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Highlights

Repairing Behavior of Termites

Applications of Genetic Programming

Discovering Thoughts, Inventing Future

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Mainstreaming Solar Energy into Residential Sectors of Nashik City

By Seema Sharma & Anoop Kumar

Abstract- Energy is one amongst the foremost vital inputs for economic growth and human development. The economic progress and urbanization are leading to rapid increase in energy demand in urban areas. With appreciation in income levels, people have started depending more on electrical run appliances for their domestic needs. Growth in industrial and commercial sectors also has an ever increasing demand for power supply. Urban areas are heavily dependent on fossil fuels for powering homes, infrastructure, transport, industry and commerce. Although India has huge proven coal reserve, the calorific value and increasing ash content in Indian coal is a major concern. With the proven statistic the oil and natural gas resource in India will last hardly for 18 and 26 years.

Most cities of India are experiencing 15% growth in the peak electricity demand. The government and electricity utilities are finding it difficult to cope with rapid rise in demand, as a result most of cities are facing severe electricity shortages. Long hours of power cuts results in disruption of activities and severely affect economic development of city.

Keywords: *solar energy, urban areas, energy conservation, environment, grid, sewage.*

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Mainstreaming Solar Energy into Residential Sectors of Nashik City

Seema Sharma [α] & Anoop Kumar [σ]

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Most cities of India are experiencing 15% growth in the peak electricity demand. The government and electricity utilities are finding it difficult to cope with rapid rise in demand, as a result most of cities are facing severe electricity shortages. Long hours of power cuts results in disruption of activities and severely affect economic development of city. With increased dependency on fossil fuels, urban areas have emerged as one of the major sources of Green House Gas (GHG) emissions, with buildings alone contributing to around 40% of total GHG emissions. CO2 emissions are creating serious global warming issues. SOx, NOx and SPM are contributing to local environmental impacts and flattering a challenge for human well being. In this context there is need to develop a framework that will encourage and assist cities in assessing their present energy consumption status, setting clear targets for and preparing action plans for generating energy through renewable energy sources and in conserving energy utilized in conducting urban services.

This paper provides a framework to harness solar energy potential to reduce the burden of peak energy demands of urban areas.

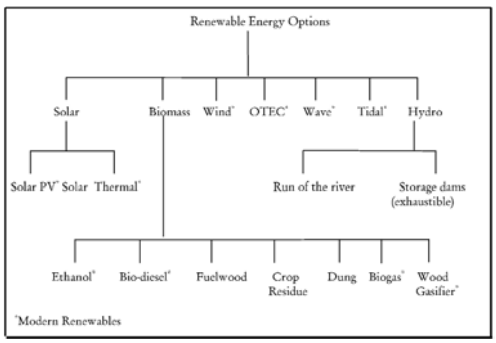
Keywords: solar energy, urban areas, energy conservation, environment, grid, sewage.

I. Energy and Environment

During the last decade the attention of the energy policy-makers, globally, was drawn to the impacts of energy use on the environment. More specially, the apparent linkage between the emissions from the fossil energy use and the green house effect made the environmental concerns a critical component of energy planning. The future energy and emission intensities from the developing countries shall be invariably decided by the development patterns. It is neither efficient nor even feasible for the developing countries to follow the past development paths of the industrialized countries.

Transport, manufacturing, the power sector, commercial and residential energy use, all contribute to problems of air quality. Motor vehicles contribute to all forms of air pollution. Residential burning of unprocessed biomass fuel is the single largest source of carbon monoxide and suspended particulate matter. Power generation contributes most of the nitrogen oxides and sulphur dioxide.

The escalating demand for power, rapid proliferation of motor vehicles, expansion of industries and rising living standards will all combine to have significant impact on the quality of air, especially in urban areas India has huge potentials for the effective use of renewable energy. Various renewable energy sources like small hydro, biomass, and solar energy have power generation potential in India.



II. Analytical Framework

There is a need to develop a framework that will encourage and assist cities in assessing their present energy consumption status, setting clear targets for and preparing action plans for generating energy through renewable energy sources and in conserving energy utilized in conducting urban services.

S. No.	Objective	Task	Approach
1	To prepare energy conservation plan	a. Checklist of energy saving devices.	Market survey

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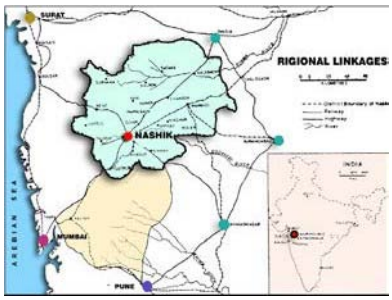
2	To prepare energy generation plan	a. Classify energy generation possibilities at sector level	Literature review,
		b. P.V application details	Literature review, interview with field experts and manufacturers.
3	To check Technical feasibility	a. Check efficiency	Literature review, interview with field experts and manufacturers.
		b. Maintenance	
		c. Life / durability	
4	To check financial feasibility	a. Applicability of subsidies/tax benefit	Review policies
		b. Calculate cost recovery period	Primary and secondary survey of manufacturers
		c. Insurance policies.	Review policies

III. Case Study: Nashik

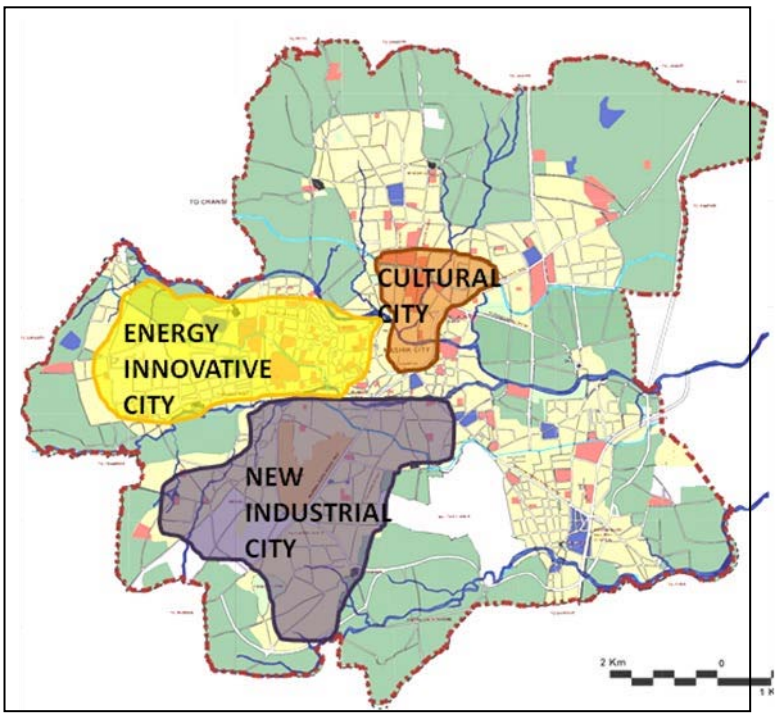
Nashik is located towards the north west of Maharashtra and lies between 19°55' and 20°05' North latitude and 73°42' and 73°55'East longitude. It is located 180 Km, towards north of the state capital, Mumbai and 220 Km towards north of Pune. River Godavari divides the city into Northern Nashik and Southern Nashik. Nashik Urban Agglomeration has a population of 1,620,000 (projected year 2014) and a total area of 259.13sq Km. which makes it the fourth largest urban area in Maharashtra in terms of population.



The coal requirement for NTPS is enormous. For full rated generation, Nashik requires 12 to 13 thousand M.T of coal per day. Nashik is linked for coal supplies with Western Coalfields and South Eastern Coalfields. Nashik being located far away from the collieries, the freight component is considerable and is normally 80 to 100% of the cost of coal.

The power situation during summers becomes worst when the small hydro power plants in the district are at the mercy of rain. MSEDC in 2014 enforced power cut from 16 hours to 40 hours a week in Industrial Areas. Residential Areas faced 6-7 hours power cut daily.

a) Study Area Delineation



The growth pattern indicates that the western area of the city has high potential for future growth to develop as a commercial, institutional and residential hub. Considering the spatial growth pattern, land use, activities and energy demand, the city can be divided into three zones.

i. *Cultural City*

The old city is characterized by narrow, shaded, winding streets, peculiar projections onto the street, streets swelling into a public courtyard and the vibrant and active bazaar streets leading towards the river. The housing typology is *wada* which means a courtyard house with sloping roof. The old city near the Godavari river is established as a rich heritage and pilgrimage centre.

Looking at physical, economical and social characteristics of old city, solar thermal or solar photovoltaic initiatives has very less potential. Area has potential of Energy conservation at existing house hold levels. Alterations or replacing electrical devices with energy efficient devices can reduce the overall energy demand within old city area.

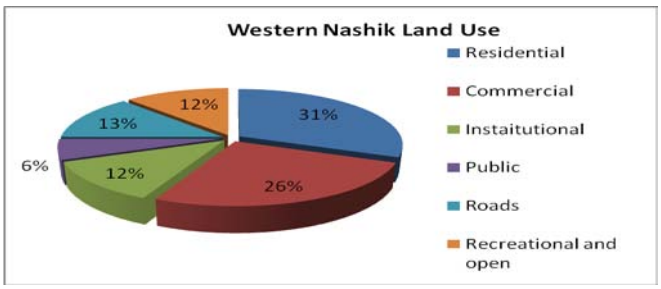
ii. *Energy Innovative City*

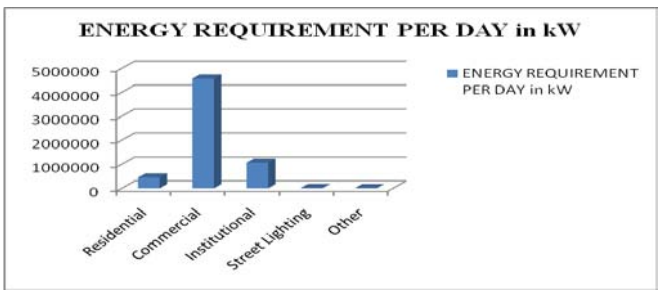
Western Nashik – New development in commercial, residential, and institutional sectors is happening in western Nashik.

Development happening can be seen in a planned approach with uniformity in the land use pattern. There is a majority of higher and higher middle income groups residing in western region.

Thus the western region can be perceived as an energy innovative city, where solar energy resource can find potential in application to reduce the energy demand. New buildings can reduce their energy demands by adopting Green building techniques. Individuals can be active part of the energy management of city, by switching to energy saving devices and solar water heating system installation. Commercial and institutional establishments can generate their own electricity with BIPV systems.

The total area of energy innovative city is 52 Km^2. Major contribution is by residential and commercial sector covering 16.12 Km^2 and 13.52 Km^2 respectively. Institutions cover 6.24 Km^2. Public, Roads, and Recreational has 3.12, 6.76 and 6.24Km^2 area respectively.





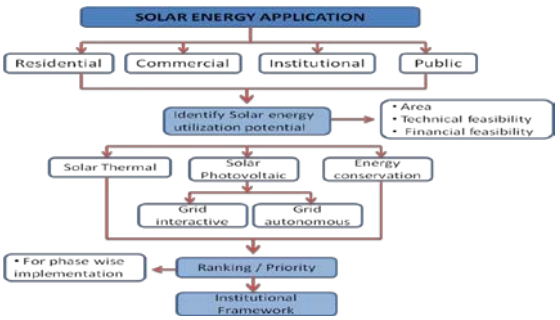
The energy requirement in a day by commercial sector is the highest for western Nashik, followed by institutional which is 4569879.6 and 1065240 kW respectively. Residential sector has an average requirement of 443139.84 kW in a day. Street lighting requires 14919 kW and others like signal lighting, lighting on hoardings and park require 7959.5 kW.

iii. *New Industrial City*

The industrial activity within Nashik Municipal Corporation area is mainly concentrated at the industrial Estates of Maharashtra Industrial Development Corporation viz, the Satpur Industrial Estate & Ambad Industrial Estate. These well planned and established industrial area has a potential to incorporate industries manufacturing solar technology. The new industrial city will encourage use of renewable technology by providing easy local technological assistance.

b) Framework and Proposal for Solar Energy Utilization

i. *Framework*



Solar energy is majorly utilized in two forms, as solar thermal and solar photovoltaic. Solar thermal finds its potential into residential sector, where there is hot

water requirement. Solar photovoltaic has wide application. There are two ways of utilizing the output.

1. Grid Autonomous
2. Grid interactive

Grid autonomous works without the support of the conventional grid. The output is stored in the battery. For example solar street light and in Grid Interactive the panel's output is connected to the mail utility grid with help of converter.

ii. *Energy Saving in Existing House Holds*

Replacing all tubular Fluorescent Lamps (TFL) of 48 Watt/36 Watt lamps and electromagnetic ballasts (copper chokes) to energy saving T-8 or T-5 TFL of 28watt/33 watt and electronic ballasts.

Replacing all general Lighting Service (GLS) bulbs of 100 watt/ 60 watt to compact Fluorescent (CFL) of 20watt/16watt.

Replacing all existing ceiling fans that consume 60 watt to 80 watt, varying with size and age to energy efficient 50 – watt ceiling fans.

Replacing all existing refrigerators with BEE labeled refrigerators.

Replacing all household electrical irons that consume 1100 watts to energy efficient 750- watt irons.

IV. Result

After conservation measures, following are the power consumptions for different categories of houses as per Devices.

a) HIG group Household

Appliance	Wattage of regular device kW	Wattage of energy efficient device in kW	Appliance per house hold	Use per day (hrs)	Power consumption/ day kW	Power consumption after conservation measures/day kW
Tube Light with regular ballast	0.048	0.033	5	3.5	0.84	0.5775
Incandescent Lamps	0.06	0.02	2	2	0.24	0.08
Television	0.1		1	10	1	1
Fans	0.075	0.05	3	8	1.8	1.2
Refrigerators	0.1		1	24	2.4	2.4
Geysers	2		1	0.75	1.5	1.5
Electric iron	1	0.75	1	0.2	0.2	0.15
Washing machine	0.5		1	0.5	0.25	0.25
Computer	0.1		1	2	0.2	0.2
Mixer grinder	0.5		1	0.5	0.25	0.25
Air cooler	0.25		1	6	1.5	1.5
TOTAL	10.18	9.1075				
Total Energy saving per day	**1.07**					
Annual Energy saving per HH in kW	**391.46**					

b) MIG Household

Appliance	Wattage of regular device kW	Wattage of energy efficient device in kW	Appliance per house hold	Use per day (hrs)	Power consumption/ day kW	Power consumption after conservation measures/day kW
Tube light with regular ballast	0.048	0.033	2	4.5	0.432	0.297
Incandescent Lamps	0.06	0.02	3	2	0.36	0.12
Fans	0.075	0.05	2	8	1.2	0.8
Television	0.1		1	8	0.8	0.8
Refrigerator	0.1		1	16	1.6	1.6
Geyser	2		1	0.5	1	1
Mixer Grinder	0.5		1	0.5	0.25	0.25
TOTAL					5.642	4.867
Total energy saving in kW						**0.775**
Annual Energy saving per HH in kW						**282.875**

c) LIG Household

Appliance	Wattage of regular device kW	Wattage of energy efficient device in kW	Appliance per house hold	Use per day (hrs)	Power consumption/ day kW	Power consumption after conservation measures/day kW
Tube light with regular ballast	0.048	0.033	2	3.5	0.336	0.231
Incandescent lamps	0.06	0.02	2	3	0.36	0.12
Television	0.1		1	6	0.6	0.6
Fans	0.075	0.05	1	9	0.675	0.45
Mixer grinder	0.5		1	0.2	0.1	0.1
TOTAL	2.071	1.501				
Total energy saving per day	**0.57**					
Annual Energy saving per HH in kW	**208.05**					

V. Conclusion

Energy consumption plays an excellent role in every country's sustainable growth and environmental performance. In general, energy capacity has focused on energy efficiency. Being efficient in the use of all resources makes an important involvement toward both environmental and economic sustainability.

The study describes the findings to be aware of the factors and strategies that deal with energy efficiency. The information concerning energy policy and program improvement is important to generate strategies to develop technology with the aim of increasing productivity and optimizing energy consumption. The results highlight the need for policy makers and scientists to increase their attention towards energy efficiency, especially to have a positive impact in non-energy intensive sectors as well.

Less impact on the environment with the avoidance of new plant and related transmission lines. Reduction of electricity demand through the use of more efficient equipment will mean a reduction in the burning of fuel for the generation of electricity, thereby minimizing the emission of pollutants into the atmosphere.

If the entire community uses energy efficient appliances and installations, such as energy efficient lighting and air-conditioning systems, both the demand for electricity and the user's electricity bill will come down.

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Applications of Genetic Programming and Automatic Differentiation Algorithms in the Solution of Ordinary and Partial Differential Equations

By W. J. A. Lobão, M. A. C. Pacheco, D. M. Dias & A. C. A. Abreu
Pontifical Catholica University

Abstract- There is a significant number of research projects using differential equations to model important and complex problems of engineering and other scientific knowledge areas. This paper investigates the potential that computational algorithms have to determine analytical solutions for ordinary and partial differential equations. In order to do so, the evolutionary method of genetic programming and the automatic differentiation method are applied. Using the MatLab programming environment, several GPAD algorithms are developed and problems of distinct differential equations are addressed. The results are promising, with exact solutions obtained for most of the addressed equations, including ones that commercial systems could not find a symbolic solution to. The conclusion is that GPAD algorithms can be used to discover analytic solutions for ordinary differential equations and partial differential equations.

Keywords: evolutionary algorithm; genetic programming; automatic differentiation; differential equations.

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Keywords: evolutionary algorithm; genetic programming; automatic differentiation; differential equations.

I. Introduction

A significant number of research projects, in different areas of scientific knowledge, use mathematical models partially or fully formulated by differential equations. However, given the complexity of the proposed models, difficultlies with problems and unknown analytic solutions often arrise. In this instance, the solution is often sought throught the use of numerical methods.

The majority of these projects aim at achieving better results by using differential equations in order to try to describe the dynamic behavior of variables. In those cases, the numerical solutions are usually not complete. A complete solution form, however, is necessary because it allows for important and different types of analyzes, such as comparative static, knowledge of the magnitude of the partial effects, calculation of elasticities and studies on stability and stationarity.

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The primary objective of this paper is to investigate the potential of evolutionary algorithms to obtain analytic solutions to ordinary and partial differential equations (ODE) and (PDE). In order to do that, the evolutionary algorithms were developed by using the MatLab and combining genetic programming (GP) and automatic differentiation (AD). Several problems with different kinds of ODE and PDE were used for testing. More than twenty equations with analytic solutions known from literature were analyzed. An equation with an uknown analytic solution deriving from a PDE, which describes the wave function of the Schrödinger equation for helium atom, was also used. This equations is shown in [1]. The results of the tests are promising, since we obtained exact solutions for all equations with known solutions while identically reproducing the existing solutions. In the case of the Schrödinger equation, the solution obtained for this PDE is approximated. Hence, it has a low error margin.

To compare the developed methodology with the existing ones, we underwent a bibliographic review. It was verified that, although an extended amount of literature on genetic programming and automatic differential exists, the majority of the works apply these methods separately. Furthermore, amongst the works that develop combined algorithms of GP and AD, namely GPAD, papers that aim at solving differential equations are rare. Among these, the articles [2–4] stand out.

In the work of Imae et al [2], a GPAD algorithm is proposed to solve Hamilton-Jacobi-Bellman, Hamilton-Jacobi-Isaacs and Francis-Byrnes-Isidori equations in dy-namic nonlinear systems with optimal control problems. The methodology uses the conventional GP technique, combined with the AD method, developed by the authors themselves. The algorithm is applied to equations with already known symbolic solu-tions and generates approximate solutions with low estimate errors, for every simulated case. The article's conclusion is that the methodology presents promising results and is a good alternative for solving problems of optimal control.

In the work of [5], the two methods are combined to solve ordinary differential equations, with solutions that are already known. The equation of the Simple Harmonic Oscillator, of the mass-spring system, and Schrödinger equation for the hydrogen atom are used to obtain the exact solutions for the two proposed equations. The author concludes the study affirming that the combination of GP with AD is of great utility for the resolution of differential equations.

Among the researched articles, Tsoulos and Lagaris [6] present the most diverse and highest number of solved examples for differential equations using GPAD algorithms. Solutions are presented for ordinary differential equations (ODEs) and partial (PDEs), linear and nonlinear, of first and second degree. Exact symbolic solutions are found for the vast majority of the addressed problems. The developed algorithm uses gram-matical evolution for the GP algorithm and different AD methods. The conclusions are that the developed methodology is able to solve ODEs and PDEs and the results are very encouraging.

These works served as the basis of comparison to evaluate the performance of the algorithms developed and were of fundamental importance in the search for better results and the improvement of the methodology created. In addition, we have previously adopted a methodology, present in [7], that also combined genetic programming and automatic differentiation, to obtain symbolic solutions to stochastic differential equations. The results achieved were promising and indicated the effectiveness of the proposed methodology in solving such equations and modeling problems that involve stochastic differential equations. Similarly, our results in this article are encouraging, as exact solutions were achieved for the vast majority of the addressed problems. In addition, they indicate that the proposed method can be an efficient alternative to solve ODE and PDE.

This article is organized in three sections. The first section consists of a review of previous literature. The second section describes the methodological procedures adopted in the development of the GPAD algorithms. The third section discusses the application results of the proposed methodology and presents the solution for the ODEs and PDEs. The fourth and final section summarizes and concludes the article.

II. Methodological Aspects

This section introduces the methodological procedures adopted for developing the GPAD algorithm, elaborated with the purpose of solving problems of differential equations. Its description of the methodological aspects related to the structure and operation of the algorithm steps are limited. See [4, 8–10] for technical details about the genetic programming and automatic differentiation methods used in this article.

a) Automatic Differentiation

Automatic differentiation (AD) is a set of techniques based on the mechanical application of the chain rule designed to numerically evaluate the derivative of a function specified by a computer program. It exploits the fact that every computer program, no matter how complicated, executes a sequence of elementary arithmetic operations (addition, subtraction, multiplication, division, etc.) and elementary functions (exp, log, sin, cos, etc.). Derivatives of arbitrary order can be computed automatically by applying the chain rule repeatedly to these operations. This way, they accurately work precision and use more arithmetic operations than the original program.

The classical methods, however, are not bereft of problems. Symbolic differentiation often leads to relatively inefficient codes and difficulties converting a computer program into a single expression. Meanwhile, numerical differentiation can introduce round-off errors in the discretization process and cancellation. Both classical methods have problems with calculating higher derivatives, which cause the complexity and errors to increase. Furthermore, both classical methods are slow at computing the partial derivatives of a function of many inputs, as is needed for gradient-based or stochastic optimization algorithms. AD circumvents these problems at the expense of introducing more software dependencies.

Usually, two distinct modes of AD are presented: forward mode, or forward accumu-lation, and reverse mode, or reverse accumulation. Forward mode specifies that chain rule can be transvered from inside to outside. Since for the simple composition $y = g(h(x)) = g(w)$ the chain rule gives $dy/dx = (dy/dw)(dw/dx)$, the forward mode first computes (dw/dx) and then (dy/dw), while the reverse mode has the traversal from outside to inside. See [11] for details.

b) GPDA Algorithm

The algorithm is developed in MatLab programming environment and works with two basic codes operating simultaneously. The first is responsible for the implemen-tation of genetic programming, and the second performs the automatic differentiation and evaluates the individuals' fitness. The codes run a fixed number of generations and perform the following steps: the creation of initial population, fitness evaluation of individuals, selection of individuals for reproduction, reproduction and validation, survival and creation of the new population. Except for the first step, which runs only at initialization, the remaining steps are repeated in all generations.

The form of representation of individuals is the traditional tree diagram, which is appropriated to evolve equations and facilitates to interpret GPAD results. The GP parameterization is flexible and allows changes to the configuration of parameters set. Some of these

parameters are: types and forms of trees, minimum depth of initial population trees, maximum depth of trees, the number of nodes control, set of functions and terminals, number of generations, selection methods for reproduction, crossover and mutation rates, population size, and stop conditions.

Two essential components for the GP operation are the sets of functions and terminals. These are necessary for the creation and reproduction of the population of individuals and, consequently, are involved directly in the formation of the optimal solution to the problem. The set of functions is composed of basic mathematical operators $(+,-,\times,\div)$ and elementary functions (e.g., $sin, cos, exp, log, xy, tan$). The terminal set consists of constants (e.g., real numbers, complex numbers, number, and randomly generated numbers) and variables that constitute the differential equation.

The choice of both functions and constants sets is important for the GP performance. If these sets are chosen with a small number of elements, the algorithm will present premature convergence due to the lack of diversity and a acceptable solution to the problem will not be reached. On the other hand, if they are chosen with an excessive number of elements, the search space becomes very large and harms the de-termination of an acceptable solution, which also increases the computational effort. Therefore, the choice procedure must be accomplished in a balanced way, respecting the properties of closure and sufficiency, as defined by [9]. The strategy used in this paper, which has yielded good results, was to mathematically study the problem of in-terest, ODE or PDE, and identify the minimal set of functions and constants required for their solution. Then, the algorithm was started with the basic set and new func-tions and constants were added to the modelling process until a satisfactory solution was obtained.

The first step that GP undergoes is creating the initial population. Functions and terminals are selected and combined, originating the individuals that make up the initial population. In this study, each created individual is a mathematical expression represented as a tree and possibly a solution of the differential equation of interest. GPAD offers three methods for the selection of the initial population: Full, Grow, and Ramped-half-and-half. The Grow method was used in all applications on this paper because it showed more efficiency in the processing time and produced the best results.

The second step consists of a fitness evaluation of the individuals. An error measure (i.e., fitness) was defined to evaluate the performance of each individual. After ana-lyzing the measures, it was decided to work with mean absolute error (MAE) between the differential equation derived from the function proposed by GP and the differential equation of the problem in question. We also regarded penalties for missed restrictions such as initial and boundary conditions. In other words:

$$fitness = MAE + restrictions\_error \quad (1)$$

It was also necessary to incorporate a code into the GPAD algorithm that performs differential calculus and is able to calculate the fitness. The AD method was chosen because it calculates the exact values of the derivatives of a function for a given set of input values.

The AD program has the task of mathematically verifying the solutions proposed by the GP program. For this purpose, the AD programs my AD and my A2D developed by [8] were used. This programs perform the first and second order derivatives of a function, respectively, and operate in a forward mode. After adjusting the AD codes to make them compatible with the GP code, they were incorporated into the GPAD. An example is provided to illustrate this step using the following ODE problem:

$$f'(x) + 2f(x) = exp(-2x);\ x \epsilon R, initial\ conditionl\ f(0) = 3 \quad (2)$$

Suppose that the function below was newly created by an individual GP and is a possible solution to the problem.

$$f(x) = 2 + exp(-2x) \quad (3)$$

The next step is to evaluate the fitness of equation (3). The second code performs automatic differentiation and calculates the derivative of f(x) at each point of the domain defined by the algorithm (usually a grid with 50 or more points of x), reaching the solution:

$$f'(x) = -2exp(-2x) \quad (4)$$

Eequations (3) and (4) are placed within equation (2) and the proposed solution fitness is evaluated at each point. The symbolic expression of this comparison is:

$$f'(x) + 2f(x) - exp(-2x) = 4 - exp(-2x) \neq 0 \quad (5)$$

f(x) is not the exact solution to equation (2) because its error value is not zero.
However, it satisfies the initial condition, since:

$$f(0) = 2 + exp(-2 \times 0) = 2 + 1 = 3 \quad (6)$$

Moreover, the algorithm does not work with symbolic differentiation, as shown before, but with the automatic differentiation, where the derivatives are applied and evaluated at every point of the domain of the function. The error measure (fitness) for this example is:

$$fitness = (\frac{1}{n}) + \sum| f'xi \ + \ 2f(xi) \ - \ |2xi| \ + \ |f(0) \ - \ 3| \tag{7}$$

Where the first part is the MAE, calculated in n domain points considered, and the second part is the penalty for not satisfying the initial condition of the problem.

Once the fitness function is defined, the GP evaluates the newly created individu-als and selects those who are best fit to take part in the reproduction process. The algorithm provides five selection methods for reproduction: roulette, sus, tournament, lexictour and doubletour. For the purpose of this paper, the lexictour is often used, as it generates better results than others, possibly due to its use of lexicographic parsimony pressure[3].

Once the GP finishes the selection, it initiates the individuals' reproduction. This step is of fundamental importance as it leads the GP into regions with a better search space and, consequently, improves the process of optimization. Once the application of crossover and mutation operators takes place, the process of reproduction of the individuals is concluded. The new individuals are subjected to a validation test. The GP considers an individual fit to participate in the new population if its tree size does not exceed the maximum size parameter value.

In the last step, the GP selects the individuals that survive to be a part of the next population. The algorithm provides four elitism methods: replace, keepbest, halfe-litism, totalelitism. Totalelitism was used in this research, as it allows all individuals to participate in the selection and selects the fittest ones, regardless of their parent-age. Individuals are selected until the population reaches its predefined size. The new population is, then, ready to be evaluated.

The process repeats itself until it reaches the stop condition and the final solution becomes known. The algorithm's overall objective is to create an individual (i.e., the solution f(x)) that minimizes the fitness, using the GP and AD. The search for the optimal solution happens in an evolutionary way and its determination depends on other technical procedures and refinements not shown in this paper.

Table 1: GPAD Basic Parameters

Parameter	Setup	Parameter	Setup
Number of generations	25 to 50	Initialization	growinit
Population size	50 to 600	Selection method	lexictour
Number of functions	8 to 15	Crossover	one-point
Number of terminals	5 to 15	Mutation	standart
AD Algorithm(fixed)	forward	Reproduction	totalelitism

The last step performed by the methodology is the validation of the best solution generated by the GPAD algorithm. This step occurs outside the programming environment. A solution will only be considered final if it meets the following requirements:

- fitness value $< 10^{-8}$;
- satisfying the restrictions and conditions laid down by the problem;
- when evaluated by the differential calculus rules, it must present a mathematical expression identical to the differential equation originally proposed.

If a final solution, validated by the requirements above, achieves fitness equal to zero, it will be considered an exact solution to the proposed problem. Otherwise, this solution is considered an approximate solution.

III. Applications and Results

This section presents the results of four examples, two ODE and two PDE, which illustrate how solutions of differential equations can be achieved through the use of GPAD.

In General, the GPAD was set up according to the parameters listed in table 1, for all the examples. The numeric parameters - related to the number of generations, individuals, elementary functions, and variables - were displayed in intervals of integers, as they varied according to the size and complexity of the addressed problem. The forward method was used for the application of the AD. This will be further explained in section 2.2. In all examples, the solutions obtained by the GPAD was represented in three different ways: symbolic, tree, and graphics.

a) Example 1

The first problem includes the solution of the following ODE of the second order:

$$y''(x) + y'(x) + y(x) = -1.6 + 0.4x + 0.2x^2 - 8sin(4x) - 30cos(4x);$$

$$where\ x\ \epsilon\ \kappa, y''(x) = \frac{d^2y(x)}{dx^2}, y'(x) = \frac{dy(x)}{dx}; \quad (8)$$

$$y(0) = 0\ and\ y'(0) = 0$$

The solution obtained by the GPAD is presented in function (9) and in figures 1 and 2.

$$y(x) = 2 + 0.2x^2 + 2cos(4x) \quad (9)$$

Figure 1 shows the tree representation of the solution to the ODE of example 1 (3.1), where variable (x) is denoted by (X1). The optimal solution was found in individual 5054 (best so far), for a population of 250 individuals and 60 generations. The tree had a low number of depth and nodes, which made the reading and interpretation of the function easier. The achieved solution was exact, because it presented fitness equal to zero, satisfied all the constraints defined in (8), and was identical to the ODE of the problem proposed applying the differential calculus. Figure 1 is displayed below, along with a list of the results.

- Generations: 60
- Individuals: 250
- Best so far: 5054
- Fitness: 0.00000
- Depth: 5
- Nodes: 15

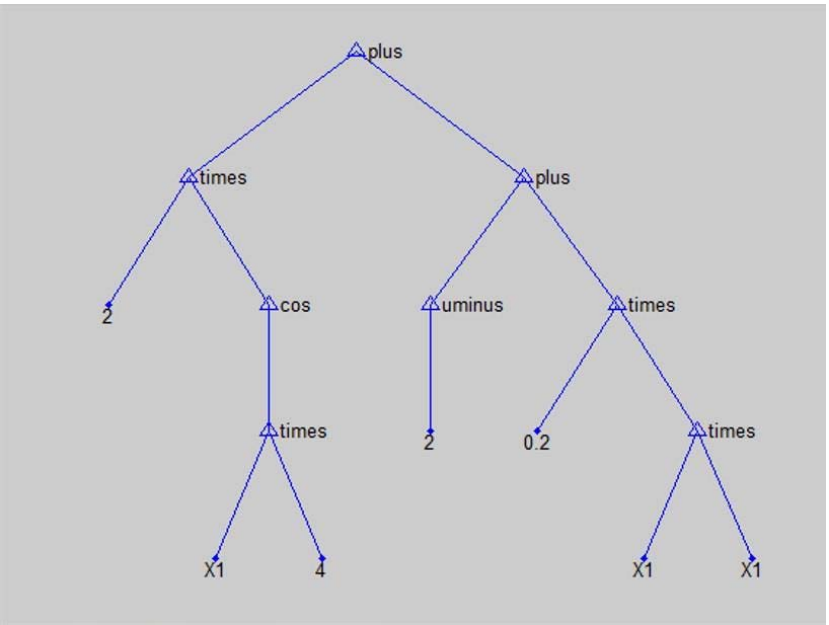

Figure 1: Tree representation of y(x), solution to the ODE of example 1.

Figure 2 shows the graph of solution (9):

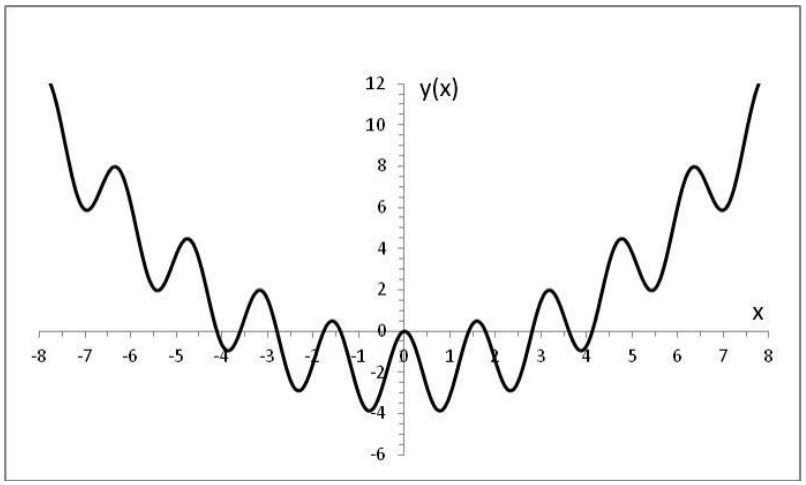

Figure 2: Graph of function y(x), solution to the ODE of example 1.

b) Example 2

The second problem contains the solution to the following ODE of second order, along with its constant coefficients:

$$y''(x) + 0.3y'(x) + 25y(x) = 25.12 + 10x - 1.5\cos(5x)exp(-0.3x);$$
$$where x \epsilon \kappa;\ y(0) = 1\ and y'(0) = 5.4 \quad (10)$$

The solution obtained by the GPAD is presented in function (11) and in the figures 1 and 2.

$$y(x) = 1 + 0.4x + sin(5x)exp(-0.3x) \quad (11)$$

Figure 3 presents a graph which shows the tree representation of the solution of the ODE in example 2, where variable (x) is denoted by (X1). The optimal solution was found in individual 6031 (best so far), for a population of 400 individuals and 40 generations. The tree had a low numbers of depth and of nodes. The solution obtained was exact and the answer was verified by the usual differential calculus. Figure 3, along with the results, is displayed below.

- Generations: 40
- Individuals: 400
- Best so far: 6031
- Fitness: 0.00000
- Depth: 6
- Nodes: 16

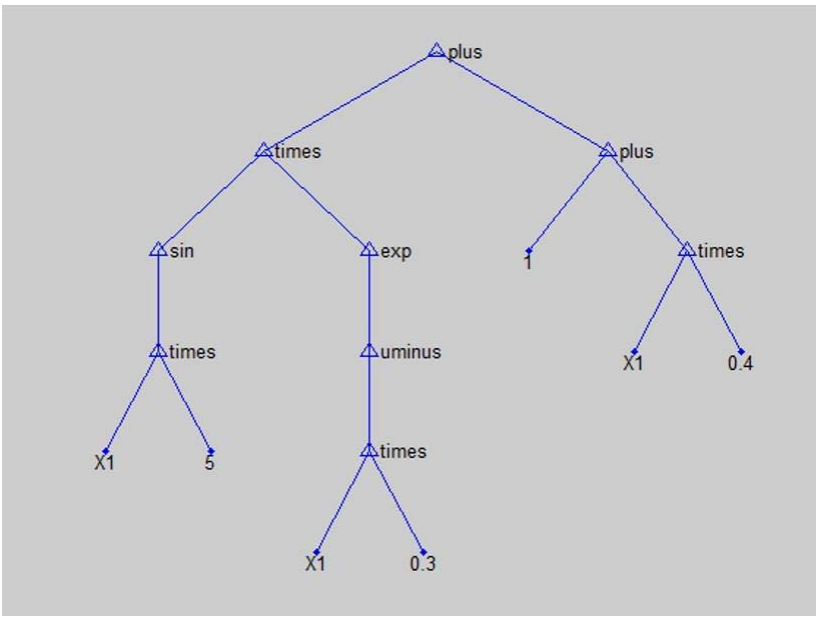

Figure 3: Tree representation of y(x), solution to the ODE of example 2.

Figure 4 contains a graph of solution (11), which exhibits non-linear and complex behavior.

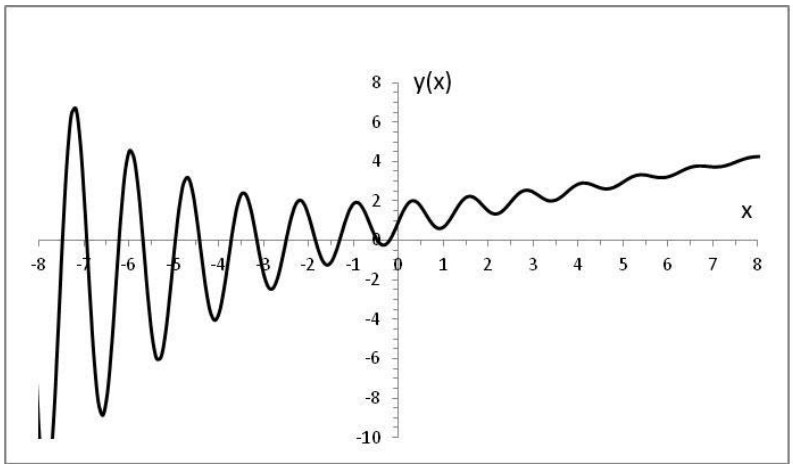

Figure 4: Graph of function y(x), solution to the ODE of example 2.

c) Example 3

The third equation contains the solution to the following ODE of the second order:

$$x^2y''(x) + xy'(x) + 4y(x) = 6sin(ln(x))$$

$$where\ \epsilon\ \kappa, x > 0;\ y(1) = 3\ and\ y'(1) = 2 \quad (12)$$

The solution obtained by the GPAD for equation (12) was:

$$y(x) = 3cos\big(2ln(x)\big) + 2sin\big(ln(x)\big) \quad (13)$$

Figure 5 shows a tree representation for the ODE solution in example 3, where (X1) denotes variable (x). The GPAD found the exact solution after 13,665 evaluations (best so far), with a population of 400 individuals and 50 generations. The tree presented depth 6 and 13 nodes. Figure 5, along with the results acquired, is displayed below.

- Generations: 50
- Individuals: 400
- Best so far: 13665
- Fitness: 0.00000
- Depth: 6
- Nodes: 13

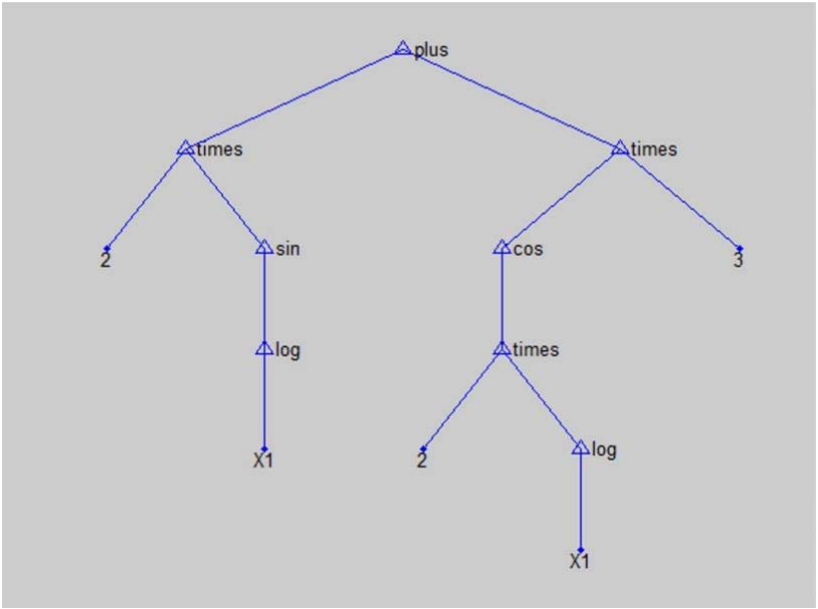

Figure 5: The representation of y(x), solution to the ODE of example 3.

Figure 6 shows the graph of solution y(x), in function (13).

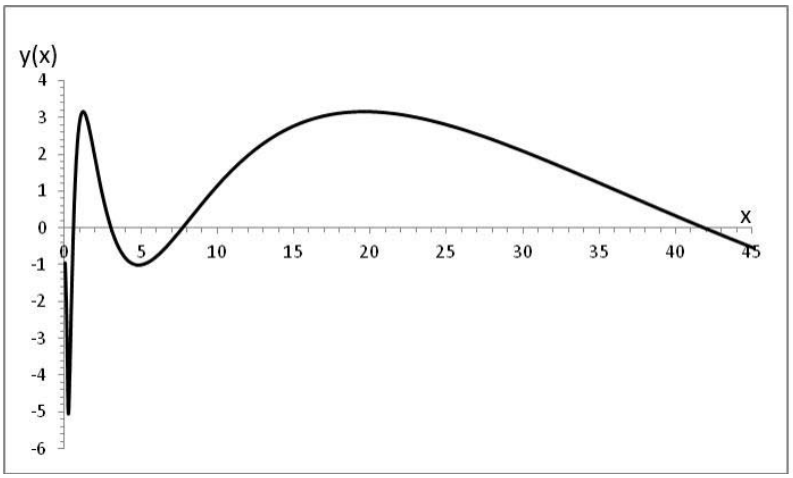

Figure 6: Graph of function y(x), solution to the ODE of example 3.

d) Example 4

The fourth application solves the following second order PDE, with variable coefficients being:

$$xf_x + 2f_t = xt\,cos(x) + 2sin(x);$$
$$where\ f_x = \partial f\,(x,t)/\partial x, f\ t = \partial f(x,t)/\partial t, x \in \kappa, t > 0\,; \quad (14)$$
$$f(0,t) = 0\ and\ f(x,0) = x^2$$

The solution obtained by GPAD to equation (14) is:

$$f(x,t) = x^2 exp(-t) + sin(x) \quad (15)$$

Figure 7 shows a tree representation for the PDE solution in example 4, where (X1) and (X2) denote variables (x) and (t), respectively. The GPAD found the exact solution after 4,823 evaluations (best so far), with a population of 600 individuals and only 25 generations. The tree has depth 6 and 12 nodes. Figure 7, along with the data acquired, is displayed below.

- Generations: 25
- Individuals: 600
- Best so far: 4823
- Fitness: 0.00000
- Depth: 6
- Nodes: 12

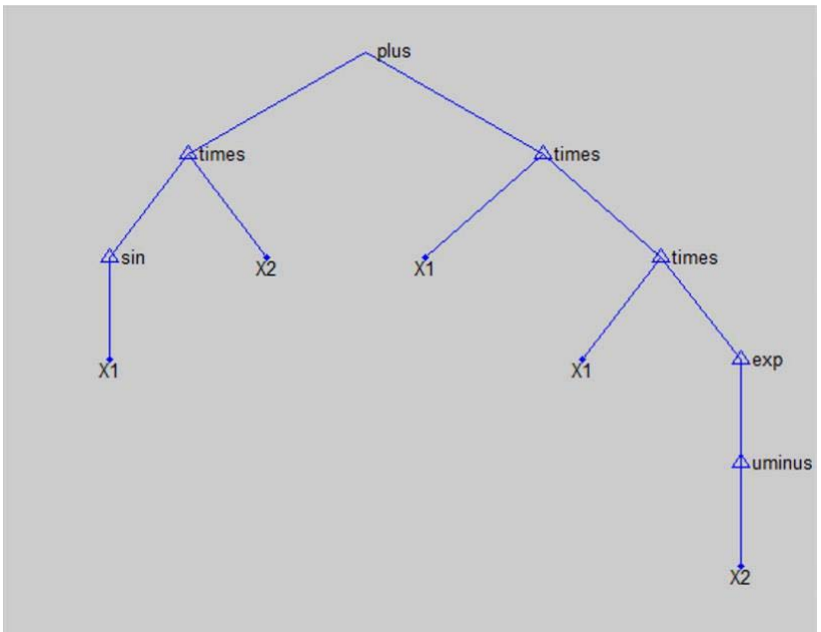

Figure 7: Tree representation of f(x,t), solution to the ODE of example 4.

Figure 8 shows a graph of solution f(x,t) in function (15).

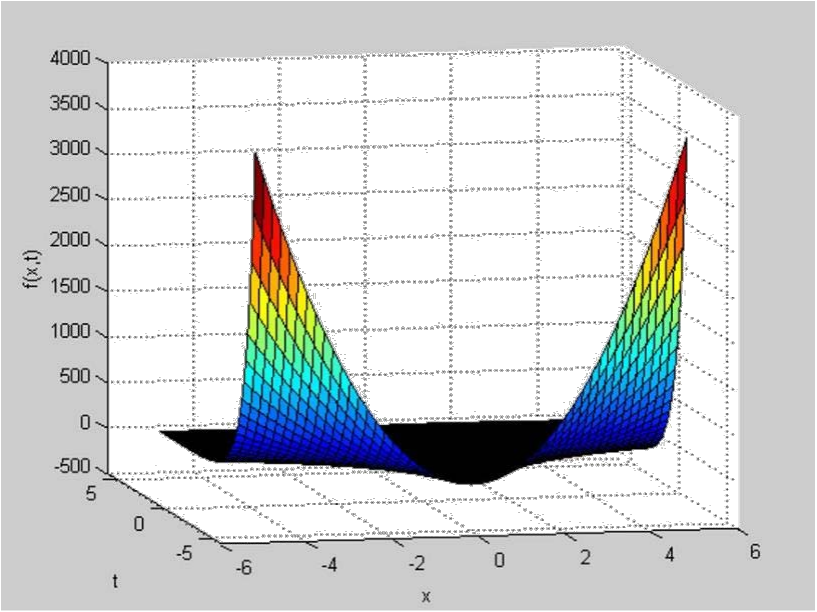

Figure 8: Graph of function f(x,t), solution to the ODE of example 4.

e) Example 5

The fifth example solves the following second order PDE, which is a heat equation particular case:

$$ft - fxx = [x\,cos(t) - 4(x - 1)\,sin(t)]\,exp(-2x);$$
$$where\ fxx = \partial^2 f(x,t)/\partial x^2, ft = \partial f(x,t)/\partial t, 0 \le x \le 1, 0 \le t \le 1; \quad (16)$$
$$f(0,t) = 0, f(x,0) = 0\ and\ f_x(1,t) + f(1,t) = 0$$

The solution obtained by the GPAD to equation (16) is:

$$f(x,t) = sin(t)x\,exp(-2x) \quad (17)$$

Figure 9 shows a tree representation for the PDE solution in example 5, where (X1) and (X2) denote variables x and t, respectively. GPAD found the exact solution after 2,054 evaluations (best so far), with a population of 80 individuals and 50 generations. The tree contains depth 6 and 10 nodes. Figure 10 shows the graph of solution f(x, t) in function (17). The gathered data is displayed below, along with figure 9.

- Generations: 25
- Individuals: 600
- Best so far: 4823
- Fitness: 0.00000
- Depth: 6
- Nodes: 12

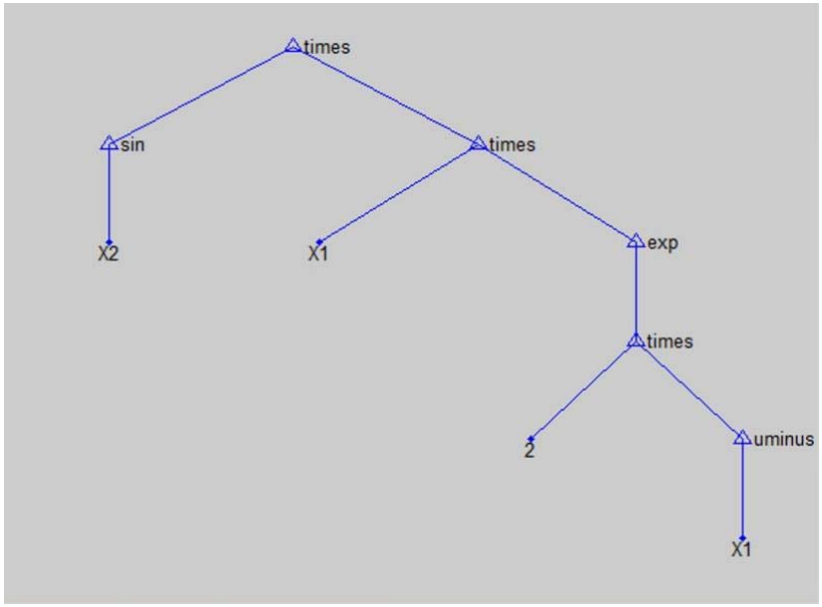

Figure 9: Tree representation of f(x,t), solution to the ODE of example 5.

Figure 10 shows the graph of solution f(x, t) in function (17).

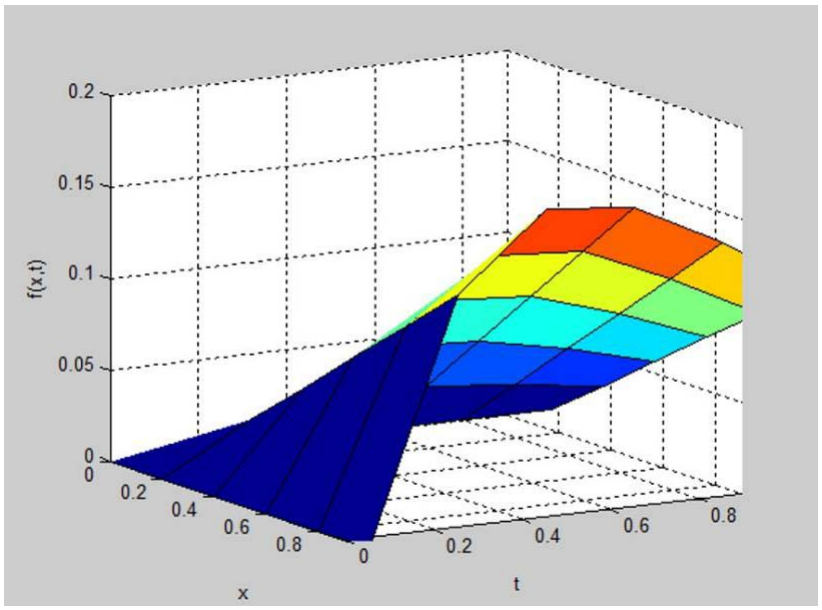

Figure 10: Graph of function f(x,t), solution of the ODE of example 5.

f) Example 6

The sixth and last example solves the following PDE:

$$f_t - f_{xx} = [x - t(4x^3 - 6x)\, exp(-x^2)];$$
$$where\ f_{xx} = \partial^2 f(x,t)/\partial x^2, ft = \partial f(x,t)/\partial t, 0 \le x \le 1, 0 \le t \le 1; \quad (18)$$
$$f(0,t) = 0, f(x,0) = 0\ and\ f_x(1,t) + f(1,t) = 0$$

The solution obtained by the GPAD to equation (18) is:

$$f(x,t) = xt\ exp(-x^2) \quad (19)$$

Figure 11 shows a tree representation for the PDE solution in example 6, where (X1) and (X2) denote variables x and t, respectively. The GPAD found the exact solution after 1,336 evaluations (best so far), with a population of 50 individuals and 50 generations. The tree has depth 5 and 9 nodes. The solution for the problem is shown below, along with figure 11.

- Generations: 50
- Individuals: 50
- Best so far: 1336
- Fitness: 0.00000
- Depth: 5
- Nodes: 9

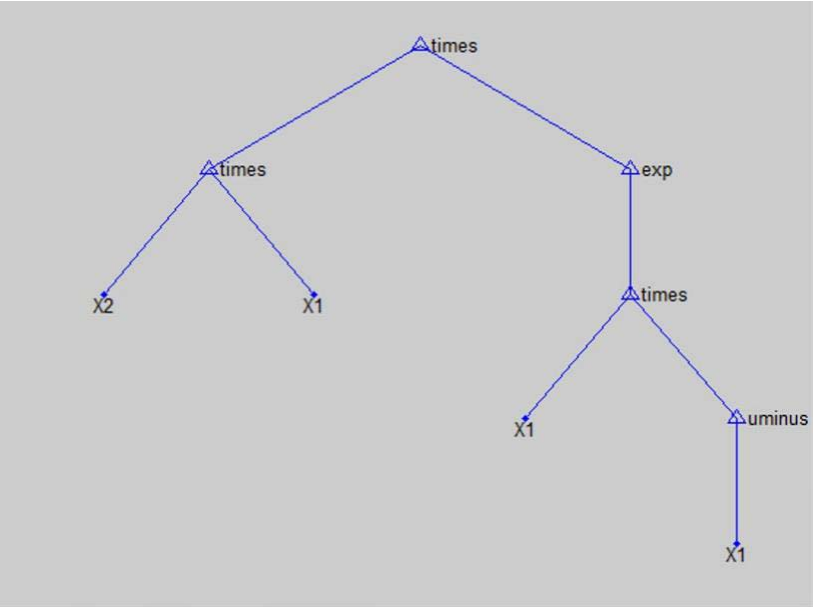

Figure 11: Tree representation of f(x,t), solution of the ODE of example 6.

Figure 12 contains the graph of solution f(x, t) in function (19).

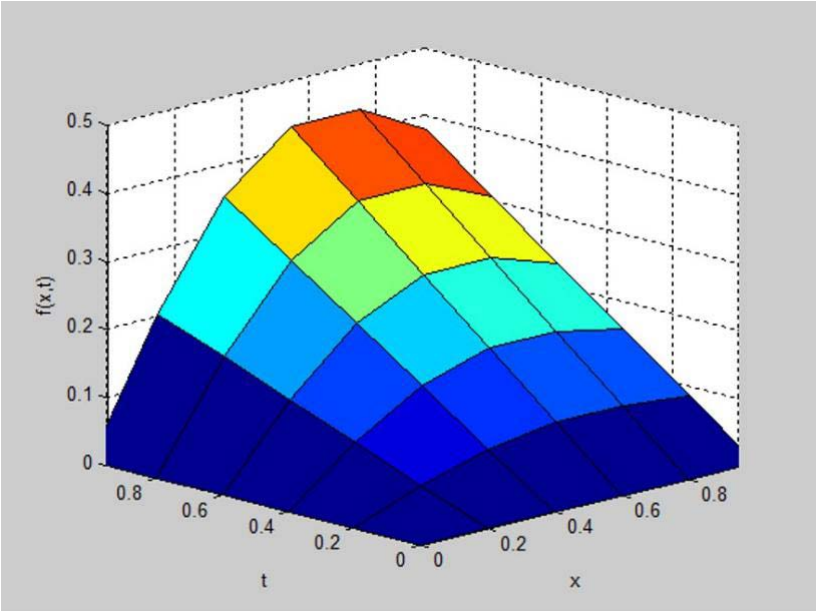

Figure 12: Graph of function f(x,t), solution of the ODE of example 6.

IV. Discussions and Conclusions

This study aimed at investigating the potential of evolutionary algorithms, developed with the combination of GP and AD, to obtain symbolic solutions for problems of differential equations. This is not an issue solely of academic interest. It has great practical relevance, as the ODEs and PDEs are used to model the dynamics of com-plex problems of engineering and of other areas. Examples of research projects applied in engineering include: construction of electrical circuits; modeling of networks cables dilatation; digital filter of "Butterworth", in the area of signal processing; modeling problems of beams; deflection and vibration; mass balance of a chemical reactor; deter-mination of the rate of disintegration or decay of a radioactive element, carbon-14 type; automotive suspensions planning, defining the mechanical damping system; projects of planning and

construction of aircraft, turbines, engines and navigation; and industrial projects in general. In addition to engineering, differential equation models are also present and applied in economics, finance, statistics and physics.

With this purpose, GPAD algorithms were developed and a methodology of solu-tion was conceived. Although, in section 3, only six examples have been submitted, we believe this quantity is sufficient to illustrate the results of the applications made. More than twenty problems of ODEs and PDEs, of different types and degrees of dif-ficulty, were used to test the quality and effectiveness of the new methodology. The exact solution was found for all equations tested, with the exception of the EDP for the Schrödinger equation of the helium atom. However, in helium's case, an approxi-mate solution with low-level error was found. The difficulty to solve the equation was expected due to its high complexity.

In order to compare our results with the results of known software, with the ex-ception of the Schrödinger equation, the remaining equations were also tested on the DSolve of Mathematica and in ODE-PDE-Solver Functions of MatLab. The results showed that only the linear ODEs could be solved symbolically. The nonlinear ODEs and PDEs tested, including three PDEs presented in section 3, have not been resolved in symbolic form for these software. Therefore, the results of these tests are very impor-tant, because they show the difficulty of obtaining symbolic solutions of differential equations through computational methods and they confirm the advantages of the GPAD algorithms.

When compared, our study possesses the following similarities with works [2–4]: the examples of ODEs and PDEs used are, in small part, similar to those presented in [6]. This occurred purposefully, because we use three examples of this work as a basis for comparison for evaluating computational efficiency of algorithms developed. However, the similarities are only in the functional form of differential equations, as it was necessary to solve exercises identical to be able to compare effectively the results. These comparisons were of fundamental importance, since they allowed us to pursue better results and develop algorithms that are more efficient.

The modeling and development of the algorithms were overall different, since we used traditional GP method in the form of a tree, while they used the grammatical evolution method. The similarities with articles [2,3] are directly related to the fact that both works intend to solve ODEs and PDEs using the same technique of GP in tree form. However, the examples developed are very different, which leads to different computational modelling.

Based on the results obtained, with exact symbolic solutions for almost all of the problems addressed, we believe that the objective of the study has been achieved and that the GPAD methodology proposed is a new contribution to the literature of evolutionary algorithms and, especially, an effective alternative to assist in the resolution of complex problems of ODEs and PDEs.

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Repairing Behavior of Termites *Odontotermes obesus* (Rambur), (Blattodea: Termitidae) in Response to the Damage of Indoor Mudtube

By C. R. Satpathi
Bidhan Chandra Krishi Viswavidyalaya

Abstract- The termite *Odototermes obesus* (Rambur) either tunnel through soil or move inside the 'mudtube' usually found on walls or in cracks between boards and walls. The mudtube formation could provide the initial proof of the termite infestation. The study analyses the behavioral changes of termite when the indoor mudtube was damaged. The response of termites was recorded by video camera at certain intervals until the mud tube was repaired and closed.

Seasonal effects on repairing of damaged mud tube by termite indicated that during rainy season the time required for repairing an unit area of indoor mud tube was about half of the summer season. Based on change of behavioral patterns due to the damage of mud tube the responses of the termites were divided into 6 different categories which reflected the different division of labors that were distributed among the workers after sudden disturbance. The studies on measuring activity of work found out the time required for different steps of work for repairing the damage.

Keywords: *termite, house, mud tube, tunnel, seasons, sand.*

GJRE-J Classification: *DDC Code: 595.799 LCC Code: QL568.A6*

Strictly as per the compliance and regulations of:

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C. R. Satpathi

Abstract- The termite *Odototermes obesus* (Rambur) either tunnel through soil or move inside the 'mudtube' usually found on walls or in cracks between boards and walls. The mudtube formation could provide the initial proof of the termite infestation. The study analyses the behavioral changes of termite when the indoor mudtube was damaged. The response of termites was recorded by video camera at certain intervals until the mud tube was repaired and closed.

Seasonal effects on repairing of damaged mud tube by termite indicated that during rainy season the time required for repairing an unit area of indoor mud tube was about half of the summer season. Based on change of behavioral patterns due to the damage of mud tube the responses of the termites were divided into 6 different categories which reflected the different division of labors that were distributed among the workers after sudden disturbance. The studies on measuring activity of work found out the time required for different steps of work for repairing the damage.

Keywords: termite, house, mud tube, tunnel, seasons, sand.

I. Introduction

Unlike ants, termites do not move around on the open ground. Most of the species either tunnel through the soil or move inside 'mud tube' that they build from soil, sand, slits and rocks and wood particles or whatever the termites feed on. Mud tubes are usually found on foundation wall or from cracks between boards and walls. Old 'mud tubes' are dry and crumble easily and that may be visible for years. Sometime they abandoned the apex of the 'mud tube' if disturbed. The average circumference of a mudtube is relatively thin over the concrete wall, although they can be larger in soil surface. On an average 2 to 3 termites could easily move side by side inside a mud tube. Besides maintaining a microclimate the mud tube protects the termites from the attack of ants and other predators. Two common types of mudtubes are built by the termite of which first one is 'working tube' that run from the nest to the identical food sources. The other type is an 'exploratory tube' which is used for searching food sources. Several studies that examined the response of termites to a disturbance like knocking were conducted on arenas containing food and termite foragers (Hu, Apple and Traniello, 2003, Schwinghammer and Houseman, 2006, Gautam and Henderson 2012). The studies showed that termites immediately escaped from the source of disturbance to other container (without food) through connecting tubes, but they returned after short period (within several seconds or minutes). Based on these observation researchers concluded that termite would not abandon food sources 'for extensive period of time as a result of mechanical disturbances (Gautom and Henderson 2012). Using a special experimental setting, Wang et al. 2016 had first reported study that some termite species escaped along the wall of Petridis after a disturbance was created by knocking, and unidirectional escaping flow (either clockwise or anticlockwise) lasted for long periods. During, the escaping process little congestion was observed, probably because most worker termite follow each other, whereas only a few workers reversed or moved backwards against escaping flow. The nests of subterranean termites in urban areas may be found in the soil under buildings. Robinson (1996) reported that swarming is generally synchronized over wide areas, but it also depends on environmental conditions or seasonal phenomenon such as wind, rain and soil moisture. It was proven that moisture content does not affect termites tunneling activity when they first emerged, but when termites move further from their nesting site, they have a tendency to look for areas with higher moisture content (Su and Puche 2003) Different termite species showed different tunneling geometry (Campora and Grace 2001). They will minimize their total tunnel length to one location in a search area. Once they find a suitable food source, they will follow the direct foraging route to reduce the amount of energy used (Hedlund and Henderson 1999, Campora and Grace 2001, Puche and Su 2001, Arab and Costa-Leonardo 2005).

The incidence of termite is very common in most of the houses during May to July which makes an alarming situation among the dwellers of Eastern India. The 'mudtube' formation is an indication of a termite infestation. It is a common practice of a household to determine the presence of termite by breaking open the mud tubes. Termites often rebuild the broken part which is another indication of current activity. The present study deal with the seasonal effect on repairing the damaged mud tube along with the behavioral changes of *Odontotermes obesus* (Rambur) when an indoor

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mudtube was consequently damaged at certain interval after repairing in a termite prone area of Kolkata, West Bengal, India for 2 consecutive seasons during 2020 and 2021 respectively.

II. Materials and Methods

a) Study Site

The study was conducted from April to June of 2019, 2020 and 2021 on a termite prone areas of Kolkata, West Bengal located at 24.50° North latitude and 86.00 to 89.00 East longitude with mean sea level 9.75 meter. The season is broadly classified dry and warm (March to May), wet and warm (June to October), dry and cool (November to February). The mean maximum temperature is usually high 38.9°C in April and low 7.1°C in early part of the January. Normal rainfall varies from 1271to 1800mm. The termite species was previously identified by Zoological Survey of India, Kolkata. Altogether 5 mud tubes were selected at 5´ above the ground on a concrete wall at Ballygunge, Kolkata, West Bengal, India.

Tests were conducted between 6.00 AM to 12.00 AM. A scale was fitted along the length of each tube for measuring a area breached during study period. The response of termites were recorded by camera at certain intervals until the mud tube was repaired and closed.

b) Mudtube Repairing

Video recording was taken to measure the area of the mud tube that was repaired from the top to bottom or bottom to top and along the side of breached part until the whole damaged part was covered. The pooled data for 2019, 2020 and 2021 are incorporated for calculation of time per unit area.

III. Results

a) Seasonal Effect on Repairing Damaged Mud Tube

The termite nests are usually built in a particular area and mud tubes are formed year after year from the same location. The termites were observed to be active in summer and some workers were found to prepare mud tube over the old concrete wall using sand and saliva. The indoor mud tube formation was more frequent during April to July in Kolkata, West Bengal, India. A simple study was made to find out the time required for repairing 10mm length x5mm breadth x2mm height of a breached tube over a concrete wall during summer and rainy season and the results are given in Fig. 1 & 2.

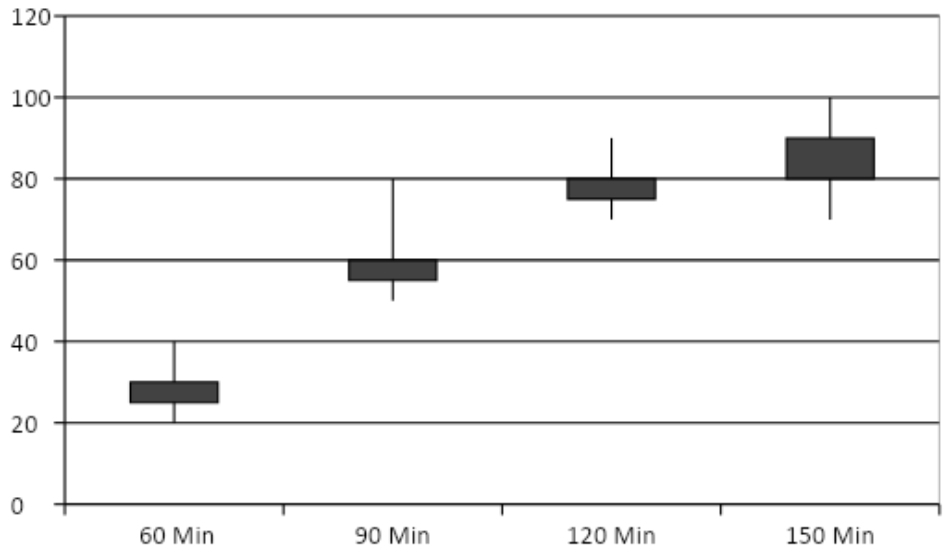


Fig. 1: Time required to repair a10mm length x 5m breadth x2mm height broken mud tube during rainy season

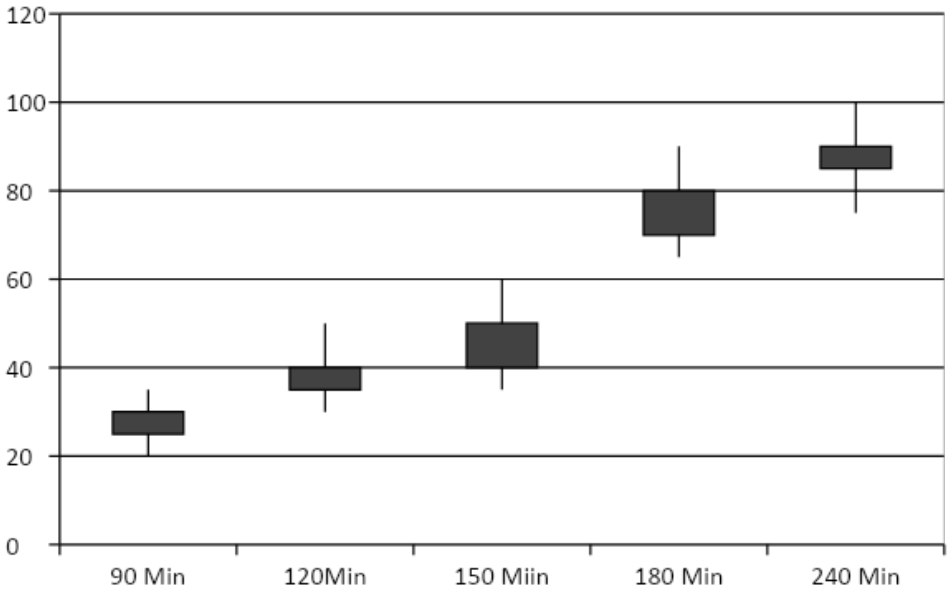
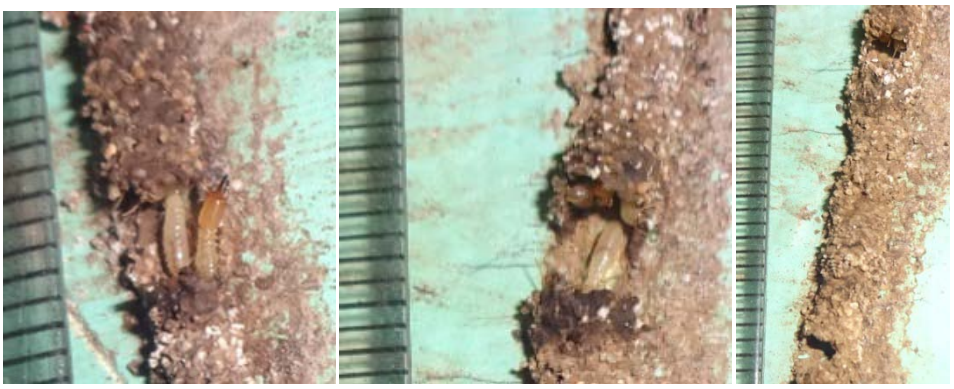


Fig. 2: Time required to repair a 10mm length x 5m breadth x2mm height broken mud tube during Summer season

It could be observed that during rainy season the time required for repairing an unit area of indoor mud tube was about half of the summer season. During both the seasons the termite initiated works at least one hour after breaking the tube but in summer season the time duration was extended up to 240 minutes. The total 100 cubic millimeter spaces were covered during 150 and 240 minutes in rainy and summer seasons respectively.

b) *Cateogories of Termite Responses after Breaking the Mudtube*

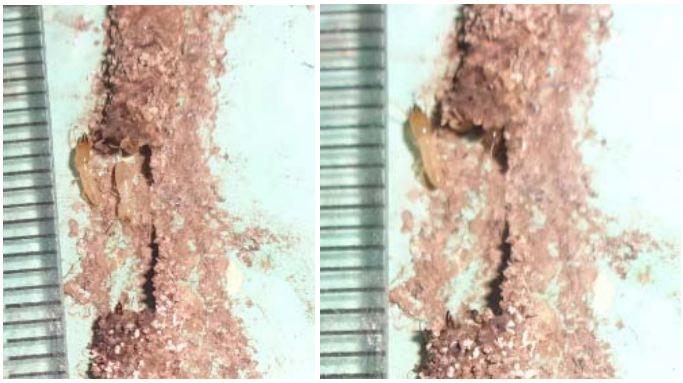
Based on changes of behavioral pattern in response to the damage of a 100mm length x5mm breadth x 2mm height mud tube, the termite responses were divided into 6 exclusive categories. (1) type-1: mud tubes were closed within 2 hours. (2) type-2: mud tubes were closed within 4 hours (3) type-3: both the end of the breached area of the tube were closed together (4) type-4: one or more numbers moved from base to apex (5) type 5: one or more numbers move from apex to base. (6) type-6: some members came outside the surrounding of breached area.



Type-1

Fig. 3: Damaged (10%) mud tube (10 mm length x 5mm breadth x 2mm height) closed within 2 hours

Type 1: The mud tube was closed within 2 hours when the damage was very small about 10% (10mm length x 5mm beadth x 2mm height) of the total area. Here the workers immediately started to cover the area from both the end of breached area. When multiple damages ranging up to 8 in numbers of same size were broken over this tube more numbers of workers were engaged to cover the breached area. On an average they attempted 5 to 6 times per day or 60 to 70 times per week to repair their working tube if it was artificially damaged (<10%) by needle during the month of June (Fig 3).

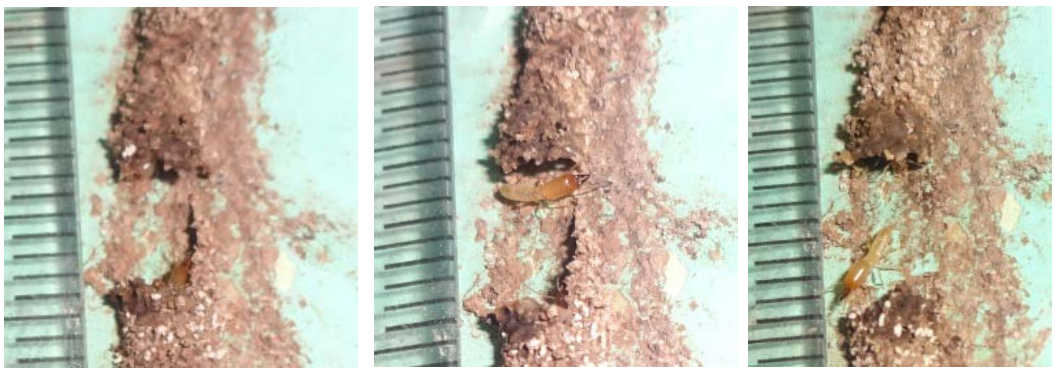


Type-2

Fig. 4: Damaged (20%) mud tube (20 mm length x 5mm breadth x 2mm height) closed within 4 hours

Type 2: The repairing period was extended with the increase of surface of breached area of mud tube. Here the time required to cover the broken part was 4 hours when the breached area was increased to 20% (20mm length x5mm breadth x 2mm height) of the total area. If two breached areas of same size were located in single mud tube the termites initially completed one followed by a 30 to 40 minutes rest before initiation of second one (Fig-4).

Type 3: When the breached part of mud tube was about 20 to 30% of the total area then they initiated to repair from both the ends of the broken parts together.



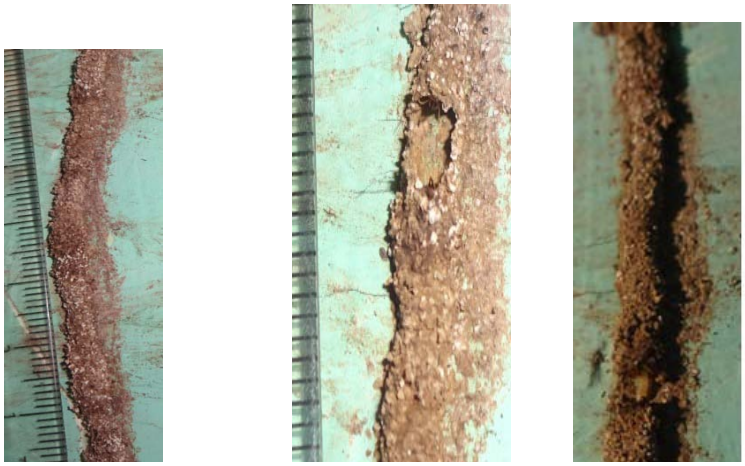
Type-3

Fig. 5: Damaged (> 20%) mud tube (22 mm length x 5mm breadth x 2mm height) closed within 4 to 5 hours

Meanwhile 2 special workers were engaged to construct the side wall. The entire work was completed within 4 to 5 hours period of ceaseless work (Fig 5).

Type 4: In general, the termites advanced from base to apex and vice versa in search of food. Entire program altered with the breaking of mud tube. From the average of 5 video recording it was found that if the broken part was nearer to base about two third of total population immediately rushed to the apex through this breached area and one third of the population turned back to the base from apex (Fig 6).

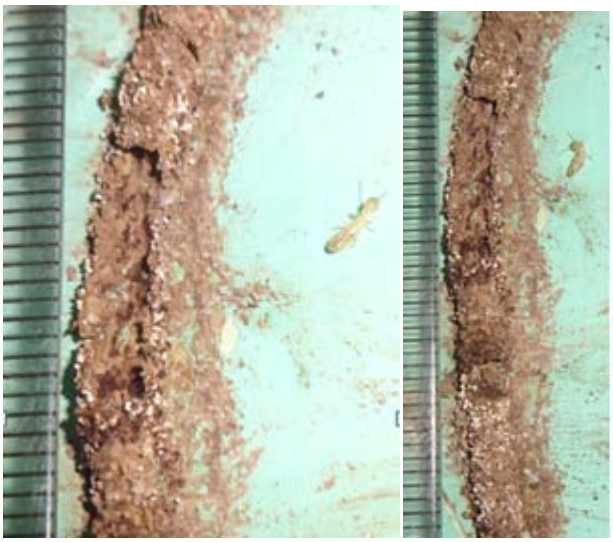
Type 5: If the broken part was nearer to apex very few population were found to cross over the breached area as monitored through 5 video clippings. Here about 25% population came from base who participated in repairing the broken area (Fig 6).



mud tube, Type 4 Type5

Fig. 6: A segment of mud tube (70mm length x5mm breadth x 2mm height) and its damage in base (Type4) and apex (Type5)

Type 6: A special group of termites which were aggressive and immediately came outside looking for the presence of natural enemies but after 3to 4 minutes they returned back to base through the opening end of breached area (Fig 7).



Type 6

Fig. 7: A special group of termites came outside looking for the presence natural enemies

c) *Measurement of the Repairing Activity of Termite*

The actual area of mud tube was repaired by termites at every 15 minutes interval following removal of 10m x 5m x 2m area from 50m x 5m x 2m area of mud tube. Here the entire area of breached tube was repaired within 2 hours of initiation of work. Each segment of broken tube was separated in 3 parts of which basal part nearer to nest was denoted by 'B', side wall was denoted by 'S' and rear end was denoted by 'A" as given in Fig 8.

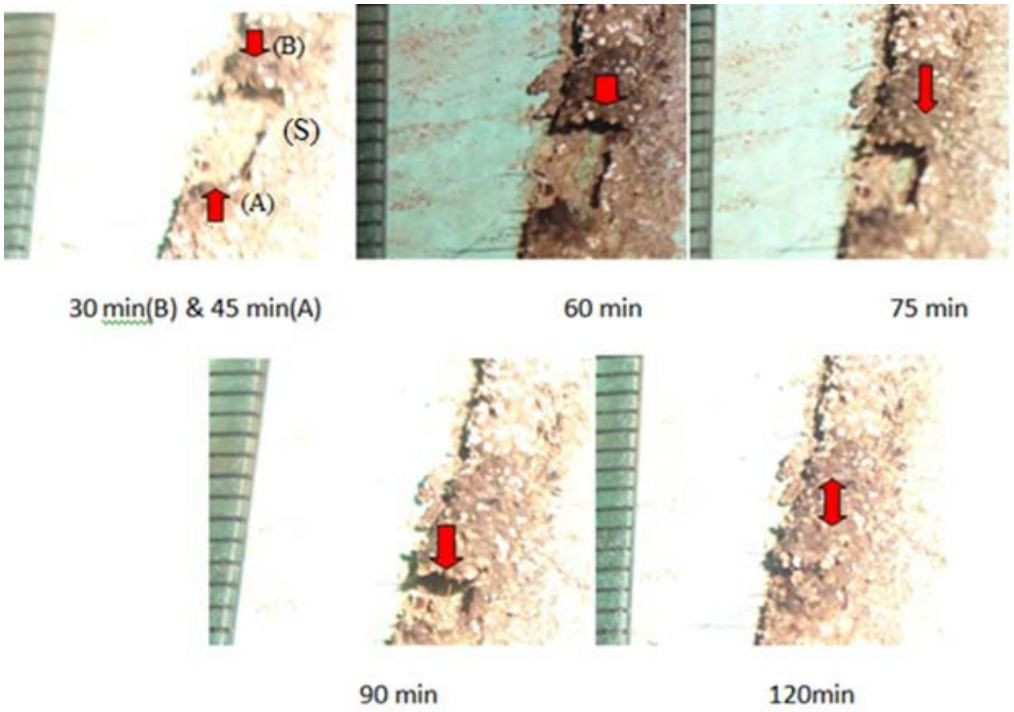


Fig. 8: Measurement of the repairing activity (area/minute) of termite

The Figure 8 showed that initially the termites started to repair from base (B) and completed 8% of the total area within first 30 minutes followed by 15% from both base and apex in 45 minutes. Meanwhile two special workers were found to repair both side wall of breached area (S) for 10 to 15 minutes each. Although the work done was performed from both the ends simultaneously for 90 minutes, the area in rear end (A) was one third of the base (B). The remaining part of work was completed after 30 minutes, a special worker was engaged to prepare last part keeping the body horizontally to the ground before closing the tube (Fig 9).

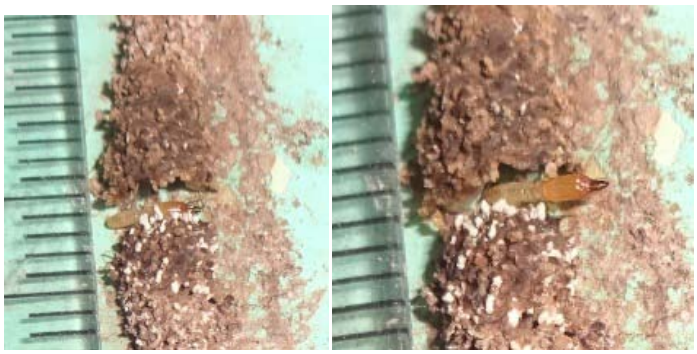


Fig. 9: Repairing the last part of mudtube by special worker

Sometimes during constructing the mudtube, fraction remains suspended above while a portion remains concealed beneath the tile or cracks of the wall, this part is left unrepaired if its surface was artificially damaged by external forces (Fig 10). This type of structure formations were up to 50 mm in length and 1 to 1.5 mm in width hollow so that one or two termites could easily move from their base to apex. The apex of this suspended structure may be club shaped or bifurcated and the opening was not clearly visible from outside.

Fig. 10: Suspended mudtube over the concrete wall

IV. Discussions

Termite *Odontotermes obesus* (Rambur) is a common pest of both agriculture and house hold. Termite swarm could easily be seen everywhere as large numbers of adults are attracted to light. If anyone does not see the swarm, the mud tube formation is a subtle sign of termite infestation. A mud tube infestation can only be deemed active if after its mutilation, subsequent worker and soldier termites emerge in floods for its rebuild in rapid succession. Otherwise an abandoned mudtube remains isolated independent of its breakage and thus assumed to be old and inactive. The repairing behavior is also determined by several factors which are discussed in length herewith. The time required to repair the damaged tube was less in rainy season than summer as the termites require moisture to construct tunnels out of the mud to connect their nest in the ground with their food sources. Cowie et al. (1989) reported that termites move up or down in the soil to meet changing moisture and humidity conditions. Based on changes of behavioral pattern in respect to damage of mud tube, the termites are divided into 6 exclusive categories which can give an idea about the division of work immediately after breaking of mud tube. Using the experimental settings Xiong et al. (2018) also divided termite into 4 exclusive categories on the basis of behavioral patterns of repairing, escaping and presence of predators. From the measuring of repairing activity we can estimate the working efficiency of termite per unit time in response to the damage of mud tube. Here the initial working efficiency was lower but the maximum outputs were obtained just 30 minutes before covering the damaged mudtube. Xiong et al. (2018) also reported that up to 15 minutes after breaking the number of downwards moving termite was significantly higher than the number of termites performing all other behavior except repairing. The termites build these suspended mud tube or "hanging" shelter tubes down toward the ground so they have better access along the length of the food sources".

From the result it is to be concluded that the studies on repairing activity in response to the damage of mud tube in two different seasons indicated that termite require higher humidity for quick formation of mud tube. The behavioral study after breaking the mudtubes also indicated that no single termite would be in charge of repairing the damage. The procedure of repair begins with construction of three fourth base succeeded by one fourth of the apex. However much preference is given in the architecture of side walls even more so than ends. The suspended mud tube or hanging shelter tube is rarely constructed by termite as an extra temporary sanctuary. Further evidence resides in the fact that these are seldom repaired and are only utilized as an easy access for food sources.

Acknowledgement

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Conflict of Interest

The authors declare that he has no conflict of interest.

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Analysis of Trending Hi-Tech and Software Industry in Bangladesh

By Norottom Paul

Abstract- Hi-Tech/Software Technology parks are being developed in many countries to create an efficient work environment for knowledge based industrial development. Major aim of these technology parks is to attract foreign companies to set up operations and to transfer the indigenous technological capability for the development of the local industries. The aim of this work is to find out factors that influence technology park development and a suitable strategic framework for successful implementation of Hi-Tech (HTP) and Software Technology Park (STP) in Bangladesh. For this study Analytic Hierarchy Process is applied as a Multi-Criteria Decision-Making Method (MCDM) which is a technology assessment tool. The assessment has been conducted by considering infrastructure, strategic & business support & governance as criteria and basic facility, digital facility, social facility, research & strategic facility, industrial chain & innovation facility, capacity development, policy support, operational modality, and park management as sub criteria. IBM SPSS (Statistical Package for the Social Sciences) software also used for identifying the key variables.

Keywords: hi-tech park, software technology park, technology park, multi-criteria decision-making method (MCDM).

GJRE-J Classification: DDC Code: 005.1 LCC Code: QA76.76.D47

Strictly as per the compliance and regulations of:

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Keywords: hi-tech park, software technology park, technology park, multi-criteria decision-making method (MCDM).

I. Introduction

Knowledge-based industries, particularly related to information technology have been recognized as the top priority sector by countries making transition from agro-industrial economy to information economy. Hi-Tech/Software Technology parks are being developed in different countries, both developed and developing, to provide a range of infrastructure and administrative support services to create an efficient work environment for development of IT/ITES enabled industry [1,2].

Considering the world trends, Bangladesh has also recognized that new directions must be set for the future prosperity of the country. Information technology has been identified as a "thrust sector" for the economy of Bangladesh. Strategic plans have been prepared to enable Bangladesh to embrace the information age and to become an important player in the global market in information and other high technology sectors. The Government of Bangladesh has declared ***Vision 2021*** with a target to transform Bangladesh into Digital Bangladesh [3]. Government has taken initiative to established Hi-Tech/Software Technology Parks around the country to ensure knowledge-based industry.

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II. Elements of Technology Parks

Technology parks need to provide wide ranges of services to the company or investors. As a result, it requires a mixed eco system to operate efficiently and effectively for the client in the park. It depends on a close linkage with knowledge-based partners to ensure technology transfer, commercialization, education, and training. Study suggests the following elements are very important for technology parks.

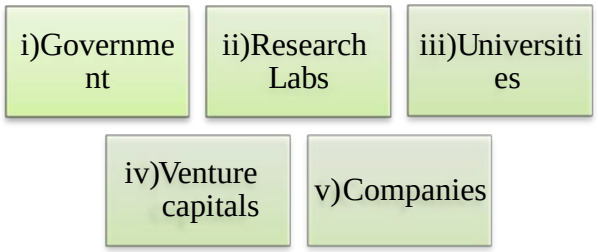

Figure 1: Basic elements of technology parks

III. Study of Technology Parks

Nations around the globe realized that innovation targets and transition economics requires appropriate technological infrastructures. Infrastructures that can add value to the society, can create employment, promote knowledge-based product with commercialization, transfer technology and ensure high return on investment. Technology Park is such an eco-system. Nations understood the importance of knowledge industry for sustainable economic growth and commence for the establishment of technology park of different geographical scale. Many researchers studied the concept of technology park, its development history, working process, focus area, role & responsivity towards economic development, policy, R&D institution requirement and common services. Several models have been developed for technology park. However, technology park in developed country and developing country varies. Sometimes, it is seen that anchor tenants plays a vital role in developing country technology park [4].

Around the globe technology parks operates in various mode, i.e., Private, Government, Public-Private

partnership model, Mixed model (university, government, industry). Whatever the model is, research and development play a vital role for sustainability.

IV. Technology Park Best Practices

During the last couple of decades, technology parks practices different firework for success. The success or failure varies region to region. Based on technology parks case study and various research available shows that for long term success, high quality infrastructure is important. Specialized business infrastructure for targeted group; knowledge intensive work force; collaboration with university and research institution; R&D; Technology Transfer Support; Incubation facilities; Innovation & Patent support; Product Commercialization; Marketing Assessment; Financial Incentives are the vital player for the success. It requires a mixed eco-system.

V. Research Design

To achieve the objectives of the thesis work, four steps are followed. Initially related literature reviewed from journals, book, thesis etc. Then ongoing project site and completed project site were visited. After that survey questioner used to collect the data. Various type of tools used to analyses the collected data and finally a frame work is developed. Tools and tetchiness are very essential to analyses values, attitudes, opinions, feelings, and behaviors of individuals and understand how these affect the overall research outcome. In this study few tools are used to analyses the data to draw the result. These tools are described in the following sections.

a) Analytical Hierarchy Process (AHP)

The mathematical formulation of the AHP has been well presented by Saaty in 1978. The AHP provides a means of decomposing the problem into a hierarchy of sub-problems which can more easily be comprehended and subjectively evaluated. The subjective evaluations are converted into numerical values and processed to rank each alternative on a numerical scale. The AHP uses hierarchical decision models, and it has a sound mathematical basis. A model is a representation of a phenomenon. It can be manipulated the model, either physically if it is a physical model, or mathematically in the case of hierarchical model, to discover the important influences. The methodology of the AHP can be explained in following in figure 2.

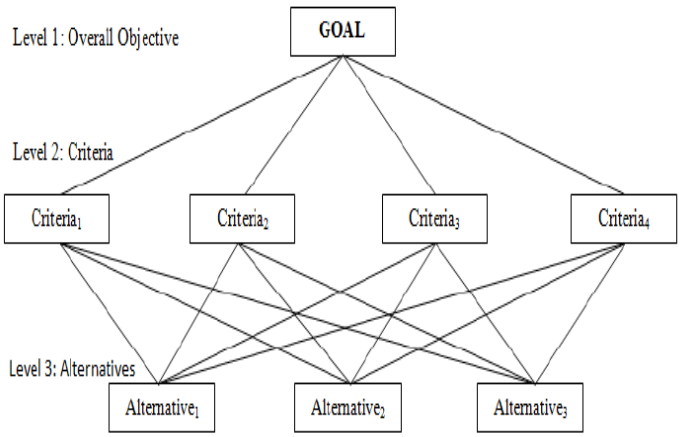

Figure 2: Generic hierarchic structure of AHP

This method used for both tangible and intangible factors analysis. for real world problems. again, mutual agreement can also be provided among decision makers prior to their final decision. Firstly, the alternatives, main and sub-criteria -if there is any- must be determined. In the next step the decision problem is modelled hierarchically by considering previously selected criteria. The decision-makers' judgments are collected through pairwise comparisons in the third step. In this step, the importance rankings of alternatives and criteria will be determined by analyzing these data which are obtained from these comparisons. Hence comparisons must be performed among these criteria and alternatives [5-7].

b) Questionnaires

Questionnaires is developed to collect expert's opinion for AHP analysis. The AHP technique is a widely used and accepted method for gathering data from respondents within their domain of expertise. The technique is designed as a group communication process which aims to achieve a convergence of opinion on a specific real-world issue. It has been used in various fields of study such as program planning, needs assessment, policy determination, and resource utilization to develop a full range of alternatives, explore or expose underlying assumptions, as well as correlate judgments on a topic spanning a wide range of disciplines. In this study seven experts are chosen for

selecting the criteria and sub criteria. The personal profile of expert panel is shown in table below. Based on the interviews and interaction of relevant experts, observation and literature review, modalities, criteria, and sub-criteria are included in this study. Sample questionnaires for the criteria are shown below and details questionnaires are included in the annexure.

Table 1: List of Experts

SN	Designation	Overall Exp. (Years)	Relevant Exp. (Good, Better, Best)	Education Qualification	Organization
1	Expert-1	25+	Best	Masters	Government Officer
2	Expert-2	25+	Best	B.Sc. Engr.	
3	Expert-3	20+	Best	B.Sc. Engr.	
4	Expert-4	20+	Better	PhD	
5	Expert-5	20+	Better	PhD	Professor
6	Expert-6	30+	Best	Masters	Senior Consultant, Asian Development Bank
7	Expert-7	40+	Best	Masters	ICT Industry
8	Expert-8	20+	Best	PhD	Professor
9	Expert-9	8+	Good	PhD	Assistant Professor
10	Expert-10	30+	Best	Masters	Senior Consultant, Asian Development Bank
11	Expert-11	40+	Best	Masters	ICT Industry
12	Expert-12	30+	Good	Masters	ICT Industry

i. *Questionnaires for Criteria*

1. Let given the frequency selection options, what is more important to you: Infrastructure (F1) or Governance (F2)?
2. Let given the frequency selection options, what is more important to you: Infrastructure (F1) or Strategic & Business Facility (F3)?
3. Let given the frequency selection options, what is more important to you: Governance (F2) or Strategic & Business Facility (F3)?

c) *Main Attributes and their Sub-attributes*

i. *Infrastructure (main attributes)*

Infrastructure is one of the most important parts for the development of HTP/STP. It is considered that within 2025 Bangladesh may require 20 million square feet buildup space for IT/ITEs sector. For HTP/STP infrastructures are considered in three way which are assumed as sub attributes i.e.,

a. *Basic Facility (sub-attributes)*

Land, working space, meeting room, auditorium/conference room, cafeteria; utility like generator, sub-station, HVAC, fire safety, 24/7 working environment, good connectivity etc.,

b. *Digital Facility (sub-attributes)*

Networking, security surveillance, lab facilities/lab equipment for rent, videoconference room, software-based utility billing system and paperless management etc.

c. *Social Facility (sub-attributes)*

Dormitory, banking services, shopping facility, gymnasium, recreation zone, health care, library, day care facility etc.

ii. *Strategic and Business Support (main attributes)*

Strategic and business support is required to create the eco-system. This is the major forces shaping the initial investment to success.

a. *Industrial Chain and Enterprise Development (sub-attributes)*

R&D facilities, industrial co-operation, international collaboration, university linkage, technology transfer center/ support etc.

b. *Innovation and Strategic Facility (sub-attributes)*

Incubation/start up development facilities, innovation & patent support service, product commercialization, marketing assessment, financial incentives, business development/mentorship etc.

c. *Capacity and Market Development (sub-attributes)*

Entrepreneurship development training, project and financial management, venture capital, co/shared workplace/workforce facility, seminar/symposium, professional membership, internship support, global standard certification support, need based on job training support, cyber security/latest technology support etc.

iii. *Governance (main attributes)*

a. *Policy Support (sub-attributes)*

b. *Operational Modality (sub-attributes)*

- Government
- Private
- Mixed Model
  - University-Industry
  - University-Govt.-Industry mixed type
  - Government- Industry

c. Park Management (sub-attributes)

- Administrative capability and employee structure
- Legal Service
- Social Service
- Innovation Culture development etc.

VI. Result

To build the pair-wise comparison matrices for the main attributes and sub-attributes, opinion of academic experts and professional experts are collected. The purposive sampling method is used. It is one where the sample is selected on need basis according to the specialization. The matrix of pair-wise comparisons depicts the intensities of expert's preference/importance. Geo metrics mean of the value of each pair wise comparison determined and then matrix is formed with respect to the goal [8-10].

Table 2: Result of main attributes

Main Attributes	Weightage	Position
Infrastructure (F1)	0.469	1st
Strategic & Business Support (F2)	0.433	2nd
Governance (F3)	0.097	3rd

Table 3: Result of sub-attributes

Main Attributes	Sub-Attributes	Weightage	Position
Infrastructure (F1)	Basic Facility (F1A1)	0.422	2nd
	Digital Facility (F1A2)	0.501	1st
	Social Facility (F1A3)	0.076	3rd
Strategic & Business Support (F2)	Research & Strategic Facility (F2B1)	0.656	1st
	Industrial Chain & Innovation Facility (F2B2)	0.253	2nd
	Capacity Development (F2B3)	0.089	3rd
Governance (F3)	Policy Support (F3C1)	0.279	2nd
	Operational Modality (F3C2)	0.658	1st
	Park Management (F3C3)	0.062	3rd

VII. Conclusion

It been seen that, most of the initiatives are infrastructure focused rather than strategy based. After infrastructural initiatives, government is taking strong actions to establish business strategy. Many initiatives are seen around the country to support innovation and entrepreneurship. Government also trying to support new idea and products. But to make these steps and HTP/STP successful targeting successful institutionalization, operation modality shall be the most important variable. From the study the following process is proposed for the development of HTP/STP in Bangladesh [11].

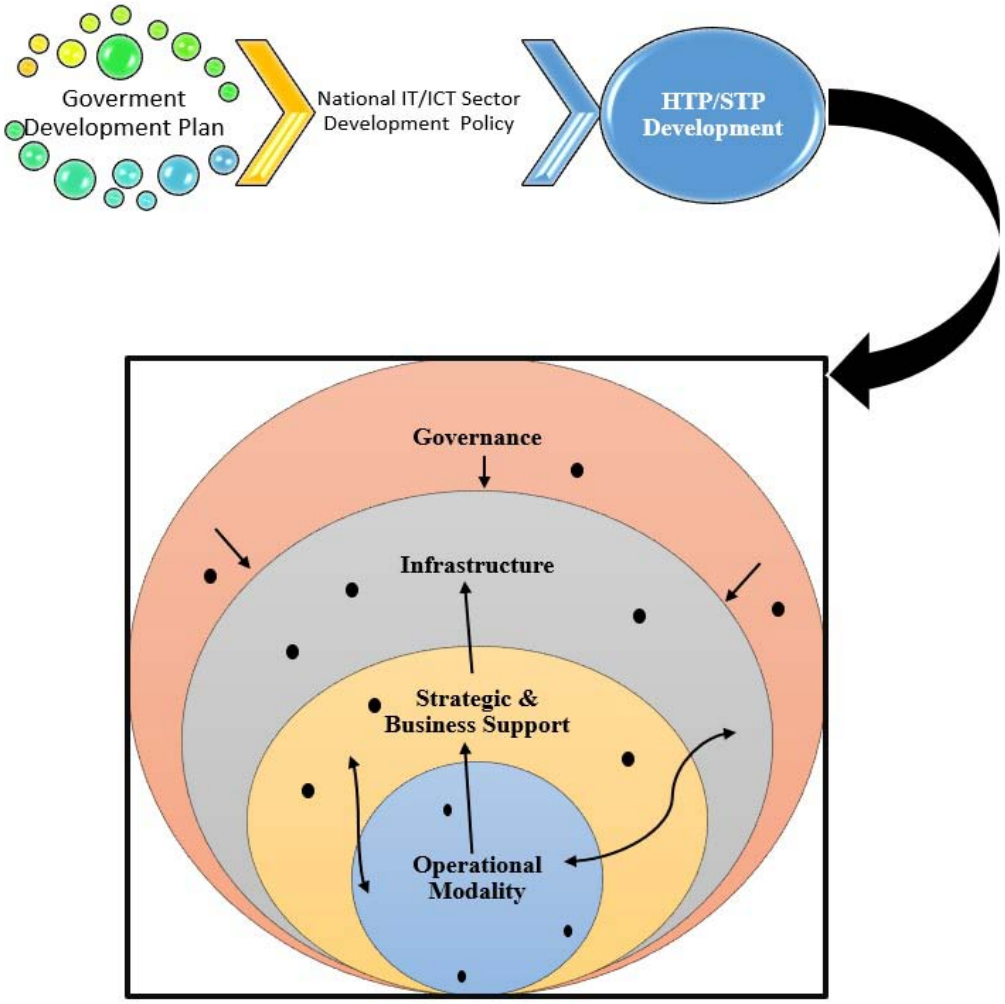

Figure 3: HTP/STP Development Process

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CO_2-Foam Monitoring using Resistivity and Pressure Measurements

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Abstract- This paper focuses on combining resistivity and pressure measurements to determine the effectiveness of foam as a mobility control method. It presents a theoretical framework to describe the expected resistivity changes during CO_2-foam displacements. With this objective, we first provide equations to estimate the resistivity for CO_2-foam systems and then utilize two distinct foam models to quantify these effects. Using analytical solutions based on the fractional flow theory, we present resistivity and mobility distributions for ideal and non-ideal reservoir displacement scenarios. Additionally, assuming pressure measurements only, we examine the inter-dependency between various foam parameters. Our results suggest that the combination of pressure and resistivity measurements in time-lapse mode could be deployed as an effective monitoring tool in field applications of the (CO_2) foam processes. The proposed method is novel as it could be employed to predict under-performing CO_2-foam floods and improve oil recovery and CO_2 storage.

GJRE-J Classification: DDC Code: 620 LCC Code: TP1183.F6

Strictly as per the compliance and regulations of:

CO_2-Foam Monitoring using Resistivity and Pressure Measurements

Metin Karakas [α], Fred Aminzadeh [σ] & Arne Graue [ρ]

Abstract- This paper focuses on combining resistivity and pressure measurements to determine the effectiveness of foam as a mobility control method. It presents a theoretical framework to describe the expected resistivity changes during CO_2-foam displacements. With this objective, we first provide equations to estimate the resistivity for CO_2-foam systems and then utilize two distinct foam models to quantify these effects. Using analytical solutions based on the fractional flow theory, we present resistivity and mobility distributions for ideal and non-ideal reservoir displacement scenarios. Additionally, assuming pressure measurements only, we examine the inter-dependency between various foam parameters. Our results suggest that the combination of pressure and resistivity measurements in time-lapse mode could be deployed as an effective monitoring tool in field applications of the (CO_2) foam processes. The proposed method is novel as it could be employed to predict under-performing CO_2-foam floods and improve oil recovery and CO_2 storage.

I. Introduction

Time-lapse seismic, resistivity, electromagnetic (EM), and pressure measurements have been used in the oil industry for water and CO_2 flooding and monitoring applications. For example, see: Passalacqua et al (2018), Davydycheva and Strack (2018) and Strack(2014). CO_2 foam injection is an effective method to control mobility during CO_2-Enhanced Oil Recovery processes in petroleum reservoirs. When it is done optimally, CO_2 foam can improve sweep efficiency, oil production, and CO_2 storage (Kuuskraaet al., 2006, Fernoet al., 2014). Laboratory studies show that foam strength is essential to achieve the desired reservoir efficiency. It has been demonstrated that the foam density is a direct function of the density of the lamellae (Kovscek and Radke, 1994). Additionally, the solubility of surfactant in CO_2 and water phases, as well as the adsorption of CO_2 on the rock, play a crucial role in these displacements. At a given reservoir temperature, the partitioning of the CO_2 soluble surfactants is dependent on pressure and strongly influenced by the attractiveness (CO_2-philicity) of the selected surfactant for foam application. Recent research indicates that various (cationic, nonionic, and zwitterionic) surfactants as the leading candidates for CO_2 foams. It is also critical to maintaining the foam strength for the entire injection period during reservoir applications. Additionally, the CO_2 mobility is higher than that of the foam, and under certain conditions, this can lead to less-than-optimal displacement in porous media.

Foam monitoring has been restricted to electrokinetic (streaming potential) measurements (Omar et al., 2013). Wo et al. (2012) ran foam experiments on unsaturated soil samples and investigated the possibility of using electrical measurements for foam monitoring. Of course, it should be realized that foam and CO_2 are charged. They connect and eventually build larger molecules. We need boundary to develop a bouble layer for charges to collect. Wo et al. (2012) reported significant changes in electrical properties with foam formation.

Karakas and Aminzadeh (2017) proposed time-lapse measurements with an array of permanently deployed sensors to detect the movement of the foam-CO_2-Oil interface in the reservoir due to CO_2-foam injection. With the proposed method, resistivity and pressure measurements are acquired simultaneously during the CO_2-foam Injection into reservoir, as shown in Fig. 1.

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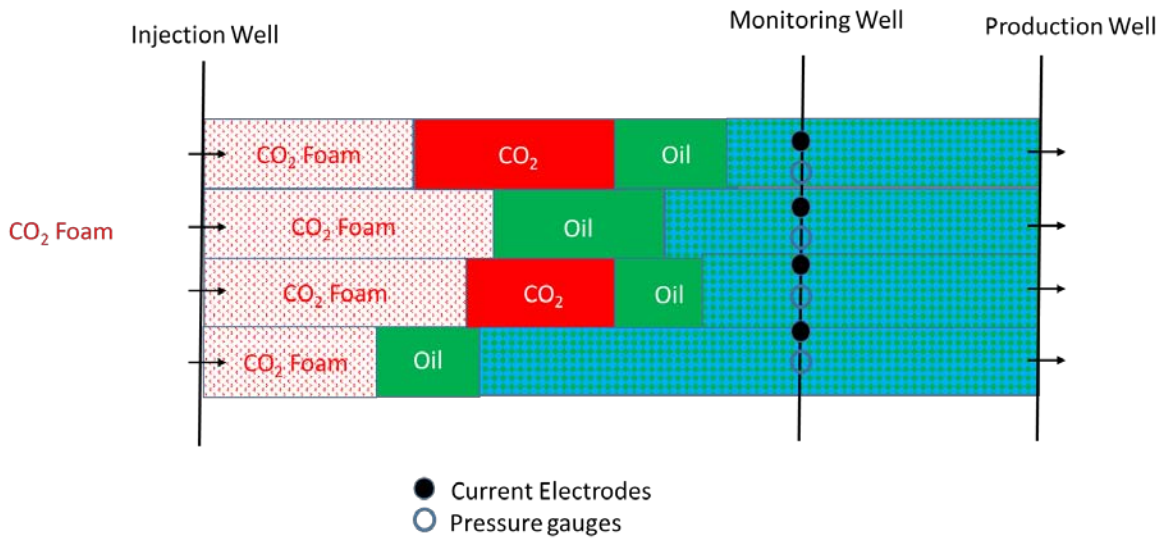

Fig. 1: Example of pressure and resistivity monitoring during a CO_2 Foam flood (Karakas and Aminzadeh, 2017).

In the proposed method by Karakas and Aminzadeh (2017), resistivity and pressure measurements are used to determine the effectiveness of foam as a mobility control method and hence, provide a way to remedy any under-performing foam (and CO_2-foam) floods to improve both oil recovery and CO_2 storage. This monitoring is crucial for applying foam (and CO_2 foam) in reservoirs where heterogeneity is involved. Figure 2 below illustrates this optimization process.

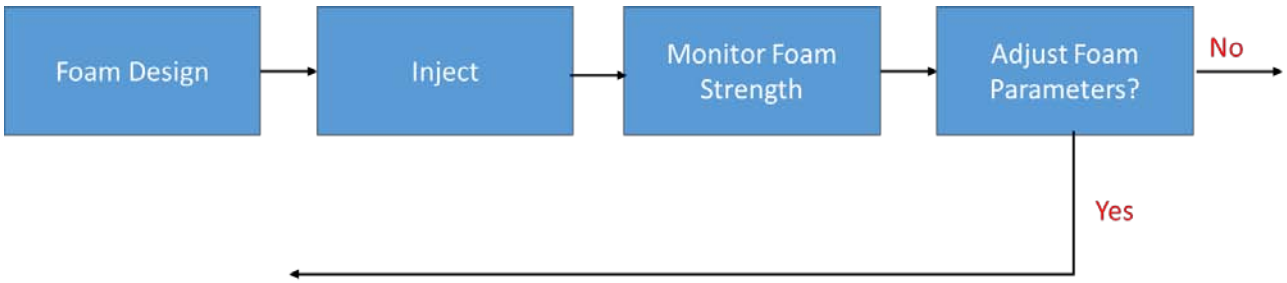

Fig. 2: Foam (and CO_2-Foam) optimization process (Karakas and Aminzadeh, 2017).

In terms of laboratory studies, Berge (2017) conducted resistivity measurements while injecting CO_2 and surfactant solution into saturated cores and Haroun et al. (2017) monitored resistivity and pressure changes during foam generation in the formation-brine saturated carbonate core plug samples. Haroun et al. (2017) reported significant increases in resistivity and pressure with foam development.

The main thrust of this paper is to the characterize the resistivity response and to present a theoretical foundation for resistivity monitoring during CO_2 foam displacements.

II. CO_2 Foam Transport Modeling

The transport of CO_2 foam can be described by several methods (Ma, K. et al., 2015). These include:

- Pore-network models
- Analytical methods
- Explicit population-based equation (PBE) methods
- Implicit foam methods

Pore-Network models provide a good insight into foam transport and are not yet practical for reservoir-scale applications. In this study, we focus on the Analytical and the explicit (or Population Based) methods. The analytical approach is based on the fractional-flow theory and steady-state foam development, as presented by Ashoori et al. (2010). The main assumptions are as follows:

- One-dimensional flow.
- Initially, the reservoir is at residual oil saturation (S_{or}) after waterflooding.
- CO_2 is injected at supercritical conditions.
- First-Contact Miscible (FCM) displacement of oil by the injected supercritical CO_2.
- The relative permeability depends on water saturation and the oil or CO_2 saturations.
- Foam effects are captured implicitly using steady-state assumption.

As demonstrated by Ashoori et al. (2010), there are two different solutions: the first one relates to an

ideal CO_2-foam displacement where the miscible (CO_2) and surfactant (foam) fronts travel at the same speed. In this case, three separate banks develop in the reservoir: Foam or surfactant (CO_2 plus water) bank, oil (with mobile water) bank, and water (with residual oil) bank. The second solution assumes a non-ideal CO_2-foam displacement. In this case, due to adsorption of the injected surfactant to the rock and its partitioning to the water phase, the foam front slows down, and the miscible (CO_2) front moves ahead of it. In this case, a separate CO_2 bank forms ahead of the foam (or surfactant) bank, which gives rise to an unfavorable mobility distribution in the reservoir. These reconstructed saturation profiles are provided in Appendix A. The fractional flow approach is based on the steady-state assumption and cannot capture the transient foam development during CO_2 foam injection (Kam S.I.,2008).

III. Population-Balance Method

In the Population Based (PBE) method, foam effects are captured explicitly by quantifying the bubble population (n_f) and correlating it to the foam mobility. In this work, we utilized the solution approach provided by Kam and Rossen (2003). The relevant foam equations are provided in Appendix B. Please note that this solution is based on the two-phase (CO_2 and water) flow, and the oil phase is ignored. This assumption is in line with most experimental work and gives good insight into foam development in porous media (Kam et al., 2004, Prigiobbe et al., 2016).

The solution of the PBE, due to nonlinear relations between injection rate and pressure gradient, is quite complex and may not be unique (Dholhawala, Z.F. et al., 2007). In this work, a numerical approach was taken for solving the transient foam equations. With this objective, a numerical foam simulator (FoamSim) was developed, in which upstream weighting was utilized to minimize the numerical dispersion effects. The numerical model was validated by comparing its results with that of Kam et al. (2004). These comparisons were made for both weak and strong foam states.

IV. Parameter Estimation using Pressure Measurements

One of the crucial considerations is the uniqueness of the model parameters obtained from pressure measurements. For this reason, we analyzed the inter dependency between various foam parameters. These included foam generation parameters (C_g & m), foam coalescence parameters (C_c& n), and the foam viscosity parameter (C_f). For this purpose, we utilized the published CO_2foam experiments by Prigiobbe et al. (2016). The foam parameters for these history matched experiments are as follows:

Table 1: Model Parameters used for Foam Simulations (From Prigiobbe et al., 2016).

	C_f	C_g	C_c	M	n	S_w*
Experiment 6	1.58E-15	3.02E+07	3.02E-01	0.588	0.73	0.121
Experiment 34	3.31E-17	3.72E+06	9.55E-03	1.140	0.29	0.01

We first ran forward simulations using FoamSim and compared our results with those of Prigiobbe et al. Two experiments (6 & 34) produced very similar (but not exact) results. The graph below shows the comparison for Experiment 6 using parameters from the table above.

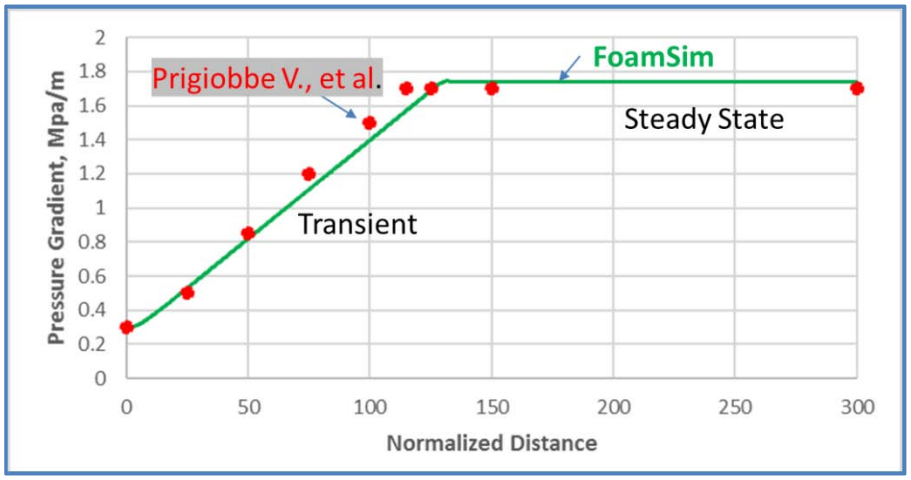

Fig. 3: Comparison of pressure gradients (experiment number 6).

The relevant sensitivity coefficients were generated using our numerical solver (FoamSim), and for experiments 6 and 34 and the duration of the lab experiments. In this analysis, the following parameters were considered:

$$X = \text{foam parameters } [C_g, C_c, C_f, m, n] \quad (1)$$

For most high-permeability systems, the critical water saturation (S_w^*) is relatively small. Therefore, due to potential numerical problems, it was not included in the analysis. In the calculations of sensitivity coefficients, we used the log transformation for all the foam parameters:

$$C_g' = \log_{10}(C_g) \quad (2)$$

The following plot shows the calculated sensitivity coefficients using data from experiment number 6:

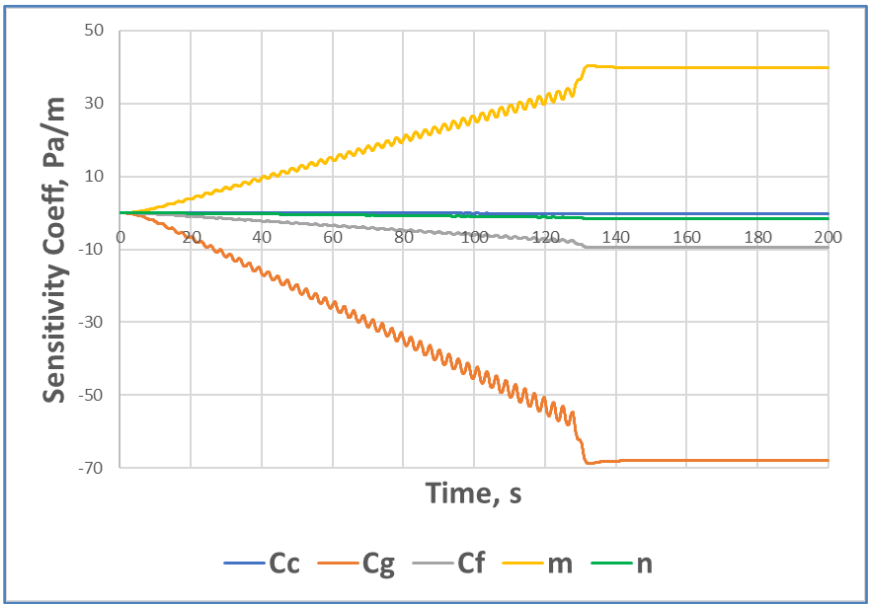

Fig. 4: Sensitivity coefficients for foam parameters (experiment number 6).

We also normalized sensitivity coefficients for an even comparison and calculated the determinant of the sensitivity matrix to examine the (ill) conditioning of the inverse problem. The determinant (d) is a function of time and is defined as follows:

$$d = [S^T S] \quad (3)$$

These calculations showed that the magnitude of the determinant increased with time (with more measurement samples):

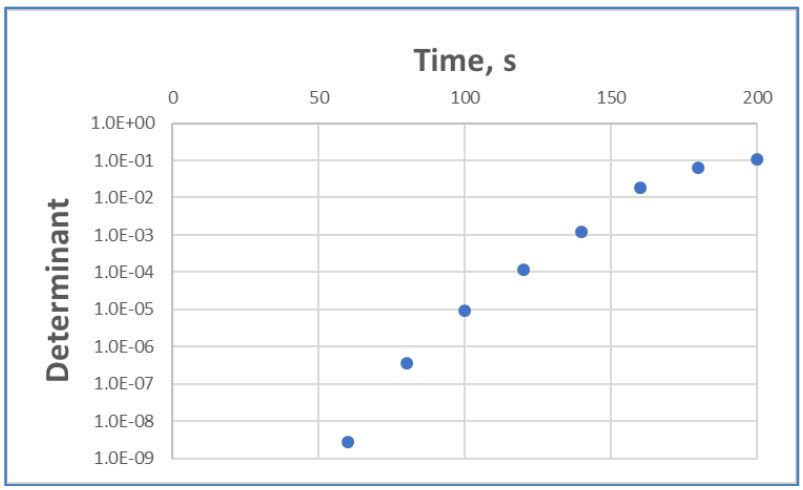

Fig. 5: Determinant of the sensitivity matrix.

We also calculated the determinant using the steady-state portion of the measurements only. For steady-state flow, the determinant became very small, which indicates a linear dependency between the selected foam parameters (Appendix B). This examination showed the following:

- Foam generation parameters, C_g & m, have by far the highest sensitivity.
- Foam viscosity coefficient, C_f, is of the middle rank.
- Foam coalescence parameters, C_c & n, have relatively less sensitivity.
- Linear independence is possible with transient data.
- Steady-State pressure measurements give rise to an ill-conditioned parameter estimation problem and the grouping of parameters is necessary.

V. CO_2 Foam Resistivity Characteristics and Modeling

Typically, nonionic surfactants are dissolved in the CO_2 phase, and the foam generation occurs in situ when injected the CO_2 plus surfactant meets the formation brine. CO_2 is highly resistive, whereas the thin water film is conductive (depending on the salinity of the in-situ reservoir fluid). During foam injection, these films enhance the electrical conductivity. With growing bubble size, these conduits become less effective, and overall, the resistivity of the foam system increases. However, with CO_2 injected brine already resistive this will only produce more resistive fluid. Reduction in resistivity will come from higher electron flow and resistivity reduction caused by pressure changes. See Boerner et al (2015) on electrical conductivity of CO_2-bearing pore waters at elevated pressure and temperature.

Assuming a uniform and hexagonal-prism shape foam, the foam conductivity σ_f is obtained using the Lemlich Relation (Lemlich, R., 1985):

$$K = \frac{D}{3} \tag{4}$$

Where K is the bulk foam conductivity. This relationship can also be written as follows:

$$K = \frac{\text{conductivity of dispersion}}{\text{conductivity of continous phase}} = \frac{\sigma_f}{\sigma_s} \tag{5}$$

Where D is the volumetric liquid fraction or = (1-X_f), and X_f is the foam quality. Using these relationships, we obtain:

$$\sigma_f = \frac{1}{3}\sigma_s\,(1 - X_f) \tag{6}$$

or another expression would be:

$$\sigma_f = c_1 * \sigma_s * (1\text{-}S_{co2}^f) \tag{7}$$

where:

c_1 = constant

S_{co2}^f = CO_2 saturation with foam

σ_s = conductivity of the thin film around bubbles

Assuming, σ_s = 1.0 S/m and X_f = 0.90 (foam quality), we obtain the following values for foam conductivity:

σ_f = 0.033 S/m (foam conductivity) or R_f = 30 ohm.m (foam resistivity)

These results suggest that foam conductivity will be order of (1 to 2) higher compared to that of the CO_2 phase only.

We propose to scale the foam conductivity with foam density as follows:

$$\sigma_f = c1\,\sigma_s\,(1\text{-}S_{co2}^f)\,(\frac{n_f}{n_{fmax}}) \tag{8}$$

where n_{fmax} is the maximum population density.

For a CO_2-Water system, lab results show that Archie's equation provides a reasonable approximation (Bergmannet al., 2013). Assuming a CO_2-Foam-Water system, the total system conductivity was calculated by utilizing the mixing law (Appendix D):

$$\sigma=\phi^2\,[S_{co2}^f\sigma_f^{\,1/2} + S_w\sigma_w^{1/2}]^{\,2} \tag{9}$$

Laboratory measurements using carbonate cores from Abu Dhabi (Harounet al., 2017) show a sharp increase in resistivity and a large pressure drop with the formation of foam during these high-temperature and high-pressure core floods. These experimental results are in line with the theoretical results provided here.

The difference between foam and CO_2 saturated reservoir depends on how much CO_2 is absorbed by the brine. However, strictly speaking, volumetrics are empirical correlations and do not often work for resistivity due to non-linearity of Archie. With fracture we increase complexity even further.

a) *Resistivity Profiles*

Using the simulated saturation and the foam densities, we can now estimate the resistivity (along with relative mobility) evolution during the CO_2-Foam displacements. For these simulations, we assumed the following bulk conductivities for water, CO_2, foam, and oil phases:

Table 2: Parameters Used For Resistivity Simulations

σ_w	5.00	S/m
σ_{CO2}	0.001	S/m
σ_f	0.100	S/m
σ_{oil}	0.001	S/m

The figure below shows the resistivity profile from one dimensional CO_2 foam flood assuming a moderately conductive water scenario. The resistivity profile has been calculated using the simulated foam densities from the FoamSim simulator, and the CO_2 foam resistivity model. To avoid using canonical resistivity values one would in practice scale the surface measurements to the borehole scale as shown by Strack et al (2022).

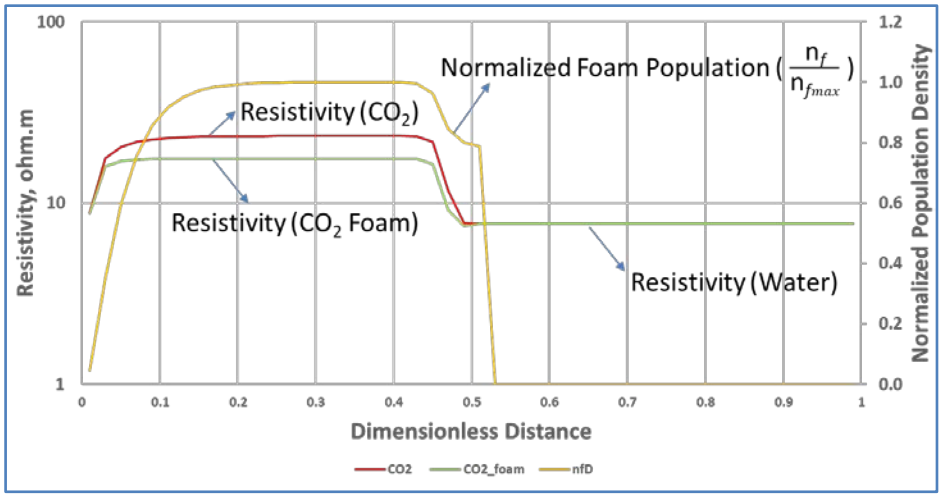

Fig. 6: Calculated resistivity profile during CO_2-Foam injection (PBE Solution).

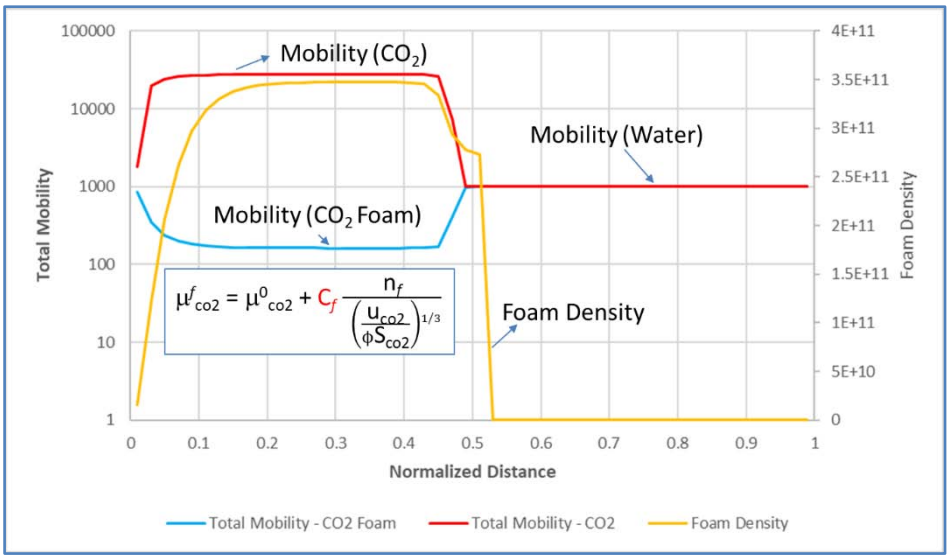

Fig. 7: Combined resistivity and mobility profile during CO_2-Foam injection (PBE Solution).

b) Resistivity Profiles – CO_2 Foam Displacement with Oil

The resistivity calculations for the CO_2 foam with oil were also made for CO_2-foam displacement with oil. For this model, the mobility effects were calculated using the steady-state assumption as outlined in Appendix A. The resistivity calculations were made assuming similar bulk conductivities as given in Table 2. The figures below show the calculated resistivity profiles for both ideal as well as non-ideal foam displacements:

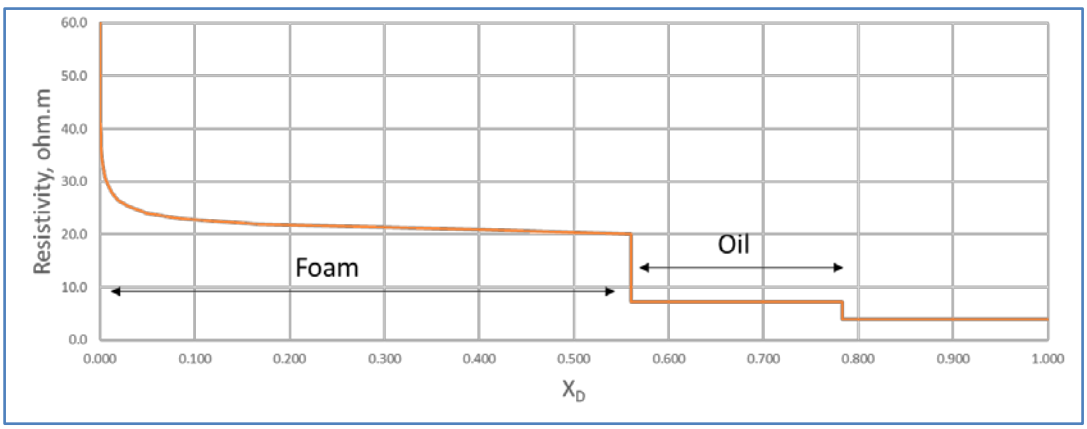

Fig. 8: Resistivity profile during ideal CO_2-Foam displacement.

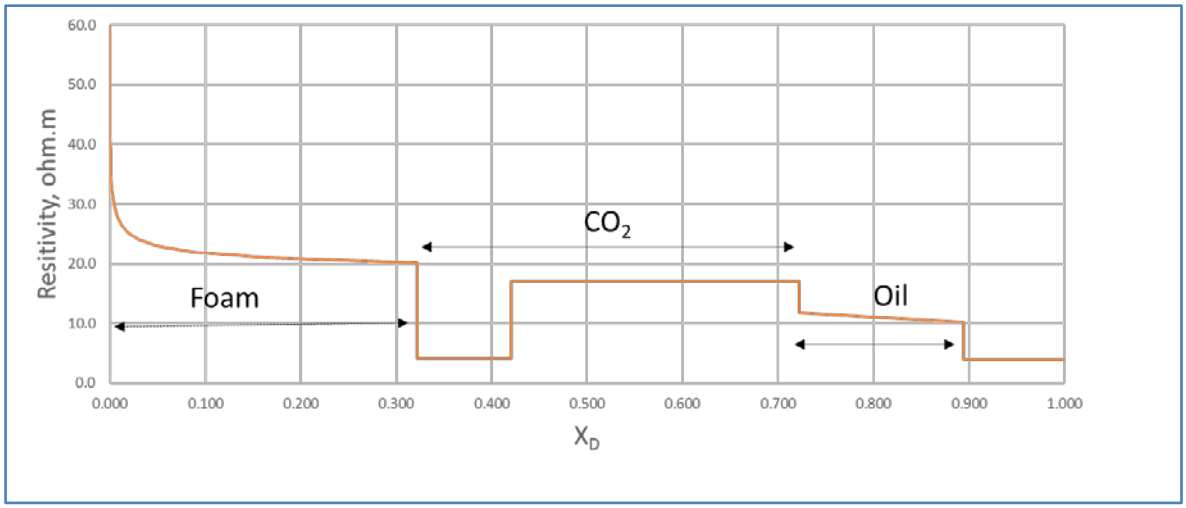

Fig. 9: Resistivity profile during non-deal CO_2-Foam displacement.

The figures below show the mobility distribution along with the resistivity profiles.

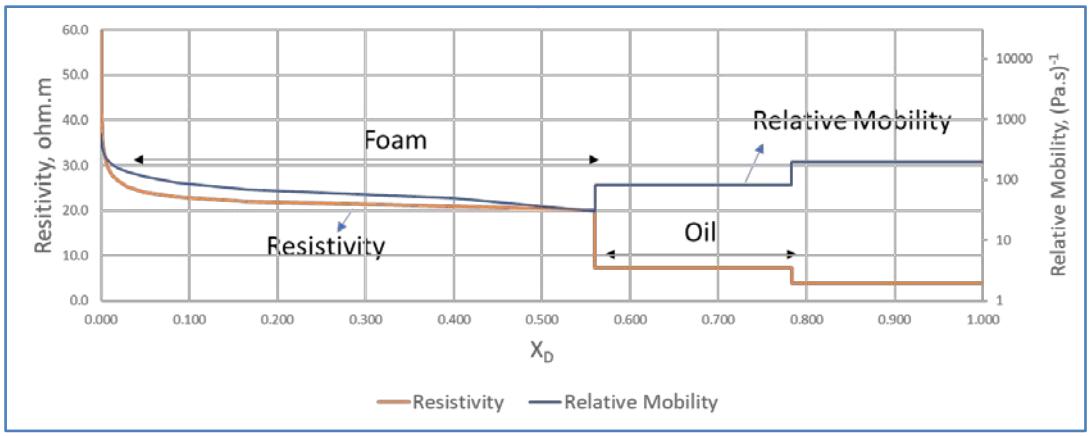

Fig. 10: Combined resistivity and mobility profile during CO_2-Foam injection (analytical Solution – ideal displacement).

As seen in Fig. 10, the resistivity profile during ideal displacement is like the PBE simulations shown earlier, and both models suggest a sharp resistivity contrast at the foam front. On the other hand, for non-ideal displacements, the resistivity profile is quite different. During these displacements, the resistivity profile, as shown in Fig. 11, indicate a staircase behavior, which extends into the miscible CO_2 bank.

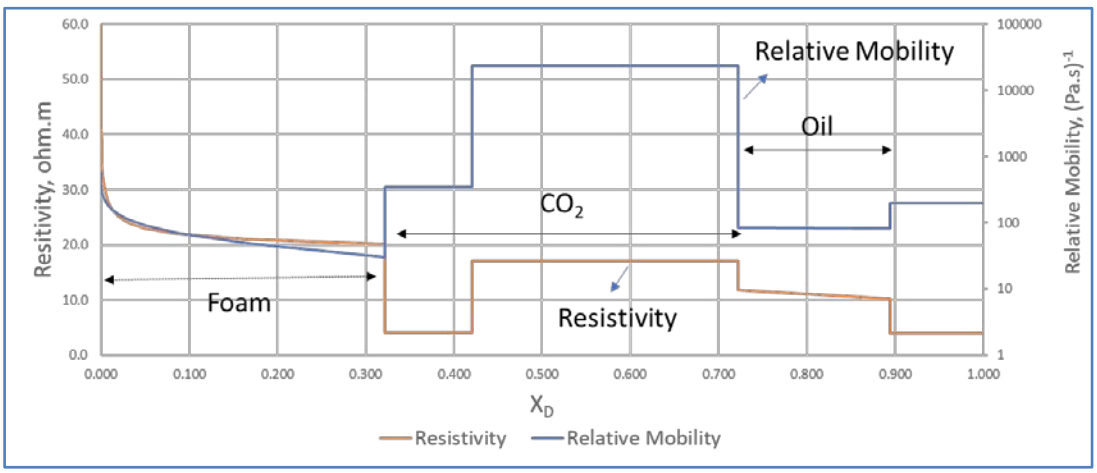

Fig. 11: Combined resistivity and mobility profile during CO_2-Foam injection (analytical solution – non-ideal displacement).

VI. Conclusions

In this paper, we presented a volumetric based foundation for resistivity and pressure monitoring during CO_2-foam displacements. Our results suggest that a combination of pressure and resistivity measurements in time-lapse mode could be deployed as an effective monitoring tool in field applications of the (CO_2) foam processes. The proposed method is novel as it could be employed to predict under-performing CO_2-foam floods and to improve oil recovery and CO_2 storage.

Other conclusions can be listed as follows:

- Pressure measurements during steady-state foam flow give rise to an ill-posed estimation problem and that grouping of foam parameters is necessary. For most reservoir applications, pressure measurements alone will not adequately describe the transient foam effects.
- Assuming brine in the reservoir, resistivity profiles during ideal CO_2 foam displacements should exhibit a distinctive signature at the foam front.
- During non-ideal CO_2 foam displacements, resistivity measurements by itself may not be enough to differentiate foam and miscible CO_2 banks. However, for these non-ideal cases, pressure measurements could be very utilized to locate these vastly contrasting mobility-fronts.

Acknowledgements

We would like to acknowledge financial support from Chevron for this research. We also acknowledge the input from Kurt Strack of KMS Technology.

Nomenclature

c_1 = a constant in the proposed foam conductivity model
C_c = a model parameter to represent foam coalescence
C_f = a model parameter to represent effective foam viscosity
C_g = a model parameter to represent foam generation
D = volumetric liquid fraction in the foam, fraction
d = value of determinant to capture the conditioning of the parameter estimation problem
epdry = a foam parameter used to capture the slope near critical water saturation
fmmob = a factor in steady-state foam model to represent the mobility factor
fmdry = a factor in steady-state foam model to represent the critical water saturation
epsurf = a steady-state foam parameter
f_{co2} = CO_2 phase fractional flow, fraction
f_w = water phase fractional flow, fraction
Fw = factor to capture the effect of water saturation on foam mobility reduction
K = bulk foam conductivity, (S/m)
k = permeability, m^2
k_{rCO2} = relative permeability to CO2 phase, fraction
k_{ro} = relative permeability to oil phase, fraction
k_{rw} = relative permeability to water phase, fraction
m = a model parameter for transient foam generation
M = measurement matrix
n = a model parameter for transient foam coalescence
R_{CO2} = resistivity of the CO_2 phase, ohm-m
R_f = resistivity of the foam, ohm-m
R_w = resistivity of water phase, ohm-m
n_f = foam texture or density, lamellae/unit volume
n_{fmax} = maximum foam density, lamellae/unit volume
r_c = foam (lamella) destruction rate
r_g = foam (lamella) generation rate
S = sensitivity matrix
S_{co2} = CO_2 saturation, fraction
S_o = oil saturation, fraction
S_w = water saturation, fraction
u_{co2} = CO_2 volumetric flux or superficial velocity, m/s
u_t = total velocity, m/s
u_w = water velocity, m/s
vf = volumetric fraction of rock and fluids, fraction
v_s = velocity of the foam front, m/s
v_w = velocity of the miscible (CO_2) front, m/s
X = vector defining the foam parameters
X_f = foam quality, fraction
μ_{co2}^{0} = CO_2 viscosity (without foam), Pa.s
μ_{co2}^{f} = effective viscosity of the CO_2 foam phase, Pa.s
ϕ = porosity, fraction
σ_{co2} = CO_2 conductivity (without foam), S/m
σ_{co2}^{f} = CO_2 conductivity (with foam), S/m
σ_f = foam conductivity, S/m
σ_w = water conductivity, S/m
∇p = total pressure gradient, Pa/m
∇p_w = pressure gradient for the water phase, Pa/m

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Appendix A – Analytical Solution

In the example provided by Ashoori et al. (2010), the following fluid and rock parameters are assumed:

Table A1: Model Parameters used for Analytical Simulations

μ_w	0.001	Pa.s
μo	0.005	Pa.s
μg	2E-05	Pa.s
ϕ	0.25	
S_{gr}	0.1	
S_{wc}	0.1	
S_{or}	0.1	

Water and Oil phase relative permeabilities are modeled as follows:

$$k_{rw}=0.20*((S_w-0.1)/0.8)^{4.2} \text{ (Water)} \quad \text{(A1)}$$

$$k_{ro}=0.94*((1-S_w-0.1)/0.8)^{1.3} \text{ (Oil)} \quad \text{(A2)}$$

Water and CO_2 phase relative permeabilities are represented by the following relationships:

$$k_{rw}=0.20*((S_w-0.1)/0.8)^{4.2} \text{ (Water)} \quad \text{(A3)}$$

$$k_{rg}{}^{0} = 0.94*((1-S_w-0.1)/0.8)^{1.3} \text{ (CO_2 without foam)} \quad \text{(A4)}$$

In these models, foam reduces the CO_2 relative permeability, using the steady-state assumptions, as follows:

$$k_{rg}^{f} = k_{rCg}^{0} * \frac{1}{1+fmmob * Fwater} \quad (A5)$$

Where:

$$F_{water} = 0.5 + \pi^{-1} tan^{-1}[epdry(Sw - fmdry)] \quad (A6)$$

where fmdry and epdry are empirical parameters based on experimental data.

In the example by Ashoori et al., 2010, the following parameters were utilized:

Table A2: Foam Parameters used for Analytical Simulations

fmmob	55000
fmdry	0.316
epdry	1000
epsurf	100

Using these parameters, fractional flow curves for foam/water, CO_2/water and oil/water phases were reconstructed. Also, we used the two separate solutions; the first solution assumes an ideal displacement where the miscible fronts and the surfactant (foam) fronts travel at the same speed. For this to happen, there must be a minimal Surfactant adsorption as well as very favorable partitioning of the surfactant into the CO_2 phase. In the ideal displacement case, the solution paths are constructed by first drawing a tangent from the M=D=(1,1) point to the curve representing the fractional flow of foam, as shown in the figure below:

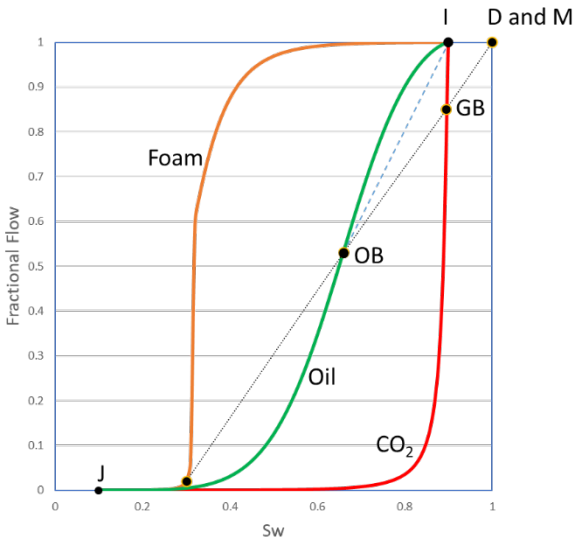

Fig. A1: Fractional flow – Ideal Displacement.

The saturation profile for the ideal displacement case is as follows:

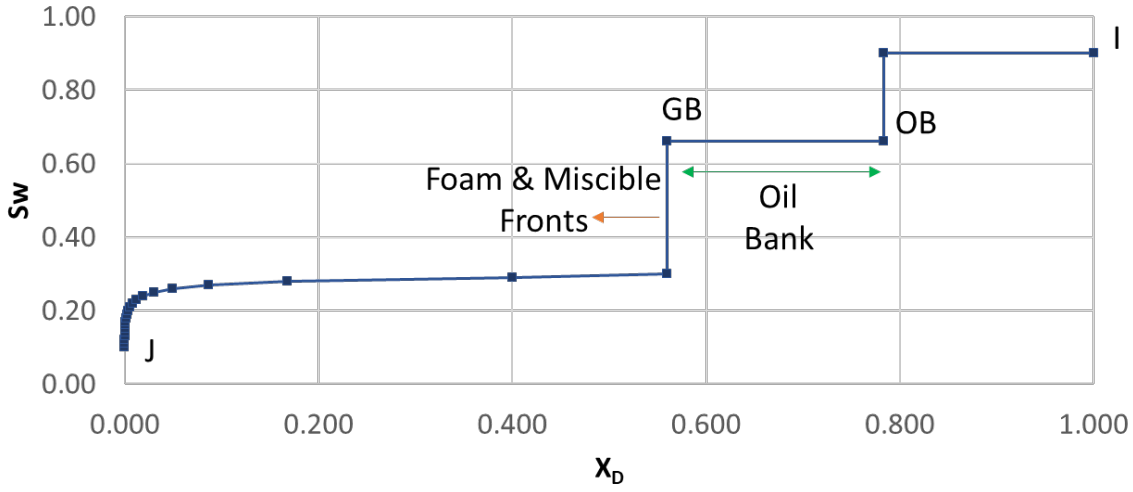

Fig. A2: Saturation profile – Ideal Displacement.

The second solution is non-ideal displacement where the miscible fronts and the surfactant (foam) fronts travel at different speeds. In this case, the surfactant adsorption as well as partitioning of the surfactant into the water phase slows down the speed of the foam (surfactant) front. On the other hand, the miscible (CO_2) front moves at the same speed as before. Therefore, miscible front shoots ahead of the foam (surfactant) front. Thus, a CO_2 bank forms. In this case, there are four different banks, and the construction of the solution paths starts first by drawing tangents from point D and the miscibility point, point M (1,1) to curves representing the fractional flow of oil and foam, respectively.

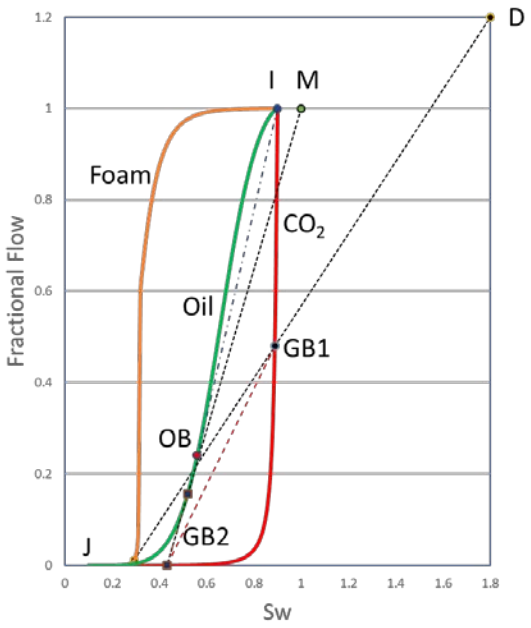

Fig. A3: Fractional flow, Non-Ideal displacement.

The saturation profile for the non-ideal displacement case is as follows:

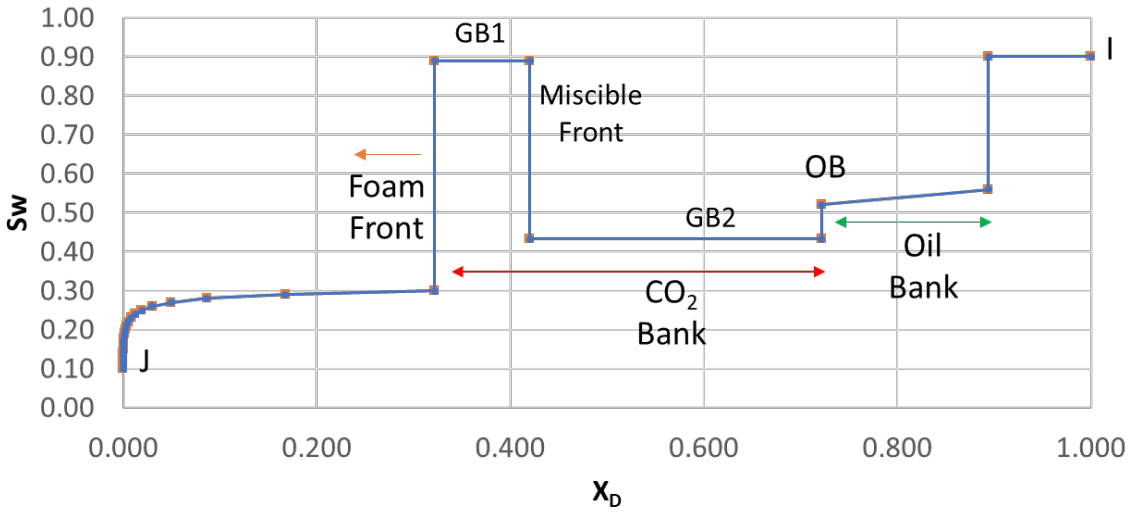

Fig. A4: Saturation profile, Non-Ideal displacement.

Appendix B – Population based Foam Model

Assuming one-dimensional flow of water and CO_2, the material balance of water is described by the following equation:

$$\phi \frac{\partial S_w}{\partial t} + u_t \frac{\partial f_w}{\partial x} = 0 \qquad \text{(B1)}$$

In this model, total flow rate (u_t) is assumed to be constant. As usual, water fractional flow is written as follows:

$$f_w = \frac{\frac{k_{rw}}{\mu_w}}{\frac{k_{rw}}{\mu_w} + \frac{k_{rco2}}{\mu^f_{co2}}} \qquad \text{(B2)}$$

where μ^f_{co2} is the CO_2– Foam viscosity and is given by (Hirasaki et al. 1985)

$$\mu^f_{co2} = \mu^0_{co2} + C_f \frac{n_f}{(\frac{u_{co2}}{\phi S_{co2}})^{1/3}} \qquad \text{(B3)}$$

In this equation, C_f is an empirical parameter based on experimental data.

Foam density ((n_f) equation is described by the following equation (Kovscek et al. 1995):

$$\phi \frac{\partial (S_{co2} n_f)}{\partial t} + u_t \frac{\partial (f_{co2} n_f)}{\partial x} = \varphi S_{co2} (r_g - r_c) \quad \text{(B4)}$$

The rate of foam generation is given by

$$r_g = C_g \nabla p^m \quad \text{(B5)}$$

and the rate of foam coalescence is given by

$$r_c = C_c n_f \left(\frac{S_w}{S_w - S_w^*}\right)^n \quad \text{(B6)}$$

Where C_g, C_c, m and n are model parameters. S_w^* is the water saturation linked with the critical capillary pressure for a foam–water system. In high permeability reservoirs, S_w^* is expected to be small. Also, the foam behavior around the critical water saturation could be quite abrupt.

The water rate is given by

$$u_w = - \frac{k\, k_{rw}}{\mu_w} \nabla p_w \quad \text{(B7)}$$

and the foam rate is given by:

$$u_{co2} = - \frac{k\, k_{rco2}}{\mu^o_{co2}} (\nabla p_w - \nabla p_c) \quad \text{(B8)}$$

At steady state conditions, the foam generation rate is equal to the foam destruction (or coalescence) rate.

$$r_g = r_c \quad \text{(B9)}$$

when this relationship is inserted into the foam-viscosity equation:

$$\mu^f_{co2} = \mu^0_{co2} + C_f \frac{n_f}{(\frac{u_{co2}}{\phi S_{co2}})^{\frac{1}{3}}} \quad \text{(B10)}$$

the following relationship is obtained, representing the foam viscosity:

$$\mu^f_{co2} = \mu^0_{co2} + \frac{C_g C_f}{C_c} \frac{\nabla p^m}{(\frac{S_w}{S_w - S_w^*})^n (\frac{u_{co2}}{\phi S_{co2}})^{\frac{1}{3}}} \quad \text{(B11)}$$

Appendix C - Sensitivity Coefficients

For a single-measurement (pressure) case, the Model response is defined as follows:

$$M(X) = \nabla p_{mod} (\bar{X}) \quad \text{(C1)}$$

Where M is a matrix representing the model response and X is a vector representing the system unknowns:

$$X = \text{foam parameters } [X_1, X_2, X_3, \ldots X_i \ldots, X_p] \quad \text{(C2)}$$

where p is the total number of unknows. In this case, the Sensitivity Coefficients are defined as follows:

$$S(X) = [\nabla_x M^T(X)] \quad \text{(C3)}$$

and the Sensitivity Matrix for the Single Response Case is defined as follows:

$$S = \begin{bmatrix} M_{11} \ldots\ldots\ldots\ldots M_{1p} \\ M_{k1} \ldots\ldots\ldots\ldots M_{kp} \end{bmatrix} \quad \text{(C4)}$$

or

$$S = \begin{bmatrix} \frac{\delta M_1}{\delta x_1} \ldots\ldots\ldots \frac{\delta M_1}{\delta x_p} \\ \frac{\delta M_k}{\delta x_1} \ldots\ldots\ldots \frac{\delta M_k}{\delta x_p} \end{bmatrix} \quad \text{(C5)}$$

where k is the number of measurements. Sensitivity of the Model response (M_i) to parameter vector X_j is defined as follows:

$$S^{(l)}_{ij} = \frac{\delta M_i}{\delta x_j} \Big|_{x^{(l)}} \quad \text{(C6)}$$

where $X^{(l)}$ represents the parameter vector which was used in generating the forward simulations.

Appendix D – Conductivity of Fluid Mixtures

Conductivity of fluid mixtures in porous media can be represented using the mixing law (Montaron, B., 2009). For a rock saturated with fluids, the total conductivity is expressed by the following equation:

$$\sigma^{1/2} = vf_1 \sigma_1^{1/2} + vf_2 \sigma_2^{1/2} + vf_3 \sigma_3^{1/2} \quad \text{(D1)}$$

where σ_i and vf_i represent the conductivity and the volumetric fraction of each component (rock and fluid), respectively. Additionally, the total volumetric fraction can be written as:

$$vf_1 + vf_2 + vf_3 = 1.0 \quad \text{(D2)}$$

for a water and oil/gas/CO_2 system these relationships become:

$$\sigma_1 = \sigma_R = 0, \qquad vf_1 = 1 - \phi \quad \text{(D3)}$$

$$\sigma_2 = \sigma_o = 0, \qquad vf_2 = S_o \phi \quad \text{(D4)}$$

$$\sigma_3 = \sigma_w, \qquad vf_3 = \sigma_w \phi \quad \text{(D5)}$$

and using the mixing law, we obtain:

$$\sigma = \sigma_w (S_w \phi)^2 \quad \text{(D6)}$$

This result is similar to Archie's law:

$$\sigma = \frac{\sigma_w S_w^n \phi^m}{a} \quad \text{(D7)}$$

where a, n and m are constants. For a CO_2-Foam and water system, the mixing law equations become:

$$\sigma_1 = \sigma_R = 0, \qquad vf_1 = 1 - \phi \quad \text{(D8)}$$

$$\sigma_2 = \sigma_f, \qquad vf_2 = S_{co2}^f \phi \quad \text{(D9)}$$

$$\sigma_3 = \sigma_w, \qquad vf_3 = \sigma_w \phi \quad \text{(D10)}$$

and finally:

$$\sigma = \phi^2 [S_{co2}^f \sigma_f^{1/2} + S_w \sigma_w^{1/2}]^2 \quad \text{(D11)}$$

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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.

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

Manuscript Style Instruction (Optional)

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

Structure and Format of Manuscript

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

A research paper must include:

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

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

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

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

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

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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.

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

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

Tables, Figures, and Figure Legends

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

Figures

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

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

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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.

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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.

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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.

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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.

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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:

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- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
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- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
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- Avoid use of extra pictures—include only those figures essential to presenting results.

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

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

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

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

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

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

Approach:

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

Introduction:

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

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

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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.

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- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
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- Do not present similar data more than once.
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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."

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- 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.
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- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

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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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