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Survey on Applications Numerical Methods in Engineering

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Abstract: ***Numerical methods assist us in solving problems swiftly and effectively on comparison with analytic solutions. Either while integrating or when solving complex differential equations, numerical methods are easier and accurate whereas it may be quite difficult using analytical mathematics or simple algebra. Numerical analysis is a proficient tool to handle large systems of equations, nonlinearities, and complicated geometries which are omnipresent in engineering disciplines and which are often non-viable or difficult to interpret analytically. Numerical methods are highly recommended tools for engineers to solve problems in their domains.***
Keywords: Numerical analysis, Mechanical, Electrical, Civil, Data engineering, Production engineering and Research.

I. INTRODUCTION

Mathematics is used by people of all walks of life. It is often used to estimate possible solutions, given a previously existed set of data. This is made simple by the use numerical analysis. With the development of mathematical theory and computer hardware, various numerical methods are proposed. The new numerical methods or their new applications lead to important progress in the related fields. We can note that numerical simulation using ANSYS, MATLAB, and Python etc. has eased many calculations, so mathematicians and engineers are using these programming languages' assistance in their research and development works. Current paper deals with cutting edge advances in field of engineering and science which uses numerical analysis.

A. Electrical And Electronic Engineering

1) The article 'Interpolation/Extrapolation and Its Application to Solar Cells[1]' checks the limit of the solar cell by calculating parameters using Newton's forward and backward interpolation, and by using Lagrange's interpolation. Due to very high cost of Si solar cells, organic solar cells are recognized as the important sources to produce cheap and clean energy. It has attracted scientific and social-economic interest induced by a rapid increase in power conversion efficiencies. The thought of interpolation is to select a function g(x) such g(x1) = f1 for each datum i which this function could also be a decent approximation for the opposite x lying between the initial data points.

2) The article 'Numerical Analysis of Planar Light-Emitting Diode with Designed P-Electrode' [2], deals with numerical analysis of the LED with top metal electrode designed as a mesh. In order to determine optical geometrical parameters of the meshed contact leading to maximum optical output, here they have used Monte Carlo Ray Tracing (MCRT) or Finite Difference Time Domain (FDTD) techniques. Numerical method and simulation strategy are developed to evaluate optical output performance of the LED with the top metal electrode patterned as a mesh. The developed process is used to simulate spatial distribution of output power along the mesh windows and total optical power of LED.

3) In the article 'Application of Numerical Methods in Calculation of Electromagnetic fields in Electrical Machines' [3], Finite Element Method(FEM) is used in solving the set of Maxwell's equations to obtain the value of magnetic vector potential and magnetic flux density in all parts of machine cross section. In the paper mentioned, three different machines are analysed. Numerical Methods are used in calculation of electromagnetic fields inside electro-mechanical devices. FEM can be applied to calculate Maxwell's equation. By FEM we identify the machine parts that are weaker. For instance parts where flux density peaks and machine operates almost at saturation point of magnetic core.

4) 'In the article Numerical Analysis of a Real photovoltaic module with various parameters' [4], a model of the photovoltaic module is developed and also the influence of some parameters are analysed as series and parallel resistances, temperature, and solar irradiation over PV module output characteristics. Simulations of module characteristics realized considering the real data of a PV module ALTIUS AFP 235 and a thermal analysis and thermal simulation is additionally realized. Here temperature influence over the PV module performance is analysed by employing a thermal model of the ALTIUS AFP-235W using the Finite Element Method (FEM).

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5) In the article 'A Numerical Method for Analysing Electromagnetic Scattering Properties of a Moving Conducting Object' [5], a unique numerical approach investigates electromagnetic Scattering properties of a moving, conducting object, based on the Finite Difference Time Domain (FDTD) algorithm. The broadband electromagnetic Scattering properties of the moving conducting surface are obtained by the Fast Fourier transform (FFT). Here Electromagnetic Scattering from a moving, perfectly conducting object, in the steady state of single frequency to transient state of a broadband, has been analyzed by the numerical methods based on the FDTD algorithm.

6) Results of the article 'Numerical Methods for the Analysis of Power Transformer Tank Deformation and Rupture Due to Internal Arcing Faults' [6], indicates increase in pressure and mechanical stress distribution are non-uniform. Also stress concentrates on interlinking components of the tank with increase in time. This paper analyses the mechanical response of tank wall under internal over-pressure due to the high energy arc fault in a 360 MVA/220 kV oil-immersed power transformer through a 3-Dimensional numerical model using finite element analysis.

7) In the article 'Numerical Methods for Semiconductor Device Simulation' [7], numerical techniques utilized in solving the coupled system of nonlinear partial differential equations which model semiconductor devices are discussed. During this they have used both a finite-difference and a finite-element approach to discretization. These numerical techniques accustomed to solve the coupled system of non-linear partial differential equations describing the intrinsic behaviour of semiconductor devices.

8) In the article 'Numerical method for power losses minimization of vector-controlled induction motor' [8], maximization of energy efficiency of the induction motor under part- load conditions is discussed. The paper provides algorithm based on the golden section technique to search for the optimal value of rotor flux current. The article makes further developments to search control direct optimization methods. Proposed method produces smooth trajectory of i_{sd} and faster than ramp-based techniques.

9) In the article 'Numerical Analysis of a $LiFePO_4$/ Graphite Lithium-ion Coin-cell Battery' [9], a $LiFePO_4$/ Graphite lithium-ion battery sealed in a CR2032-type coin cell offs is numerically analysed. COMSOL Multiphysics, a tool for Finite element analysis, is used in this work. Results are compared to those of $LiCoPO_2$ and $LiMn_2PO_4$ cathodes. This article mainly studied about the simulation results of a $LiFePO_4$/ Graphite lithium-ion coin cell battery. At low discharge rates, the decrease of the cell voltage of $LiFePO_4$/ Graphite before depletion is slower than those of other cathode materials, which would be beneficial in industrial applications of $LiFePO_4$ in near future.

10) The article 'The numerical method of inverse Laplace transforms for calculation of over voltages in power transformers and test results' [10], presents a way for analysing and calculating voltage drops within the transformer windings by using a numerical method called inverse Laplace transform. There was a comparison between the numerically analysed and calculated step responses on a three-phase 30 KVA power transformer. The tests made on the transformer showed good agreement between the analysed and calculated results for the primary and last distributions and a meaningful deviation between the distributions throughout the transition period because of parameter imprecision within the transformer winding model.

B. Civil Engineering

1) In the article 'Analyzing the behaviour of hybrid steel system of tube in tube with bracing and belt truss' [11], numerical tools were used to compare two types of trusses. A braced tube system was chosen as an alternate to the tubular system as shear lag was eminent in the former. As the height of the structure increased, use of braced tube structure wasn't effective to regulate the lateral structures. So a mixture of braced tube with the inner tube belt truss was simpler. The results were drawn that the belt truss doesn't have a favourable impact on the shear lag within the flange, but it reduced the drift significantly. Also, by adding external bracing to the tube within the tube structure with belt trusses, the performance of the structure improved significantly within the aspect of shear lag, lateral displacement and absorption percent of the shear forces.

2) In the article 'Infrared Thermography and Numerical Methods in Civil Engineering' [12], on basis of surface temperature measurement, conclusions are drawn on the condition of the observed objects. For instance, in the buildings, thermography plays a vital role in the internal control, heat losses measurement and inspection. Thermographic analysis includes qualitative and quantitative interpretation of the results. In the work mentioned, analysis was done on some characteristic parts of facade and confirmed with numerical simulation. It is concluded that numerical simulations are useful aid to analyze thermograms.

3) In the article 'Application of Geophysical Methods in Civil Engineering' [13], discussion on the use of geophysical method to extend the effectiveness of applied science projects is taken. Geophysical methods are generally cheaper, less invasive and fast. They supply a large-scale characterization of the physical properties under undisturbed conditions. This method is successfully utilized in the applied science field and has the potential to be integrated with a standard method to supply reliable information

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thus enhance the project effectiveness during the planning and construction stages. Note here that a lot of parameters are to be considered in geophysical methods, but it can be made simple by the use of numerical analysis tools.

4) In the article 'Application of Analytical and Numerical Methods to the Sequent Depths Problem in Civil Engineering' [14], in order to find the sequent depths of channels whose sections are exponential or trapezoidal, they applied two different methods: *The Lagrange's Inversion Theorem*, which is analytical and provides an exact solution. Other by *The Householder's Methods*, which numerically approximates of the solutions by using an iterative algorithm. In general, the series obtained from Lagrange's theorem have fast convergence. Otherwise, if the convergence rate is low, we use the Householder's methods. Analytical and numerical methods were applied to solve the sequent depth problems. The results given were accurate and useful in situations where no computational resource was available and to provide accurate and fast converging algorithms for future civil engineering software. However, the methods and ideas here provided unexplored ways of solving civil engineering problems.

5) In the article 'Numerical Methods in Civil Engineering Nonlinear modelling of the infill wall based on the brittle cracking model' [15], a new numerical method for the analysis of infilled steel frames with hollow clay blocks was introduced. This approach was based on the brittle cracking model of ABAQUS. Results reveal that the brittle cracking model can be useful in assessing the behaviour of masonry infill walls. It was concluded that the separation of infill walls from the steel frames is quite helpful in reducing the inappropriate effects of infill walls on the overall behaviour of buildings. The brittle cracking model can be used in any loading regime and is 'user friendly 'and easy to calibrate.

6) In the article 'Curvature Method to Detect Location and Depth of a Plastic Zone in Frame Members during an Earthquake' [16], a new method for detecting beam and frame damage caused by an earthquake was proposed. This article deals with nonlinear damage detection in structures. The proposed method is based on employing of curvature of beams so as to detect plastic zones. The curvature vectors were calculated using data from acceleration recording points. In an effort to cut back costs of actual damage detection, the amount of accelerometers was reduced by use of cubic spline method of interpolation. An experimental study was operated to indicate the effectiveness of the proposed method with reasonable accuracy.

C. Mechanical Engineering

1) In the work 'Dynamic modelling of SCARA robot based on Udwadia-Kalaba theory' [17], dynamic modelling of SCARA robot is studied and enhanced by use of Udwadia-Kalaba equation. The Udwadia–Kalaba theory, dictates the motion of a constrained system that is subjected to equality constraints. Paper discusses usage of Baumgarte stabilization method to minimise constraint violation to get trajectories with great precision. Simulations were run to test the effectiveness of the SCARA robot.

2) In the article 'Optimization study on combustion in a 1000-MW ultra-supercritical double-tangential-circle boiler' [18] the improvements to 3-D full size structure of one 1000-MW ultra-supercritical double-tangential-circle boiler is numerically understood. The effects of primary and over-fire air velocity in addition to the jet shape on NO_x emanation are examined. Numerical methods describe the existence of two inverse elliptical flow fields and temperature fields. This article gives a theoretical basis for burner design improvement.

3) In the article 'Finite element analysis of the offshore reel-laying operations for double-walled pipe' [19] bending characteristics of double-walled pipe during offshore reel-lay operations are investigated by finite element method. The numerical analysis is used to give an understanding about strength of materials over a range of effective stress and strain. By numerical methods and tools, the successful spooling of pipe onto a reel can be calculated for the desirable range of bending strain rate, prior to execution.

4) In the article 'Discrete element method simulations of load behaviour with mono-sized iron ore particles in a ball mill' [20], the geometrical shape of the mono-sized iron ore particles is established by the sphere-clump method. Through DEM simulations, the consequences of mill speed and lifter on the load behaviour of iron ore particles in a ball mill is studied. The current paper potentially improves the high-performance liners and hones the mill speed in the pre-design stage itself.

5) In the article 'Three-dimensional numerical study on flow dynamics characteristics in supercritical water fluidized bed with consideration of real particle size distribution by computational particle fluid dynamics method' [21] the detailed flow behaviours inside a supercritical water fluidized bed is studied, using computational particle fluid dynamics method considering the limitation of the two-fluid method and discrete element method. From the numerical understanding, the writers mention that the diametric distribution of particles should not be large in the practical industrial operations.

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6) In the article 'An improved numerical method for the mesh stiffness calculation of spur gears with asymmetric teeth on dynamic load analysis' [22], authors use MATLAB and finite element methods to detect the single-tooth stiffness and gear pair mesh stiffness for different types of spur gears with asymmetric teeth. Numerical analyses by use of above mentioned tools, shows dynamic gear loads are affected by mesh stiffness. So designers should take note of the mesh and tooth stiffness for the dynamic analysis of gears with asymmetric teeth.

D. Data Engineering

In the article 'Data Science: The impact of statistics' [23], shows numerical methods are one of the most important methods to provide find the structures in and to get deeper insight to the data. The article gives an overview of different proposed structures in data science and addresses the impact of statistics in data acquisition, enrichment, exploration, analysis and modelling, validation, representation and reporting. In particular, for the areas of data acquisition, enrichment and advanced modelling needed for prediction. Statisticians can play major role in exceptional field of Data Science.

E. Production Engineering

In the article **'**Analysis of vertical, horizontal and deviated wellbores stability by analytical and numerical methods' [24], the author discussed about the wellbore stability problems. This paper which has relevancy to the oil and gas industry compares four rock failure criteria, named the *Mohr–Coulomb, Mogi–Coulomb, Modified Lade* and *Tresca* yield criterion and to use them to figure out the optimum drilling direction and mud pressure. In order to show the accuracy of the predicted mud pressure the finite difference method was used. The *Mohr–Coulomb* and *Tresca* criteria estimated the best possible minimum mud pressure while the *Mogi–Coulomb* and therefore the *Modified Lade* criteria estimate the least minimum mud pressure.

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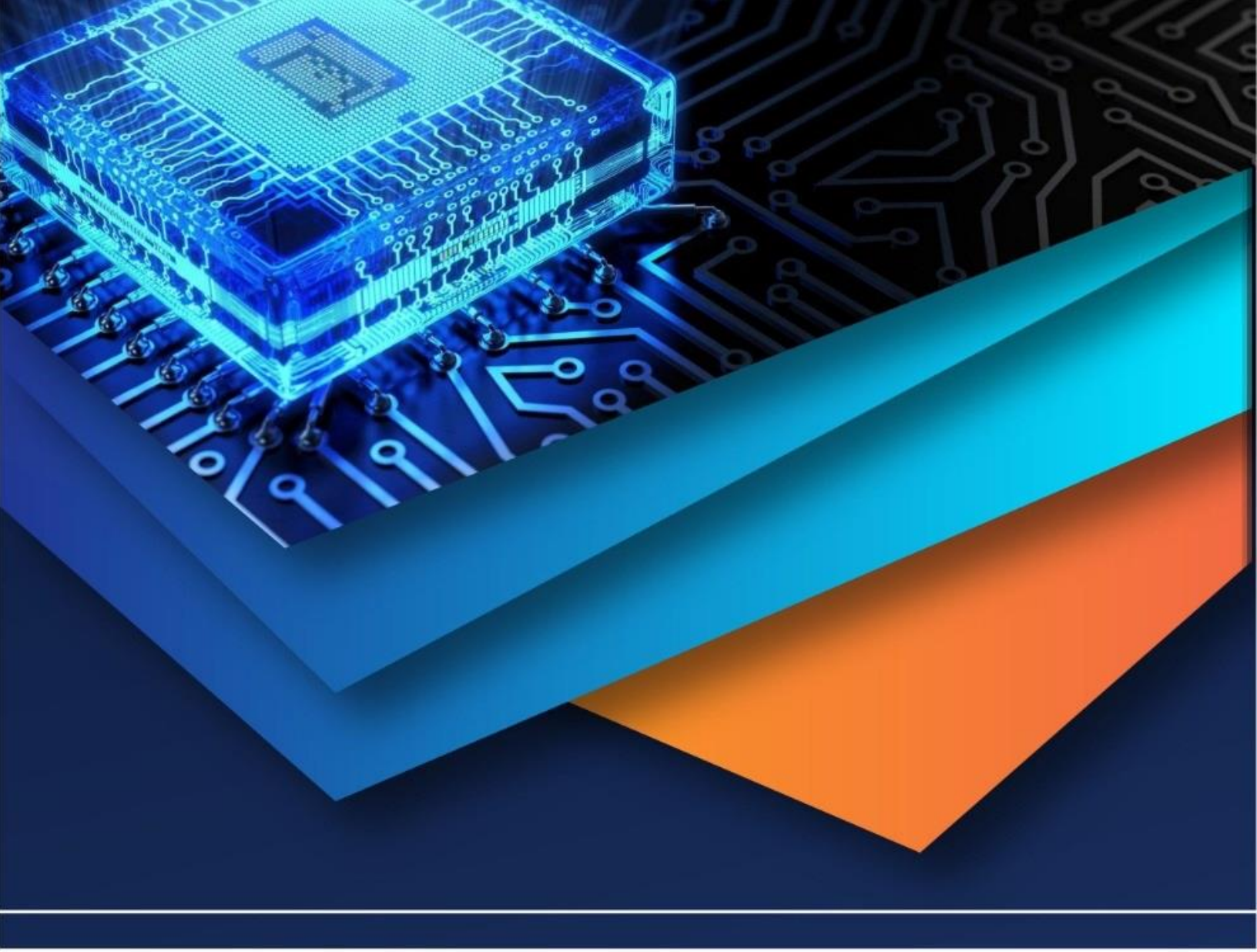
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