DESIGN, MODELLING AND SIMULATION OF SIDE AND FACE MILLING CUTTER

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ABSTRACT

Traditionally, the design field has been identified with particular end products, e.g., mechanical design, electrical design, ship design. In these fields, design work is largely based on specific techniques to foster certain product characteristics and principles . 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. The scope of this work includes, to design, model and simulate side and face milling cutter, to select cutting tool materials and also to detailed factor safety in design . When new software and manufacturing processes are introduced, traditional empirical knowledge is unavailable and considerable effort is required to find starting design concepts. Modeling and simulation of cutting processes have the potential for improving cutting tool designs and selecting optimum conditions, especially in advanced applications such as high-speed milling. Milling operation is today the most effective and productive manufacturing method for roughing and finishing large surfaces of metallic parts.. The model simulates precisely the tool kinematics and considers the effect of the cutting geometry on the resulting roughness. The accuracy of the simulation model has been thoroughly verified, with the aid of a wide variety of experiments. Metal cutting process is not only a material removal process, but also a deformation process where deformation is highly concentrated in a small zone . Thereby, it can be investigated as a chip formation process and simulated using Finite Element Method (FEM) techniques. The main advantage of such an approach is to be able to predict all process variables arisen in the deformation zones. However, material flow characteristics at the high temperature, strain-rate and strain, encountered during cutting process, are very important for predicting chip flow, cutting forces, temperatures and stresses.

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INTRODUCTION

The side-and-face cutter is designed with cutting teeth on its side as well as its circumference. They are made in varying diameters and widths depending on the application. The teeth on the side allow the cutter to make unbalanced cuts (cutting on one side only) without deflecting the cutter as would happen with a slitting saw or slot cutter (no side teeth). Cutters of this form factor were the earliest milling cutters developed. From the 1810s to at least the 1880s, they were the most common form of milling cutter, whereas today that distinction probably goes to end mills For asphalt milling machines, In a milling machine, a work piece is fed against a circular device with a series of cutting edges on its circumference. The work piece is held on a table that controls the feed against the cutter. The table conventionally has three possible movements: longitudinal, horizontal, and vertical; in some cases it can also rotate. Milling machines are the most versatile of all machine tools. Flat or contoured surfaces may be machined with excellent finish and accuracy. Angles, slots, gear teeth, and recess cuts can be made by using various cutters. See the action of side and face cutter shown in fig:1
. 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. Three-dimensional 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.

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CUTTING TOOL MATERIALS.

The selection of cutting tool materials is one of the key factors in determining the effectiveness of the machining process (ASM, 1989b). During cutting, the tool usually experiences high temperatures, high stresses, rubbing friction, sudden impact, and vibrations. Therefore, the two important issues in the selection of cutting tool materials are hardness and toughness. Hardness is defined as the endurance to plastic deformation and wear; hardness at elevated temperatures is especially important. Toughness is a measure of resistance to impact and vibrations, which occur frequently in interrupted cutting operations such as milling and boring. Hardness and toughness do not generally increase together, and thus the selection of cutting tool often involves a trade-off between these two characteristics. Cutting tool materials are continuously being improved. Carbon steels of 0.9 to 1.3% carbon and tool steels with alloying elements such as molybdenum and chromium lose hardness at temperatures above 400°F (200ºC) and have largely been replaced by high-speed steels (HSS). HSS typically contains 18% tungsten or 8% and smaller amounts of cobalt and chromium. HSSs retain hardness up to 1100F (600°C) and can operate at approximately double the cutting speed with equal life. Both tool steels and HSS are tough and resistive to fracture; therefore, they are ideal for processes involving interrupted engagements and machine tools with low stiffness that are subject to vibration and chatter. Powder metallurgy (P/M) high-speed tool steels are a recent improvement over the conventionally cast HSSs. Powder metallurgy processing produces a very fine microstructure that has a uniform distribution of hard particles.Fig13 illustrates tool life. These steels are tougher and have better cutting performance than HSS. Milling cutters are becoming a significant application for these cutting tool materials. Cast cobalt alloys, popularly known as Stellite tools, were introduced in 1915. These alloys have 38 to 53% cobalt, 30 to 33% chromium, and 10 to 20% tungsten. Though comparable in room temperature hardness to HSS tools, cast cobalt

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alloy tools retain their hardness to a much higher temperature, and they can be used at 25% higher cutting speeds than HSS tools. **13**-12 Section 13 © 1999 by CRC Press LLC

Cemented carbides offered(fig2) a four- or fivefold increase in cutting speeds over conventional HSS. They are much harder, but more brittle and less tough. The first widely used cemented carbide was tungsten carbide (WC) cemented in a ductile cobalt binder. Most carbide tools in use now are a variation of the basic WC-Co material. For instance, WC may be present as single crystals or a solid solution mixture of WC-TiC or WC-TiC-TaC. These solid solution mixtures have a greater chemical stability in the cutting of steel. In general, cemented carbides are good for continuous roughing on rigid machines, but should avoid shallow cuts, interrupted cuts, and less rigid machines because of likely chipping shown in fig 2. A thin layer of TiC, TiN, or Al2O3 can be applied to HSS or carbide substrate to improve resistance to abrasion, temperature, friction, and chemical attacks. The coated tools were introduced in the early 1970s and have gained wide acceptance since. Coated tools have two or three times the wear resistance of the best uncoated tools and offer a 50 to 100% increase in speed for equivalent tool life. Ceramic tools used for machining are based on alumina (Al2O3) or silicon nitride (Si3N4). They can be used for high-speed finishing operations and for machining of difficult-to-machine advanced materials, such as superalloys (Komanduri and Samanta, 1989). The alumina-based materials contain particles of titanium carbide, zirconia, or silicon carbide whiskers to improve hardness and/or toughness. These materials are a major improvement over the older ceramic tools. Silicon nitride–based materials have excellent high-temperature mechanical properties and resistance to oxidation. These materials also have high thermal shock resistance, and thus can be used with cutting fluids as shown in fig;12 to produce better surface finishes than the alumina tools. These tools can be operated at two to three times the cutting speeds of tungsten carbide, usually require no coolant, and have about the same tool life (see fig;13) at higher speeds as tungsten carbide does at lower speeds. However, ceramics lack toughness; therefore, interrupted cuts and intermittent application of coolants can lead to premature tool failure due to poor mechanical and thermal shock resistance. Cermets are titanium carbide (TiC) or titanium carbonitride particles embedded in a nickel or nickel/molybdenum binder. These materials, produced by the powder metallurgy process, can be considered as a type of cemented carbide. They are somewhat more wear resistant, and thus can be used for higher cutting speeds. They also can be used for machining of ferrous materials without requiring a protective coating. Cubic boron nitride (CBN) is the hardest material at present available except for diamond. Its cost is somewhat higher than either carbide or ceramic tools but it can cut about five times as fast as carbide and can hold hardness up to 200°C. It is chemically very stable and can be used to machine ferrous materials. Industrial diamonds are now available in the form of polycrystalline compacts for the machining of metals and plastics with greatly reduced cutting force, high hardness, good thermal conductivity, small cutting-edge radius, and low friction. Recently, diamond-coated tools are becoming available that promise longer-life cutting edges. Shortcomings with diamond tools are brittleness, cost, and the tendency to interact chemically with workpiece materials that form carbides, such as carbon steel, titanium, and nickel.

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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 4. Detailed the Region with FOS (factor of safety)value less than 1 in red

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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 side and face cutter , 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. 7

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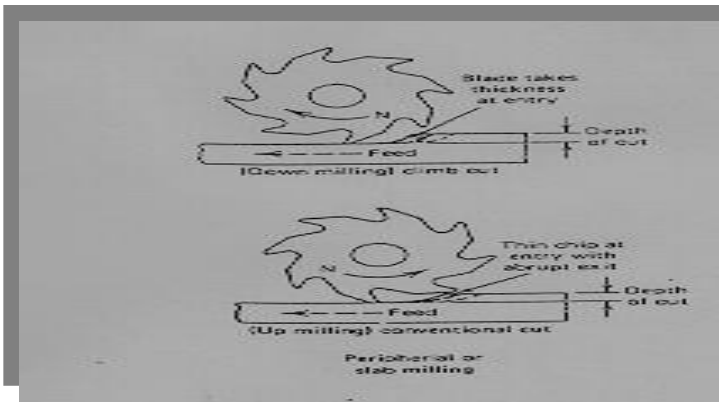


Fig 1 tool and table movement in milling machine operation

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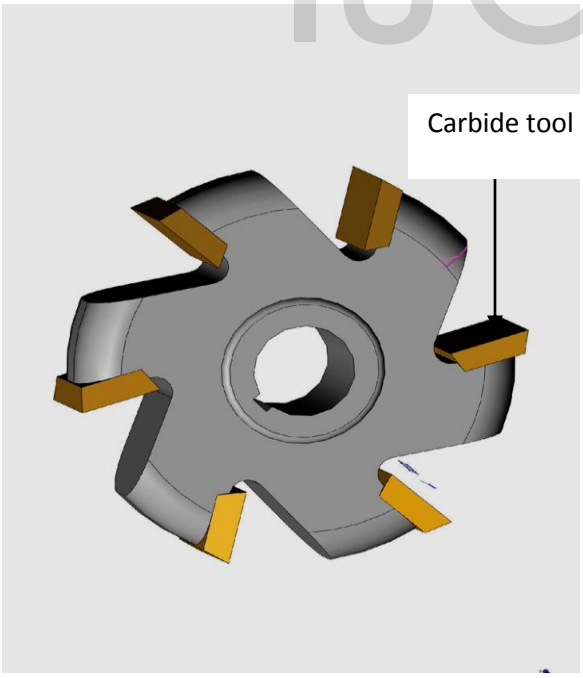


Fig ;2 Cad Model

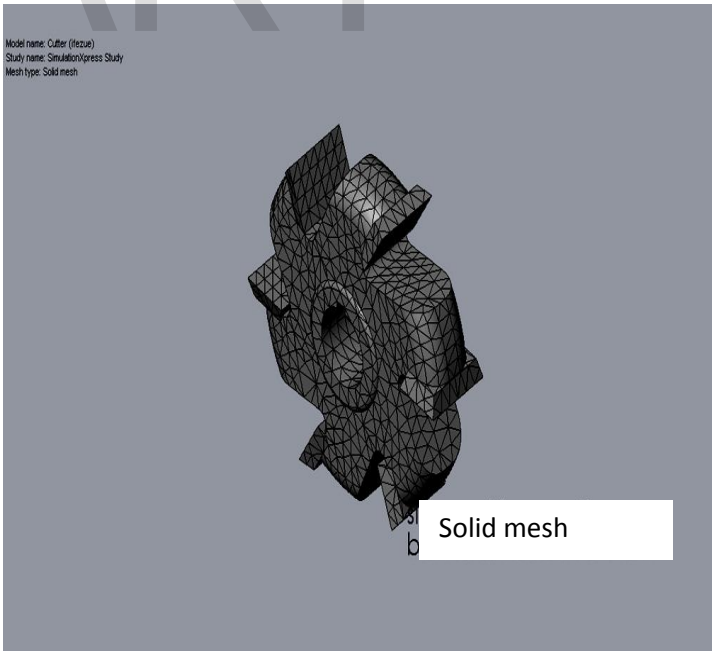


Fig ;3 solid mesh of the cutter

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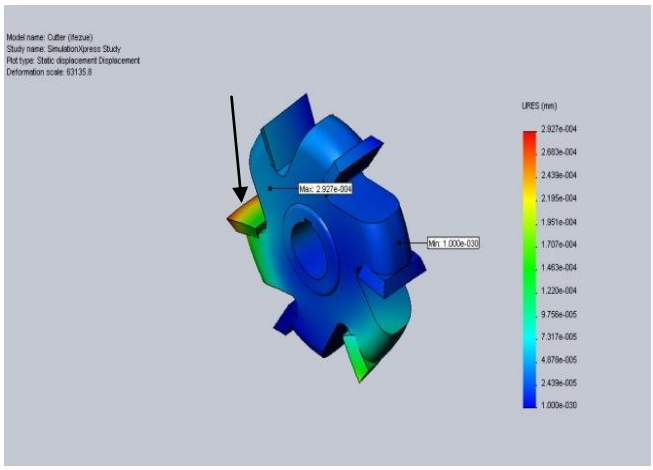
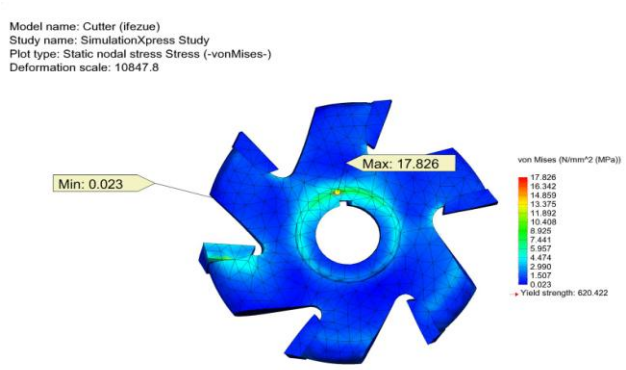
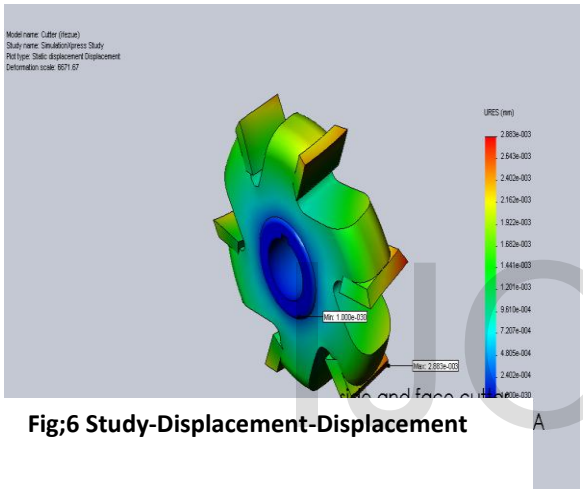


Fig:4 Region with FOS value less than 1 shown in red



Fig; 5 cutter under stress



Fig;6 Study-Displacement-Displacement

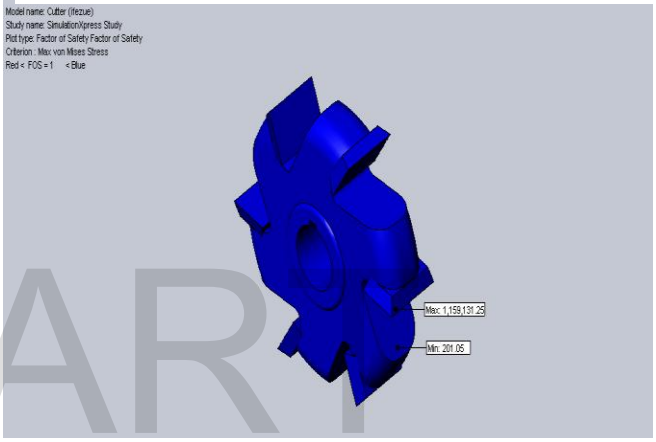
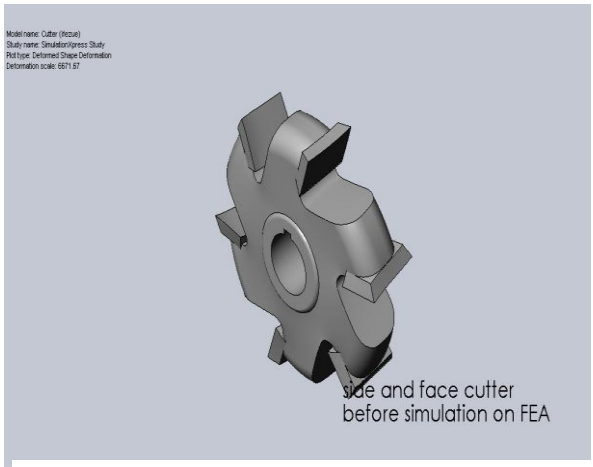
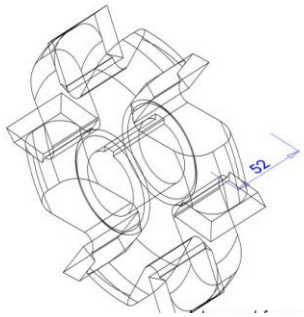


Fig **7; blue regions indicate safe regions**

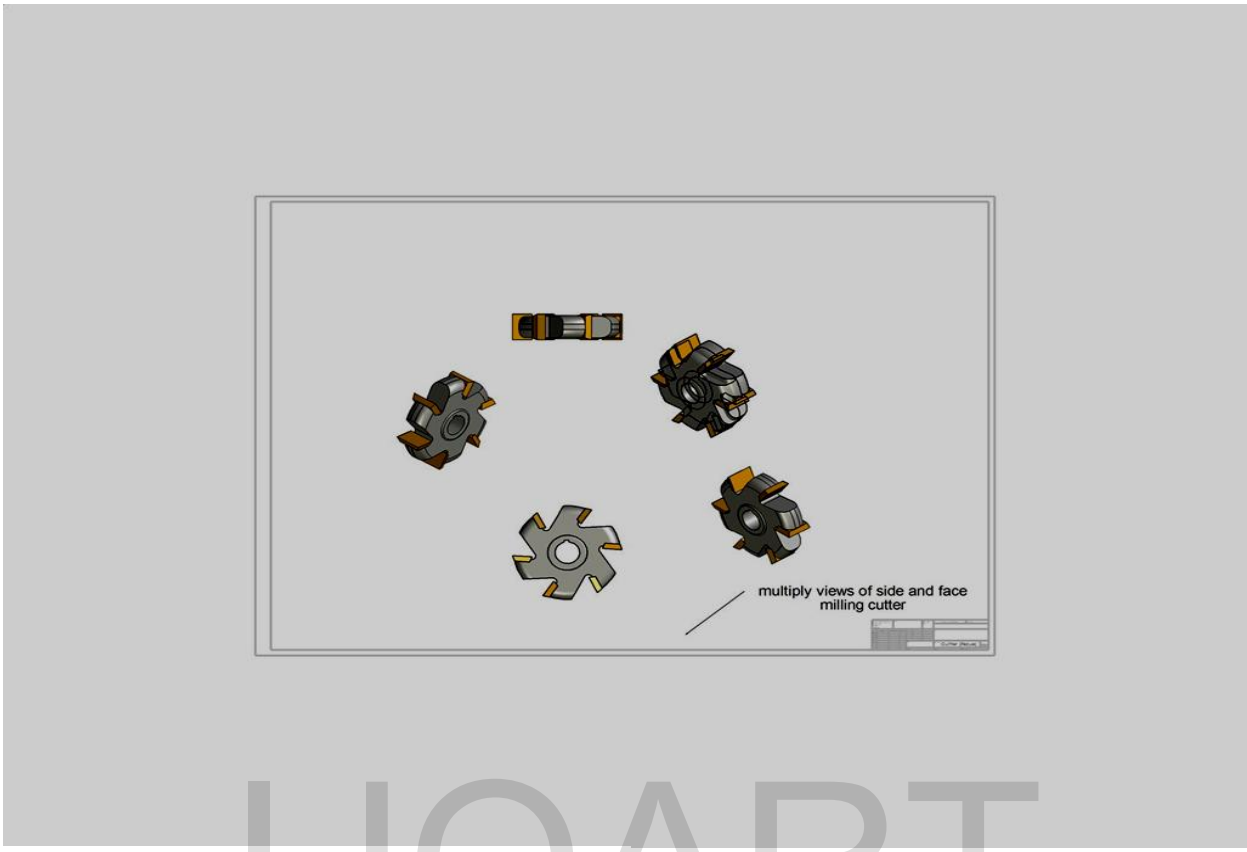


Fig;8 Study-Displacement-Deformation



Fig;10 Wire frame of side and face cutter

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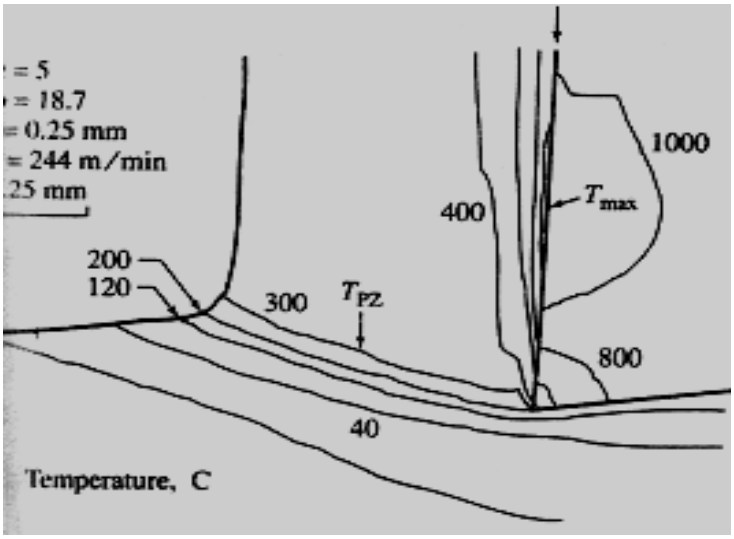


Fig;11 multiply views of side and face cutter

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Function of cutting fluids

- Lubrication
- Cooling
- Chip removal



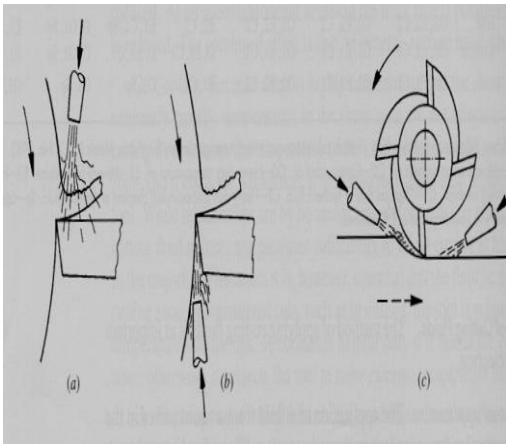


Fig ;12 functions of cutting fluid

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TOOL LIFE PREDICTION

- Taylor's tool life equation predicts tool failure based on flank wear of the tool

$$Vt^n = C$$

where V is the cutting speed, t is the tool life, n is Taylor exponent.

- n=0.125 for HSS, n=0.25 for Carbide, n=0.5 for Coated Carbide/Ceramic
- C is constant given workpiece material

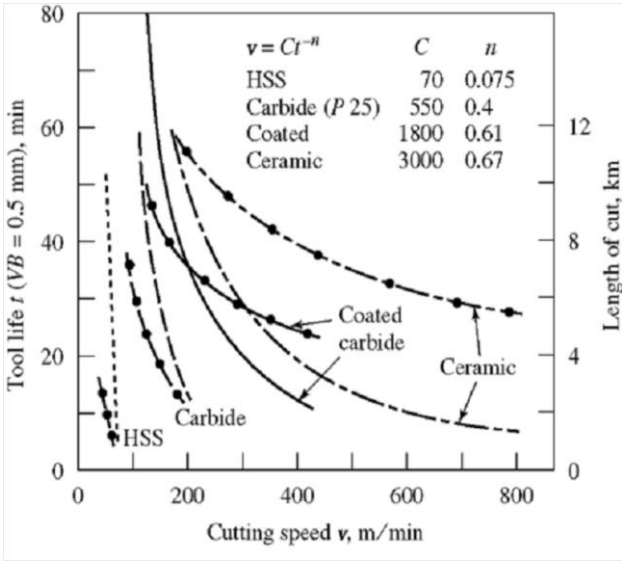


Fig: 13 Too life

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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 2½ 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.A sample drawing is shown in Fig 11

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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 11. 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

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 , 3-8,14 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.

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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, many iterations 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.

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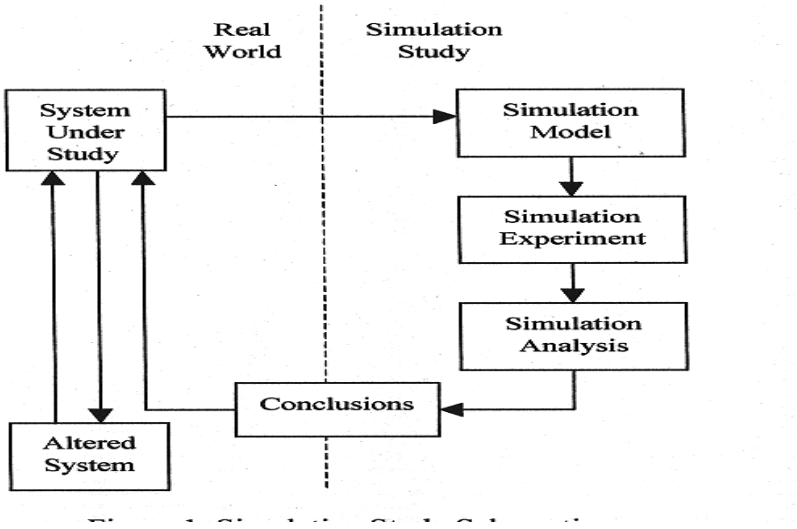


Fig 14: Simulation Study Schematic

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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:

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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.

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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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