Role of Numerical Analysis in the Field of Manufacturing Technology

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Abstract –Numerical analysis is the process of developing a model (physical of mathematical) of a real system and conducting experiments with this model for the purpose either of understanding the behavior of the system or of evaluating the probable performance of the system within the limits by a criterion of set of criteria for the operation of the system. A model intended for simulation study is a mathematical model developed with the help of simulation software. Precisely, in the broader sense, simulation is a tool to evaluate the performance of a system, existing or proposed, under different configurations of interest and over long periods of real time. Simulation is used before an existing system is altered, or a new system built, to reduce the chances of failure to meet specifications, to eliminate unforeseen bottlenecks, to prevent under or over utilization of resources, and to optimize system performance. Simulation may be defined as the process of developing a model is physical or mathematical of a real system and conducting experiments with this model for the purpose either of understanding the behavior of the system or of evaluating the probable performance of the system within the limits imposed by a criterion of set of criteria for the operation of the system. In many cases the models are used as a basis for simulation. Simulation is a very important field of computing whereby softwares may be designed to help simulate by making models, set up conditions and observe the results. Simulation is method is also used to study the dynamics of systems. The term systems is used to mean a group of limits which operates in some interrelated manner. The approach is applicable not only in engineering field but also in other fields such as medical science, nuclear science, agriculture, Finance and astronomy.

Key words - Numerical analysis, manufacturing science, modeling methods

1. INTRODUCTION

An overview of simulation modeling and analysis is recent advancements in this field, recommendations for selecting right simulation software, related technologies like artificial intelligence techniques, how they are integrated with computer simulation modeling and benefits due to development of these hybrid technologies[1,2]. Simulation is a technique of systems modeling and analysis that involves mathematical models of a dynamic nature which are solved numerically. In the field of manufacturing it is of prime importance for modern management to make crucial decisions quickly and accurately to stand at the global competitive cutting edge. In many real life situations the main interest concern the prediction of how a system will perform under various conditions of change in the environment as well as within the system[3,4,5].

Experimenting on real system is not always feasible, so it is carried on some representative unit of the system. This unit is called a model and the process modeling. Simulation is a powerful and scientific method, which is widely, applied methodology for studying the behaviour of a variety of systems in order to develop solutions to problems in their design and operation. Computer simulation is one of the popular experimental investigation techniques as it involved reduced costs, time and risks compared to experimenting decision alternatives with real world system in real time[6,7].

Modeling is the art of abstracting or representing the object, system or phenomenon. The geometric modeling is defined as the complete representation of an object with the graphical and non-graphical information[8,9]. It generates the mathematical description of the geometry and non-geometry of an object in the computer database and the image of an object on the graphic screen. In the computer simulation, developing the models of the real systems on the computer has carried out experimentation[10].The use of simulation mathematical models has been proposed to reduce the computer costs of simulation while making use of its potential of predicting the performance of complex system.

2. FINITE ELEMENT ANALYSIS

Finite Element Analysis (FEA) was first developed by R. Courant. Who utilized the Ritz method of numerical analysis and minimization of variational calculus to obtain approximate solutions to vibration systems. By the early 70's, FEA was limited to expensive mainframe computers generally owned by the aeronautics, automotive, defense, and nuclear industries. Since the rapid decline in the cost of computers and the phenomenal increase in computing power, FEA has been developed to an incredible precision. Present day supercomputers are now able to produce accurate results for all kinds of parameters.FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new design of product , and existing product refinement. A company is able to verify a proposed design will be able to perform to the client's specifications prior to manufacturing or construction. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition.

There are generally two types of analysis that are used in industry: 2-D modeling, and 3-D modeling. While 2-D modeling conserves simplicity and allows the analysis to be run on a relatively normal computer, it tends to yield less accurate results. 3-D modeling, however, produces more accurate results while sacrificing the ability to run on all but the fastest computers effectively. Within each of these modeling schemes, the programmer can insert numerous algorithms (functions) which may make the system behave linearly or non-linearly. Linear systems are far less complex and generally do not take into account plastic deformation. Non-linear systems do account for plastic deformation, and many also are capable of testing a material all the way to fracture.

FEA uses a complex system of points called nodes which make a grid called a mesh. This mesh is programmed to contain the material and structural properties which define how the structure will react to certain loading conditions. Nodes are assigned at a certain density throughout the material depending on the anticipated stress levels of a particular area. Regions which will receive large amounts of stress usually have a higher node density than those which experience little or no stress. Points of interest may consist of fracture point of previously tested material, fillets, corners, complex detail, and high stress areas. The mesh acts like a spider web in that from each node, there extends a mesh element to each of the adjacent nodes. This web of vectors is what carries the material properties to the object, creating many elements. A wide range of objective functions (variables within the system) are available for minimization or maximization:

- Mass, volume, temperature
- Strain energy, stress strain
- Force, displacement, velocity, acceleration
- Synthetic (User defined)

There are multiple loading conditions which may be applied to a system.

- Point, pressure thermal, gravity, and centrifugal static loads
- Thermal loads from solution of heat transfer analysis
- Enforced displacements
- Heat flux and convection
- Point, pressure and gravity dynamic loads

Each FEA program may come with an element library, or one is constructed over time. Some sample elements are:

- Rod elements
- Beam elements
- Plate/Shell/Composite elements
- Shear panel
- Solid elements
- Spring elements
- Mass elements
- Rigid elements
- Viscous damping elements

Many FEA programs also are equipped with the capability to use multiple materials within the structure such as:

- Isotropic, identical throughout
- Orthotropic, identical at 90 degrees
- General anisotropic, different throughout

3. TYPES OF ENGINEERING ANALYSIS

Structural analysis consists of linear and non-linear models. Linear models use simple parameters and assume that the material is not plastically deformed. Non-linear models consist of stressing the material past its elastic capabilities. The stresses in the material then vary with the amount of deformation. Vibrational analysis is used to test a material against random vibrations, shock, and impact. Each of these incidences may act on the natural vibrational frequency of the material which, in turn, may cause resonance and subsequent failure.

Analysis helps designers to predict the life of a material or structure by showing the effects of cyclic loading on the specimen. Such analysis can show the areas where crack propagation is most likely to occur. Failure due to fatigue may also show the damage tolerance of the material .Heat Transfer analysis models the conductivity or thermal fluid dynamics of the material or structure. This may consist of a steady-state or transient transfer. Steady-state transfer refers to constant thermo properties in the material that yield linear heat diffusion.

The basic idea in the finite element method is to find the solution of complicated problem with relatively easy way. The finite element method has been a powerful tool for the numerical solution of a wide range of engineering problem. Applications range from deformation and stress analysis of automotive, aircraft, building, defence, missile and bridge structures to the field of analysis of dynamics, stability, fracture mechanics, heat flux, fluid flow,magnetic flux, seepage, and other flow problems. With the advances in computer technology and CAD systems, complex problems can be modeled with relative case. Several alternate configurations can be tried out on a computer before the first prototype is built. The basics in engineering field are must to idealize the given structure for the required behaviour. The proven knowledge in the typical problem area, modeling techniques, data transfer and integration, computational aspects of the finite element method is essential. In the finite element method, the solution region is considered as built up many small, interconnected subregions called finite elements.

Most often it is not possible to ascertain the behaviour of complex continuous systems without some sort of approximations. For simple members like uniform beams,plates etc., classical solutions can be sought by forming differential and / or integral equations through structures like machine tool frames, pressure vessels,automobile bodies, ships,air craft structures,domes etc., need some approximate treatment to arrive at their behaviour, be it static deformation, dynamic properties or heat conducting property. Indeed these are continuous systems with their mass and elasticity being continuously distributed. The classical differential equation solution approach leads to intractability. To overcome this, engineers and mathematicians have from time to time proposed complex structure is defined using a finite number of well difined components. Such systems are then regarded as discrete systems. The discritization method could be finite difference approximation, various residual procedures etc.

4. NEED OF FEM

The need of finite element method to predict the behaviour of structure the designer adopts three tools such as analytical, experimental and numerical methods. The analytical method is used for the regular sections of known geometric entries or primitives where the component geometry is expressed mathematically. The solution obtained through analytical method is exact and takes less time. This method cannot be used for irregular sections and the shapes which required very complex mathematical equations. On the other hand the experimental method is used fro finding the unknown parameters of interest.

But the experimentation requires a testing equipment and a specimen for each behaviour of requirement. This in turn, requires a high initial investmest to procure the equipment and to prepare the specimens. The solution obtained is exact by the time consumed to find the results and during preparation of specimens also more. There are many numerical schemes such as finite difference methods, finite element method, boundary element and volume method, finite strip and volume method and boundary integral methods etc., are used to estimate the approximate solutions of acceptably tolerance. The finite element method is so popular because of its favourably towards use of digital computers. The finite element method predicts the component behaviour at desired accuracy of any complex and irregular geometry at least price.

Non linear finite element analysis and applications as in structural mechanics, a problem is nonlinear if the stiffness matrix or the load vector depends on the displacement. Non linearity in structures can be classed as material non linearity or as a geometric non linearity. A change configuration may cause loads to alter their distribution and magnitude or cause gaps to open or close. Mating parts may stick or slip,forming and extrusion processes must be analyzed in an attempt to reduce the production costs.

The various material non linearities are plasticity, creep, other complex constitutive relations, in flow type situations the dependendance of viscosity on velocity distribution. These material non linear problems can often be simply dealt without reformulation of the discetization precedes indeed,if a solution to the linear problem can be arrived at by some trial and error process in which, at the final stage. The material constants are so adjusted that the appropriate new constitutive law is satisfied, that a solution is achieved. One important point needs, However, to be mentioned while in linear problems the solution was always unique this no longer is the case in many non linear situations.

5. MODELLING SOFTWARES

There are many solid modeling software available to do the modeling, some of the familiar are given below as

1. I-DEAS
2. PRO-E
3. SOLID-EDGE
4. IRON-CAD
5. SOLID WORKS
6. UNI-GRAPHICS

6. RESULTS OF NUMERICAL ANALYSIS

FEA has become a solution to the task of predicting failure due to unknown stresses by showing problem areas in a material and allowing designers to see all of the theoretical stresses within. This method of product design and testing is far superior to the manufacturing costs which would accrue if each sample was actually built and tested.

Fluid flow - FLOTRAN CFD

The ANSYS/FLOTRAN CFD (Computational Fluid Dynamics) offers comprehensive tools for analyzing twodimensional and three-dimensional fluid flow fields. ANSYS is capable of modeling a vast range of analysis types such as: airfoils for pressure analysis of airplane wings (lift and drag), flow in supersonic nozzles, and complex, three-dimensional flow patterns in a pipe bend. In addition, ANSYS/FLOTRAN could be used to perform tasks including:

- Calculating the gas pressure and temperature distributions in an engine exhaust manifold
- Studying the thermal stratification and breakup in piping systems Using flow mixing studies to evaluate potential for thermal shock
- Doing natural convection analyses to evaluate the thermal performance of chips in electronic enclosures
- Conducting heat exchanger studies involving different fluids separated by solid regions

FLOTRAN analysis provides an accurate way to calculate the effects of fluid flows in complex solids without having to use the typical heat transfer analogy of heat flux as fluid flow. Types of FLOTRAN analysis that ANSYS is able to perform include:

- Laminar or Turbulent Flows
- Thermal Fluid Analysis
- Adiabatic Conditions
- Free surface Flow
- Compressible or incompressible Flows
- Newtonian or Non-Newtonian Fluids
- Multiple species transport

7. CONCLUSIONS

The conclusions are drawn from role of numerical analysis in the area of manufacturing as follows. In the computer simulation, developing the models of the real systems on the computer has carried out experimentation. The use of simulation metamodels has been proposed to reduce the computer costs of simulation while making use of its potential of predicting the performance of complex system. This analysis for application of modeling and simulation techniques can be used in various areas in solving of practically oriented problems such as banking systems, traffic management, production, manufacturing, thermal problems, etc.

The outstanding results of using this technique in critical field make this analysis even more beneficent than ever. The procedure involved in a simulation model developing, simulation experiment designing and performing analysis of simulation are identifying the problem, formulate the problem, collect and process input data, develop simulation model, validate the model, document model for future use, select the appropriate determine the sample size, performs the simulation runs, and collect, analyze and implement the results.

A good model is a judicious tradeoff between realism and simplicity. Finally this concludes analysis, to view the mathematical modeling process in the simplest form as an iterative multi step process and the simulation in project network techniques, although very popular is found to yield overly optimistic results. Hence, computer simulation has been accepted as powerful decision making tool in the advanced manufacturing environment. Finite element analysis simulation is to mimic the real system by developing its theoretical model. A model should be a close approximation to the real system and incorporate its most of its salient features with appropriate assumptions.

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