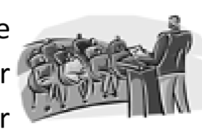

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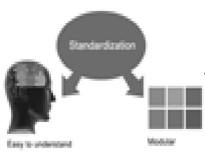

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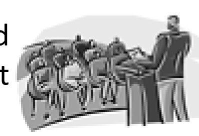

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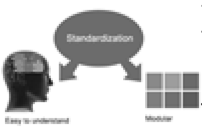

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- Ideas
- Findings
- Writings
- Diagrams
- Graphs
- Illustrations
- Lectures

- Printed material
- Graphic representations
- Computer programs
- Electronic material
- Any other original work

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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

Contributors to the research other than authors credited should be mentioned in Acknowledgments. The source of funding for the research can be included. Suppliers of resources may be mentioned along with their addresses.

Declaration of funding sources

Global Journals is in partnership with various universities, laboratories, and other institutions worldwide in the research domain. Authors are requested to disclose their source of funding during every stage of their research, such as making analysis, performing laboratory operations, computing data, and using institutional resources, from writing an article to its submission. This will also help authors to get reimbursements by requesting an open access publication letter from Global Journals and submitting to the respective funding source.

Preparing your Manuscript

Authors can submit papers and articles in an acceptable file format: MS Word (doc, docx), LaTeX (.tex, .zip or .rar including all of your files), Adobe PDF (.pdf), rich text format (.rtf), simple text document (.txt), Open Document Text (.odt), and Apple Pages (.pages). Our professional layout editors will format the entire paper according to our official guidelines. This is one of the highlights of publishing with Global Journals—authors should not be concerned about the formatting of their paper. Global Journals accepts articles and manuscripts in every major language, be it Spanish, Chinese, Japanese, Portuguese, Russian, French, German, Dutch, Italian, Greek, or any other national language, but the title, subtitle, and abstract should be in English. This will facilitate indexing and the pre-peer review process.

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.

Format Structure

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.

Preparation of Eletronic Figures for Publication

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.

Color charges: Authors are advised to pay the full cost for the reproduction of their color artwork. Hence, please note that if there is color artwork in your manuscript when it is accepted for publication, we would require you to complete and return a Color Work Agreement form before your paper can be published. Also, you can email your editor to remove the color fee after acceptance of the paper.

Tips for Writing a Good Quality Engineering Research Paper

Techniques for writing a good quality engineering research paper:

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 though 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:

- o Single section and succinct.
- o An outline of the job done is always written in past tense.
- o Concentrate on shortening results—limit background information to a verdict or two.
- o 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:

- o Explain the value (significance) of the study.
- o 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.
- o Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- o 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

Administration Rules to Be Strictly Followed before Submitting Your Research Paper to Global Journals Inc.

Please read the following rules and regulations carefully before submitting your research paper to Global Journals Inc. to avoid rejection.

Segment draft and final research paper: You have to strictly follow the template of a research paper, failing which your paper may get rejected. You are expected to write each part of the paper wholly on your own. The peer reviewers need to identify your own perspective of the concepts in your own terms. Please do not extract straight from any other source, and do not rephrase someone else's analysis. Do not allow anyone else to proofread your manuscript.

Written material: You may discuss this with your guides and key sources. Do not copy anyone else's paper, even if this is only imitation, otherwise it will be rejected on the grounds of plagiarism, which is illegal. Various methods to avoid plagiarism are strictly applied by us to every paper, and, if found guilty, you may be blacklisted, which could affect your career adversely. To guard yourself and others from possible illegal use, please do not permit anyone to use or even read your paper and file.

Criterion for Grading a Research Paper (Compilation)
by Global Journals

Please note that following table is only a Grading of "Paper Compilation" and not on "Performed/Stated Research" whose grading solely depends on Individual Assigned Peer Reviewer and Editorial Board Member. These can be available only on request and after decision of Paper. This report will be the property of Global Journals.

Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	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
Introduction	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
Methods and Procedures	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
Result	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
Discussion	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
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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