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Design, Modeling, Simulation and Analysis Compress Spring

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***Abstract:** The accuracy of the simulation model has been thoroughly verified, with the aid of a wide Varity of experiments .Computer technology has touched all areas of today's life, impacting how we obtain railway tickets, shop online and receive medical advice from remote location, computer-based design analysis is nowadays a common activity in most development projects. Compression springs are open-coil helical springs that offer resistance to a compressive force applied axially. They are usually coiled as constant diameter cylinders. Other common forms of compression springs, such as conical, tapered, concave, or convex springs or various combinations of these, are used as required by the application. While square, rectangular, or special-section wire may have to be required, round wire is predominant in compression springs because it is readily available and adaptable to standard tooling. The scope of this work include, to design, model and simulate compressive spring , to select materials for spring and also to detailed factor of safety in design process. Spring designing is a complex process. It is an interactive process which may require several iterations before the best design is achieved. Many simplifying assumptions have been made in the design equations, and yet they have proved reliable over the years. When more unusual or complex designs are required, designers should rely on the experience of a spring manufacturer. Those who design machines and who have an interest in productivity and cost control serve their "customers" well if risks are at a minimum, as interruptions called accidents will also be at a minimum. There are two types of heat treatment of springs: low- heat treatment of pre strengthened materials and high-temperature heat treatment to strengthen annealed materials. Low temperature heat treating, sometimes called stress relieving is by far the more common process. Its purposes are to stabilize the spring dimensionally, relieve excessive residual stresses, and increase the yield strength of cold-drawn materials. Stress relief is accomplished in certain beryllium copper and nickel base alloys with a heat-treatment process called age hardening. A quality approach to engineering design usually mandates physical testing as the final means of validating structural integrity to a measured precision*

I. INTRODUCTION

Super Springs was established in 1984 with a vision of manufacturing Superior quality springs for different industrial applications. Simple non-coiled springs were used throughout human history e.g.,the bow (and arrow). In the Bronze Age more sophisticated spring devices were used, as shown by the spread of tweezers in many cultures. Ctesibius of Alexandria developed a method for making bronze with spring-like characteristics by producing an alloy of bronze with an increased proportion of tin, and then hardening it by hammering after it is cast. Coiled springs appeared early in the 15th century, in door locks. The first spring powered-clocks appeared in that century and evolved into the first large watches by the 16th century. In 1676 British physicist Robert Hooke discovered the principle behind springs' action, that the force it exerts is proportional to its extension, now called Hooke's law. There are two types of main springs a non-coiled spring and a coiled spring. The non-coiled spring has been around forever. A great example of a non-coiled spring is a bow and arrow. A bow and arrow has been around to help with food and protection. This is one of the earliest spring technologies. Anytime a string is tightened to create a bounce, that can be considered a “spring”. In the 1300’s there was spring technology being used in chariots. Chariots had a complex spring and suspension system built in, that helped give them more miles. In the 18th century the French put on a plate, onto a carriage. This metal plate is considered a leaf spring, it was the first ever leaf spring used on a vehicle. In 1493, Leonardo Da Vinci built the first spring into a pistol. This spring was customized just for the pistol. It made it possible for the pistol to be shot off in a single hand. This spring was the beginning of revolutionizing the gun. Guns today use all sorts of spring technology to make guns work efficiently. It wasn’t until 1763 when R. Tradwell invented the first ever coiled spring. It was a Brittish patent, number 792. It was considered a step up from the leaf spring. The leaf spring had to be lubricated often and was quite squeaking. The best was that the spring didn’t have to be spread apart. The word coil meant to wind cylindrically or spirally. In the year 1857 the first ever steel coil spring was invented. It was used for chair seats. Ever since the inventions of these coil springs, springs have been used in everything from shoes to trampolines. Springs help make the car industry what it is today. Springs are used in every type of machinery and they really do help make the world go around see fig;1 the working diagram of spring.

Simulation is a powerful approach to modeling manufacturing systems in that many complex and diverse systems can be represented. Can predict system performance measures that are difficult to assess without a model. It is a proven, successful tool and has been in use since the 1950s. The current languages take advantage of the capabilities of today’s microprocessors and provide the user with the needed on-line support for model development, management, and analysis. CAD (computer-aided design) has its roots in interactive computer graphics. Before the CAD era, engineering drawings were prepared manually on paper using pencils and drafting instruments on a drafting table. The advent of interactive computer graphics replaced the drafting table with a computer monitor and the pencil with an input device such as a light pen or mouse. Instead of using physical drafting instruments, software commands and icons on the computer display are used. The drawing can be created, modified, copied, and transformed using the software tools. At the time, CAD stood for computer-aided drafting. Drafting was confined to 2D because of the paper limitation. With the computer, such limitation is removed. CAD systems were developed in the 1960s. In 3D CAD, objects are modeled using 3D coordinates (x, y, and z) instead of 2D coordinates (x and y). The need for modeling parts and products with complex surfaces motivated the development of free-form surface modelers. A **coil spring**, also known as a helical spring, is a mechanical device, which is typically used to store energy due to resilience and subsequently release it, to absorb shock, or to maintain a force between contacting surfaces. They are made of an elastic material formed into the shape of a helix which returns to its natural length when unloaded. One type of coil spring is a torsion spring: the material of the spring acts in torsion when the spring is compressed or extended. The quality of spring is judged from the energy it can absorb. the spring which is capable of absorbing the greatest amount of energy for the given stress is the best one. Metal coil springs are made by winding a wire around a shaped former -a cylinder is used to form cylindrical coil springs. Tension/extension coil springs, designed to resist stretching. They usually have a hook or eye form at each end for attachment. Compression coil springs, designed to resist being compressed. A typical use for compression coil springs is in car suspension systems. Torsion springs, designed to resist twisting actions. Often associated to clothes pegs or up-and-over garage doors

II. SUITABLE MATERIALS

There are five major metallurgical classifications of wire spring materials: (1) high carbon steel, (2) alloy steel, (3) stainless steel, (4) nickel-base alloys, and (5) copper base alloys. In selecting spring materials, the designer must consider such factors as temperature and corrosion resistance, conductivity, physical properties, formability, and availability. When there are a large number of stress cycles and a long fatigue life is therefore required, the quality of the material must be tightly controlled. The wire material must have a uniform internal structure, and its surface must be free of pits, seams, scratches, and any other flaws that can impair its fatigue life. The most common long-service materials are high-carbon steels or alloy steels, since both can be obtained free of seams and of aircraft quality (such as is specified for valve springs). The costs of spring wire materials vary widely and are constantly changing. In general, the common spring materials, in order of relative cost from lowest to highest, are hard drawn steel, oil-tempered steel, alloy steel, music wire, stainless steel (average of several), phosphor bronze, and beryllium copper.

III. DESIGN RECOMMENDATIONS

Dimensional and load requirements must be specified in designing any type of spring for any application. Depending on the type of application, there may be these additional considerations: operating environment, spring rate, dynamic load characteristics, space occupied, and operating life. Specifying dimensional and load tolerances closer than needed may add unnecessarily to the cost of a spring. No tolerances should be specified at all unless they are required by the spring’s function. Dimensional tolerances that do not exceed commercial standards permit the spring to be fabricated by ordinary production methods. The functional design characteristics of the spring should be given as mandatory specifications. Among the most important specifications is spring load, which is defined as the force that is applied to a spring and causes deflection to a finite position. Spring rate is linear in only about the central 60 percent of its deflection range. Secondary characteristics, which may be useful for reference, should be identified as advisory data. This practice controls the essential requirements while providing as much design flexibility as possible to the spring manufacturer in meeting these requirements. The solid height of a compression spring is defined as the length of the spring when it is under sufficient load to bring all coils into contact with adjacent coils and additional load causes no further deflection. Solid height should be specified by the user as a maximum allowable within the available space. The actual number of coils in the spring is determined by the spring manufacturer. There are four basic types of compression-spring ends, The particular type of end specified affects the pitch, solid height, number of active and total coils, free length, and seating characteristics of the spring. Since grinding is a separate operation, compression springs with unground ends are more economical. Open ends, ground or unground, may involve additional cost in assembly because the springs are then more susceptible to tangling.

IV. DIMENSIONAL FACTORS

The very nature of spring forms, materials, and standard manufacturing processes causes inherent variations. Such spring characteristics as load, mean coil diameter, free length, and the relationship of ends or hooks therefore change to some degree throughout a production run. The amount of manufacturing variation in particular spring characteristics depends in large part on changes in other spring characteristics, primarily spring index but also wire diameter, number of coils, free length, deflection, and ratio of deflection to free length. Therefore, normal or average tolerances on performance and dimensional characteristics differ for each spring design. For this reason, block tolerances, which may be preprinted on drawing forms, cannot realistically be applied to springs. If the designer specifies spring tolerances that are equal to or wider than normal manufacturing variations, no special production methods or inspection procedures will be necessary. Designers have tended to underemphasize or overlook the preceding factors and have concentrated their efforts on only three factors: the function (performance), features, and appearance of the product that they develop. They have tended to neglect the “downstream” considerations that affect the usability and cost of the product during its lifetime. AT&T Bell Laboratories recognized the need to satisfy these objectives and used the term DFX to designate designing for all desired factors.2 DFX was described as a design procedure in which the objective broadly covers cost-effective “downstream” operations: distribution, installation, service, and customer use. Reliability, safety, conformance to environmental regulations, and liability prevention are also objectives. These are in addition to low manufacturing costs. DFX is “the process where the full life-cycle needs of the product are addressed during the product’s design.” AT&T made note of the value of incorporating DFX knowledge into CAE/CAD (computer aided engineering/computer aided design).

V. APPLYING COMPUTERS TO DESIGN

No other idea or device has impacted engineering as computer have. All engineering disciplines routinely use computer for calculation, analysis, design and simulation .Many of the individual tasks within the overall design process can be performed using a computer. As each of these tasks is made more efficient, the efficiency of the overall process increases as well. The computer is especially well suited to design in four areas, which correspond to the latter four stages of the general design process. Computers function in the design process through geometric modeling capabilities, engineering analysis calculations, automated testing procedures, and automated drafting.

STATIC ANALYSIS determines reaction forces at the joint positions of resting when a constant load is applied. As long as zero velocity is assumed, static analysis can be performed on mechanisms at different points of their range of motion. Static analysis allows the designer to determine the reaction forces on whole mechanical systems as well as interconnection forces transmitted to their individual joints. The data extracted from static analysis can be useful in determining compatibility with the various criteria set out in the problem definition. These criteria may include reliability, fatigue, and performance considerations to be analyzed through stress analysis methods fig 6. Detailed the Region with FOS (factor of safety) value less than 1 in red

EXPERIMENTAL ANALYSIS involves fabricating a prototype and subjecting it to various experimental methods. Although this usually takes place in the later stages of design, CAD systems enable the designer to make more effective use of experimental data, especially where analytical methods are thought to be unreliable for the given model. CAD also provides a useful platform for incorporating experimental results into the design process when experimental analysis is performed in earlier iterations of the process.fig 2 shows the final design of spring , and fig;7 factor of safety indicated that our design is save(material) from that region. Blue region indicate safety which is larger than 1.0 while red region indicate unsafe regions which is 1.0 shown in fig. 6

VI. ANALYSIS OF THE SPRING /GEOMETRY AND MESH

The Relevance setting listed below controlled the fineness of the mesh used in this analysis. For reference, a setting of -100 produces a coarse mesh, fast solutions and results that may include significant uncertainty. A setting of +100 generates a fine mesh, longer solution times and the least uncertainty in results. Zero is the default Relevance setting.

Compress Spring	**Statistics**
Bounding Box Dimensions	41.81 mm,89.28 mm 41.82 mm
Part Mass	0.2298 kg
Part Volume	2.927e+004 mm^3
Mesh Relevance Setting	52
Nodes	20154
Elements	10328

Table 1 Compress Spring Statistics

Bounding box dimensions represent lengths in the global X, Y and Z directions.

Material Data

The following material behavior assumptions apply to this analysis:

Linear - stress is directly proportional to strain.

Constant - all properties temperature-independent.

Homogeneous - properties do not change throughout the volume of the part.

Isotropic - material properties are identical in all directions.

Young's Modulus	2.1e+005 MPa
Poisson's Ratio	0.3
Mass Density	7.85e-006 kg/mm^3
Tensile Yield Strength	207.0 MPa
Tensile Ultimate Strength	345.0 MPa

Table 2 Steel

Loads and Constraints

The following body loads act on the part. The Location column applies only to rotational velocity. Location represents a point on the axis of rotation.

Name	Magnitude	Vector	Location
		-3.958e-031 deg/s	2.042e-002 mm
Rotational Velocity	10.0 deg/s	10.0 deg/s -1.522e-030 deg/s	20.74 mm -0.2244 mm
Standard Earth Gravity	9807 mm/s^2	9807 mm/s^2 0.0 mm/s^2 0.0 mm/s^2	N/A

Table 3 Body Load Definitions

The following loads and constraints act on specific regions of the part. Regions were defined by selecting surfaces, cylinders, edges or vertices

Name	**Type**	**Magnitude**	**Vector**
Fixed Constraint 1	Edge Fixed Constrain	Edge Fixed Constrain	9.0 mm 9.0 mm 9.0 mm
Frictionless Constraint 1	Surface Frictionless Constraint	N/A	N/A
Frictionless Constraint 2	Surface Frictionless Constraint	N/A	N/A

Table 4 Load and Constraint Definitions

Name	Force	Vector	Moment	Moment Vector
Fixed Constraint 1	2.326 N	2.295 N		-658.7 N·mm
		-0.3756 N		-3783 N·mm
		-2.367e-002 N		-4088 N·mm
Frictionless Constraint 1	2.296 N	2.295 N -4.984e-002 N -2.367e-002 N	4356 N·mm	-11.42 N·mm 1347 ·mm -4143 N·mm
Frictionless Constraint 2	2.296 N	2.295 N -4.984e-002 N -2.367e-002 N	4356 N·mm	-11.42 N·mm 1347 N·mm 4143 N·mm

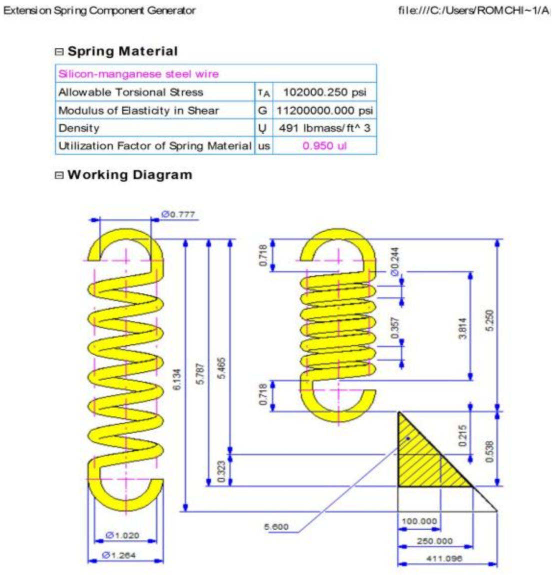
Table 5 Constraint Reactions

Note: vector data corresponds to global X, Y and Z components. The table below lists all structural results generated by the analysis. The following section provides figures showing each result contoured over the surface of the part. Safety factor was calculated by using the maximum equivalent stress failure theory for ductile materials. The stress limit was specified by the tensile yield strength of the material.

Name	**Minimum**	**Maximum**
Equivalent Stress	5.9e-005 MPa	12.56 MPa
Maximum Principal Stress	-0.1208 MPa	14.43 MPa
Minimum Principal Stress	-2.728 MPa	1.283 MPa
Deformation	12.69 mm	12.73 mm
Safety Factor	15.0	N/A

Table 6 structural Results

VII.MODELING AND SIMULATION OF SPRING



Extension Spring Component Generator file:///C:/Users/ROMCHI~1/A

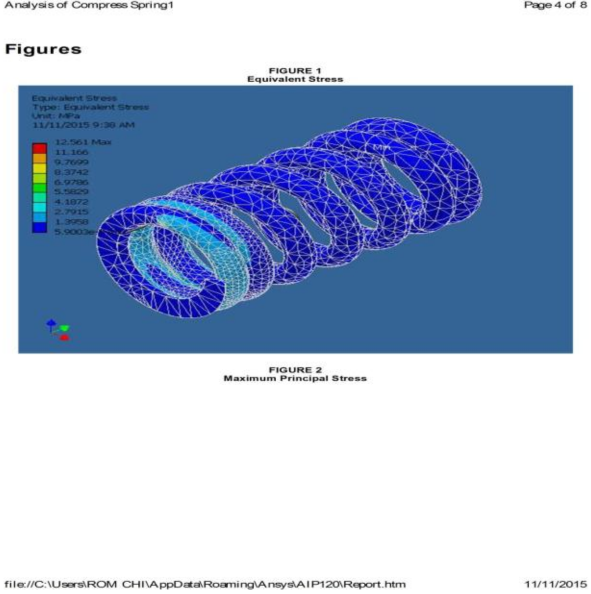
⊟ **Spring Material**

Silicon-manganese steel wire		
Allowable Torsional Stress	τ_A	102000.250 psi
Modulus of Elasticity in Shear	G	11200000.000 psi
Density	ρ	491 lbmass/ft^ 3
Utilization Factor of Spring Material	us	0.950 ul

⊟ **Working Diagram**

Fig 1. Working Diagram Spring

Fig 2. CAD



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Figures

FIGURE 1
Equivalent Stress

FIGURE 2
Maximum Principal Stress

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Fig 3. Maximum Principal Stress

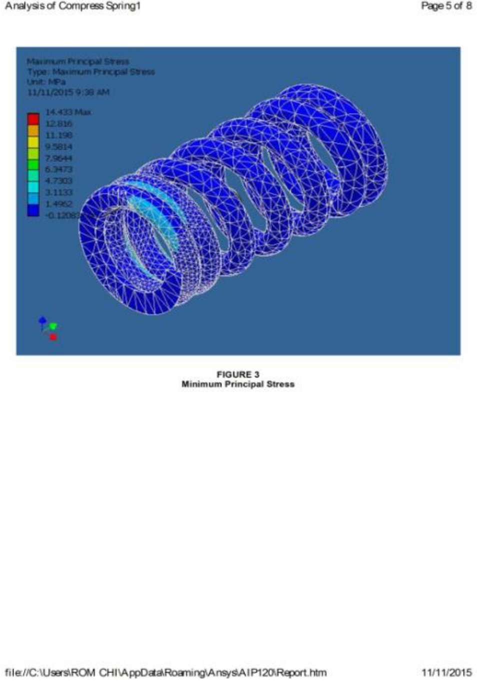

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FIGURE 3
Minimum Principal Stress

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Fig 4. Minimum Principal

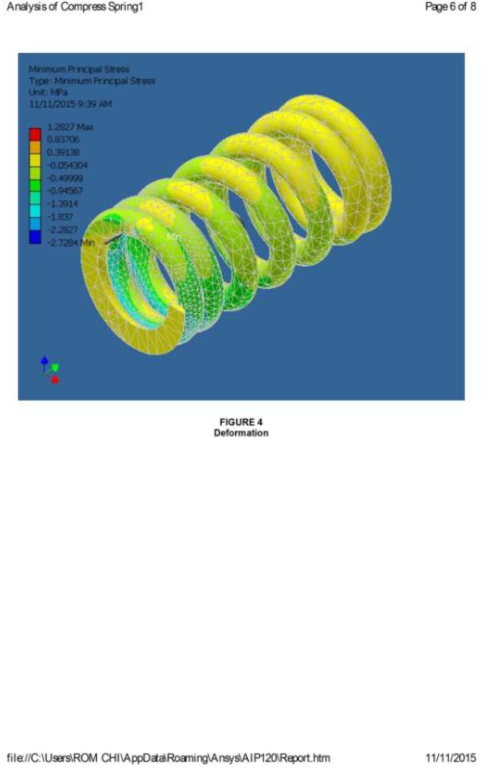

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FIGURE 4
Deformation

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Fig 5. Deformation

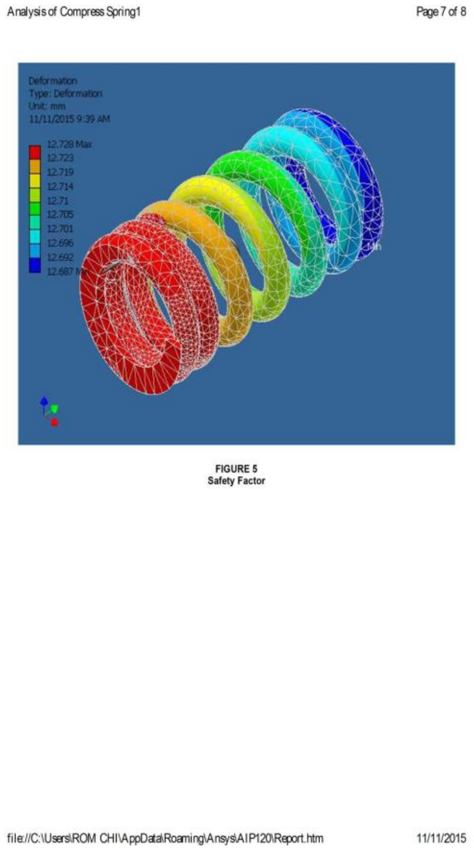

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FIGURE 5
Safety Factor

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Fig 6. Unsafe Regions

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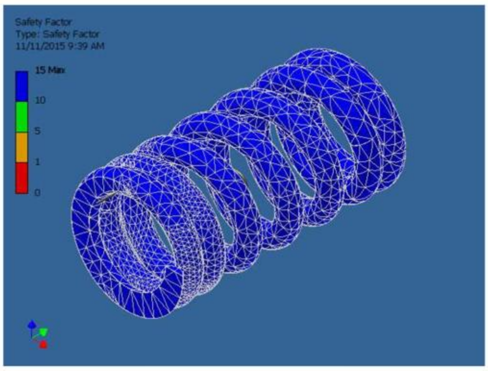

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Fig 7. Safety Factor

VIII. DESIGN PROCESS

The ability to create something out of nothing makes design one of the most exciting aspects of engineering. To be successful, design engineer require abroad set of talents include knowledge creativity, people skill and planning ability .Engineers use CAD to create two− and three−dimensional drawings, such as those for automobile and airplane parts, floor plans, and maps and machine assembly. While it may be faster for an engineer to create an initial drawing by hand, it is much more efficient to change and adjust drawings by computer. In the design stage, drafting and computer graphics techniques are combined to produce models of different machines. Using a computer to perform the six−step'art−to−part' process: The first two steps in this process are the use of sketching software to capture the initial design ideas and to produce accurate engineering drawings. The third step is rendering an accurate image of what the part will look like. Next, engineers use analysis software to ensure that the part is strong enough shown in fig;2 .Step five is the production of a prototype, or model CAD began as an electronic drafting board, a replacement of the traditional paper and pencil drafting method. Over the years it has evolved into a sophisticated surface and solid modeling tool. Not only can products be represented precisely as solid models, factory shop floors can also be modeled and simulated in 3D. It is an indispensable tool to modern engineers

WIRE FRAME The most basic functions of CAD are the 2D drafting functions. 2D geometry such as line, circles, and curves can be defined. A 2D profile can also be extruded into a 21⁄2 D object. The extruded object is a wireframe of the object CAD also allows a 3D wire-frame to be defined. To cover the wire-frame model, faces can be added to the model. This creates a shell of the object. Hidden line/surface algorithms can be applied to create realistic pictures. Many menu functions are used to help simplify the design process. Annotation and dimensioning are also supported. Text and dimension symbols can be placed anywhere on the drawing, at any angle, and at any size.

MODELLING Modeling is the process of producing a model; a model is a representation of the construction and working of some system of interest as shown in fig 2. A model is similar to but simpler than the system it represents. One purpose of a model is to enable the analyst to predict the effect of changes to the system. On the one hand, a model should be a close approximation to the real system and incorporate most of its salient features. On the other hand, it should not be so complex that it is impossible to understand and experiment with it. A good model is a judicious tradeoff between realism and simplicity. Simulation practitioners recommend increasing the complexity of a model iteratively. An important issue in modeling is model validity. Model validation techniques include simulating the model under known input conditions and comparing model output with system output. Generally, a model intended for a simulation study is a mathematical model developed with the help of simulation software. Mathematical model classifications include deterministic (input and output variables are fixed values) or stochastic (at least one of the input or output variables is probabilistic); static (time is not taken into account) or dynamic (time-varying interactions among variables are taken into account). Typically, simulation models are stochastic and dynamic

IX. SIMULATION

A simulation of a system is the operation of a model of the system. The model can be reconfigured and experimented with; usually, this is impossible, too expensive or impractical to do in the system it represents. The operation of the model can be studied, and hence, properties concerning the behavior of the actual system or its subsystem can be inferred. In its broadest 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. For instance, simulation can be used to answer questions like:What is the best design for a new network? What are the associated resource requirements? How will a telecommunication network perform when the traffic load increases by 50%? How will new routing algorithm affect its performance? Which network protocol optimizes network performance? What will be the impact of a link failure? The subject of this tutorial is *discrete event* simulation in which the central assumption is that the system changes instantaneously in response to certain discrete events. For instance, in an M/M/1 queue - a single server queuing process in which time between arrivals and service time are exponential - an arrival causes the system to change instantaneously. On the other hand, continuous simulators, like flight simulators and weather simulators, attempt to quantify the changes in a system continuously over time in response to controls. Discrete event simulation is less detailed (coarser in its smallest time unit) than continuous simulation but it is much simpler to implement, and hence, is used in a wide variety of situations. Figure , 2-8,8 is a schematic of a simulation study. The iterative nature of the process is indicated by the system under study becoming the altered system which then becomes the system under study and the cycle repeats. In a simulation study, human decision making is required at all stages, namely, model development, experiment design, output analysis, conclusion formulation, and making decisions to alter the system under study. The only stage where human intervention is not required is the running of the simulations, which most simulation software packages perform efficiently. The important point is that powerful simulation software is merely a hygiene factor - its absence can hurt a simulation study but its presence will not ensure success. Experienced problem formulators and simulation modelers and analysts are indispensable for a successful simulation study. The steps involved in developing a simulation model, designing a simulation experiment, and performing simulation analysis are:

[1.] Step 1. Identify the problem.
[2.] Step 2. Formulate the problem.
[3.] Step 3. Collect and process real system data.
[4.] Step 4. Formulate and develop a model.
[5.] Step 5. Validate the model.
[6.] Step 6. Document model for future use.
[7]. Step 7. Select appropriate experimental design. Step [8.] Establish experimental conditions for.
[8.] Step 9. Perform simulation runs.
[9.] Step 10. Interpret and present results.
[10.] Step 11. Recommend further course of action. Although this is a logical ordering of steps in a simulation study, much iteration at various sub-stages may be required before the objectives of a simulation study are achieved. Not all the steps may be possible and/or required. On the other hand, additional steps may have to be performed. The next three sections describe these steps in detail.

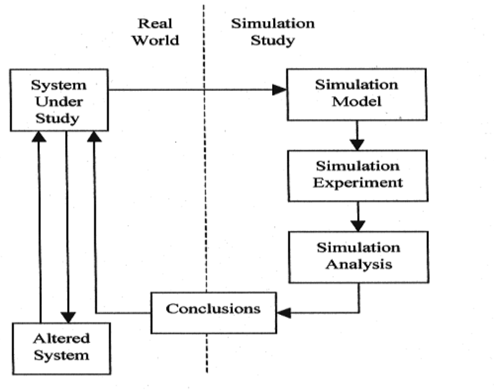

Fig 8: Simulation Study Schematic

X. RESULT AND DISCUSS

Engineering analysis can be performed using one of two approaches: analytical or experimental. Using the analytical method, the design is subjected to simulated conditions, using any number of analytical formulae. By contrast, the experimental approach to analysis requires that a prototype be constructed and subsequently subjected to various experiments to yield data that might not be available through purely analytical methods. There are various analytical methods available to the designer using a CAD system. Finite element analysis and static and dynamic analysis are all commonly performed analytical methods available in CAD.

SAFETY An engineer must always design products that are safe for the end user and the artisans who construct the product. it is impossible to design completely safe products because they would be too costly. Therefore, the engineer often must design to industry standards for similar product

FACTOR OF SAFETY is the ratio of ultimate strength of the material to allowable stress. The term was originated for determining allowable stress. The ultimate strength of a given material divided by an arbitrary factor of safety, dependent on material and the use to which it is to be put, gives the allowable stress. In present design practice, it is customary to use allowable stress as specified by recognized authorities or building codes rather than an arbitrary factor of safety. One reason for this is that the factor of safety is misleading, in that it implies a greater degree of safety than actually exists. For example, a factor of safety of 4 does not mean that a member can carry a load four times as great as that for which it was designed. It also should be clearly understood that, though each part of a machine is designed with the same factor of safety, the machine as a whole does not have that factor of safety. When one part is stressed beyond the proportional limit, or particularly the yield point, the load or stress distribution may be completely changed throughout the entire machine or structure, and its ability to function thus may be changed, even though no part has ruptured. Although no definite rules can be given, if a factor of safety is to be used, the following circumstances should be taken into account in its selection:

1. When the ultimate strength of the material is known within narrow limits, as for structural steel for which tests of samples have been made, when the load is entirely a steady one of a known amount and there is no reason to fear the deterioration of the metal by corrosion, the lowest factor that should be adopted is 3.
2. When the circumstances of (1) are modified by a portion of the load being variable, as in floors of warehouses, the factor should not be less than 4.
3. When the whole load, or nearly the whole, is likely to be alternately put on and taken off, as in suspension rods of floors of bridges, the factor should be 5 or 6.
4. When the stresses are reversed in direction from tension to compression, as in some bridge diagonals and parts of machines, the factor should be not less than 6.
5. When the piece is subjected to repeated shocks, the factor should be not less than 10.
6. When the piece is subjected to deterioration from corrosion, the section should be sufficiently increased to allow for a definite amount of corrosion before the piece is so far weakened by it as to require removal.
7. When the strength of the material or the amount of the load or both are uncertain, the factor should be increased by an allowance sufficient to cover the amount of the uncertainty.
8. When the strains are complex and of uncertain amount, such as those in the crankshaft of a reversing engine, a very high factor is necessary, possibly even as high as 40.
9. If the property loss caused by failure of the part may be large or if loss of life may result,

as in a derrick hoisting materials over a crowded street, the factor should be large.

XI. CONCLUSION

CAD combines the characteristic of designer and computer that are best applicable made CAD such as popular design tool. CAD Has allowed the designer to bypass much of the Manuel drafting and analysis . Simulation tools enable us to be creative and to quickly test new ideas that would be much more difficult, time-consuming, and expensive to test in the lab. (Jeffrey D. Wilson, Nasa Glenn Research Center) It also help us reduce cost and time-to-market by testing our designs on the computer rather than in the field. Many of the individual tasks within the overall design process can be performed using a computer. As each of these tasks is made more efficient, the efficiency of the overall process increases as well. The computer is well suited to design in four areas, which correspond to the latter four stages of the general design process; Computers function in the design process through geometric modeling capabilities, engineering analysis calculations, testing procedures, and automated drafting, From the result of the testing and the affordability in terms of cost, it can be concluded that the project is successful. Therefore software design should be encouraged in our institution of higher learning base on the following facts, long product development, countless trial and error, and accountability and limited profitability.

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