Design Of CNC Lathe Bed For Weight And Cost Reduction

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Abstract: CNC is the acronym for Computer Numerical Control. It is an outgrowth of the older term "NC", which stands for just "Numerical Control". It refers to the idea of controlling machine tools programmatically via computer. With the older "NC" term, a computer need not be involved. The machine might be controlled using, for example, punched tape.

NC, and later CNC, allowed for tremendous increases in productivity for machine tools because the machines could be run automatically without requiring constant attention from their operator. Before the advent of such automation, there was a lesser automation opportunity in the form of hydraulic tracer systems. Such systems used hydraulics to cause the cutting tools of a lathe or mill to follow a template. The taper attachments available for many manual lathes are not unlike the hydraulic tracer capability; it's just that the tracer is capable of more elaborate templates than simple tapers. But the advent of first NC and then later CNC radically increased the amount of automation that was possible.

Index Terms – Optimization, CNC.

I INTRODUCTION:

Fig:1 CNC Lathe

Computer numerical controlled (CNC) lathes are rapidly replacing the older production lathes (multispindle, etc.) due to their ease of setting, operation, repeatability and accuracy. They are designed to use modern carbide tooling and fully use modern processes. The part may be designed and the tool paths programmed by the CAD/CAM process or manually by the programmer, and the resulting file uploaded to the machine, and once set and trialed the machine will continue to turn out parts under the occasional supervision of an operator.

The machine is controlled electronically via a computer menu style interface; the program may be modified and displayed at the machine, along with a simulated view of the process. The setter/operator needs a high level of skill to perform the process, however the knowledge base is broader compared to the older production machines where intimate knowledge of each machine was considered essential. These machines are often set and operated by the same person, where the operator will supervise a small number of machines (cell).

The design of a CNC lathe varies with different manufacturers, but they all have some common elements. The turret holds the tool holders and indexes them as needed, the spindle holds the work piece and there are slides that let the turret move in multiple axis simultaneously. The machines are often totally enclosed, due in large part to occupational health and safety (OH&S) issues.

With rapid growth in this industry, different CNC lathe manufacturers use different user interfaces which sometimes make it difficult for operators as they have to be acquainted with them. With the advent of cheap computers, free operating systems such as Linux, and open source CNC software, the entry price of CNC machines has plummeted.

How does CNC Lathe work?

A CNC lathe is basically the same as a conventional lathe. The major differences are:

- It is controlled by a computer program
- Does not have the manual hand wheels
- Has tool posts that provide placing for multiple cutting tools
- Is usually fully enclosed with sliding doors

The material to be machined into a component along with the drawing of the component is evaluated and a program is written on a computer for machining the component in various steps with the different required tooling.

Once the program is done, it is transferred to the CNC. The program can be directly programmed into the CNC too. Tooling is then selected, mounted and set into the CNC's database so the machine knows exactly where the tip of the tool is in relation to the work piece.

The CNC is then run without the work piece and watched by the Setter to ensure there are no irregularities during the machining process. When all is ready and the settings are done, the setter would place the material into the chuck and clamp it.

The machining cycle is started and the setter would do it in steps on the first component in order to adjust some tooling stopping distances, feeds, coolant on/off and tooling offsets.

Once the first component is finished, the production cycle is started. The operator then puts the material into the machine and pushes the start button and will remove the completed component without human interference. The components are often checked for accuracy and adjustments are made when necessary.

The program of a CNC composes of sets of commands that tells the machine what-, when-, how fast-, and with what tooling to do a certain operation. Also what should be turned on or off at the time.

These commands control relays, servo motors, solenoids, hydraulic valves, etc. to achieve the multiple operations of the machine.

History of CNC

The first commercial NC machines were built in the 1950's, and ran from punched tape. While the concept immediately proved it could save costs, it was so different that it was very slow to catch on with manufacturers. In order to promote more rapid adoption, the US Army bought 120 NC machines and loaned them to various manufacturers so they could become more familiar with the idea. By the end of the 50's, NC was starting to catch on, though there were still a number of issues. For example, g-code, the nearly universal language of CNC we have today, did not exist. Each manufacturer was pushing its own language for defining part programs (the programs the machine tools would execute to create a part).

CNC Lathe Machine Parts and Components

Feed or Lead screw

Both of these helps with the gears of the CNC lathe machine. The feed screw is the drive shaft for the machine and works with the gears to drive the mechanism of the carriage. The feed screw is also driven by either the quick change gearbox or the change gears. There are other gears that allow for the correct ratio so that the parts that are made are accurate. The feed screw and lead screw work together with the spindle to make the correct amount of screw threads on the work that you are doing.

Tailstock

Fig: 2 Tailstock

The tailstock is located on the opposite end of the lathe from the headstock. It supports one end of the work when machining between centers, supports long pieces held in the chuck, and holds various forms of cutting tools, such as drills, reamers, and taps. The tailstock is mounted on the ways and is designed to be clamped at any point along the ways. It has a sliding spindle that is operated by a hand wheel and clamped in position by means of a spindle clamp. The tailstock may be adjusted laterally (toward or away from the operator) by adjusting screws. It should be unclamped from the ways before any lateral adjustments are made, as this will allow the tailstock to be moved freely and prevent damage to the lateral adjustment screws.

Carriage

within the carriage is the tool bit that turns either in a perpendicular or longitudinal direction depending on how the operator controls it. The operator will set this on a CNC machine where it would use a hand wheel on the older machines. The hand wheels are there and can be used to manually move the carriage or to automate it. Also, the hand wheels have calibrations on them for ease of use.

Cross slide

This is a small part that sits on top of the carriage. It has both a main spindle axis and a lead screw. The lead screw actually moves along the main spindle axis in a perpendicular fashion so that it can perform facing operations; only one direction can be done at a time. Depending on the CNC lathe you have, there will also be a computer component where you can program either the CAD or CAM program to do exactly what you want it to do. Although these machines seem complicated, they are not as difficult once you start to use it.

Live Center and Dead center

Fig:3 Live center (top); dead center (bottom)

A soft dead center is used in the headstock spindle as the work rotates with the centre. Because the centre is soft it can be trued in place before use. The included angle is 60°. Traditionally, a hard dead center is used together with suitable lubricant in the tailstock to support the work piece. In modern practice the dead center is frequently replaced by a live center, as it turns freely with the work piece — usually on ball bearings — reducing the frictional heat, especially important at high speeds. When clear facing a long length of material it must be supported at both ends. This can be achieved by the use of a traveling or fixed steady. If a steady is not available, the end face being worked on may be supported by a dead (stationary) half center. A half center has a flat surface machined across a broad section of half of its diameter at the pointed end. A small section of the tip of the dead center is retained to ensure concentricity. Lubrication must be applied at this point of contact and tail stock pressure reduced.

Control System (optional)

FANUC-Oil Mate TC

Standard Features:

- AC digital spindle drive
- AC digital servo drive for both axes
- Linear motion guide ways for X and Z axes
- 8 station bi-directional turret
- 3 Nos boring bar holders
- 1 No. axial tool holder
- Coolant system
- Centralised and programmable lubrication
- Quality electrical devices with air conditioned panel
- Controlled temperature, humidity and dust free electronics
- Lube oil connector

Optional Features:

- Hydraulically operated tail stock
- Rotating centre for tail stock
- Rear chip conveyor
- Bar feeder with bar puller
- Auto door
- Servo turret with live tools
- Part catcher
- Reduction sleeves
- Hydraulic collet chuck
- Renishaw probe for auto tool

- Tooled up machine to meet customer need

FEATURES OF CNC

Computer NC systems include additional features beyond what is feasible with conventional hard-wired NC. These features, many of which are standard on most CNC Machine Control units (MCU), include the following:

Storage of more than one-part program: With improvements in computer storage technology, newer CNC controllers have sufficient capacity to store multiple programs. Controller manufacturers generally offer one or more memory expansions as options to the MCU

Various forms of program input : Whereas conventional (hard-wired) MCUs are limited to punched tape as the input medium for entering part programs, CNC controllers generally possess multiple data entry capabilities, such as punched tape, magnetic tape, floppy diskettes, RS-232 communications with external computers, and manual data input (operator entry of program).

Program editing at the machine tool: CNC permits a part program to be edited while it resides in the MCU computer memory. Hence, a part program can be tested and corrected entirely at the machine site, rather than being returned to the programming office for corrections. In addition to part program corrections, editing also permits cutting conditions in the machining cycle to be optimized. After the program has been corrected and optimized, the revised version can be stored on punched tape or other media for future use.

II.LITERATURE REVIEW

S.S. Abuthakeer, P.V. Mohanram and G. Mohankumar : studied Static and Dynamic Performance Improvement of Conventional Computer Numerical Control Machine Tool Bed with Hybrid Welded Steel. The advancements in machine tools to maximize the production by increasing spindle speeds have caused vibration in machine tools. The two functional requirements of machine tool bed for machine tools are high structural stiffness and high damping, which cannot be satisfied simultaneously if conventional metallic materials such as cast iron are employed. Hence there is a need to replace cast iron with alternate materials.

R. Staniek, A. Gessner, J. Zielnica, W. Ptaszyński, A. Myszkowski, O. Ciszak, A. Stoic : Predicted stress and displacement analysis of a modern design lathe body by the finite element method. The Finite element method (FEM) was used in this study for the analysis of the strain and stress of a turning machine body. The final design decisions were made on the basis of stress and displacement field analysis of various design versions related to the structure of the considered machine tool.

S. Syath Abuthakeer, P.V. Mohanram and G. Mohan Kumar: predicted the dynamic characteristics analysis of micro lathe bed. The micro-lathe was one of key components in "Micro-factories" claiming "small machine tools for small mechanical parts”. There is an alternative to manufacture micro-components by micro-machine tools and micro-manipulators using conventional mechanical techniques.

Jagadish M. S. and H. V. Ravindra : conducted experiment on Monitoring the Machine Elements in Lathe Using Vibration Signals that in any manufacturing industry, machine tools play an important role in the production of parts. The dimensional accuracy and surface finish of the work piece depends mainly on the condition of the machine. To analyze the condition of the existing machine tool numerically finite element method has been used.

TECHNICAL SPECIFICATION OF CNC LATHE MACHINE

DESCRIPTION	UNIT	VALUE
CAPACITY		
Swing over way covers	mm	350
Admit between centre	mm	375
Maximum turning length(with Chuck)	mm	275
Maximum turning diameter	mm	220
JOB HOLDING		
Hydraulic chuck - Standard	mm	135(5")
- Optional	mm	165(6")
SLIDES		
Cross travel X-axis	mm	130
Longitudinal travel Z-axis	mm	375
Rapid rate X-axis	m/min	24
Z-axis	m/min	24
Ball screw X-axis(dia×pitch)	mm	32×10
Z-axis (dia×pitch)	mm	32×10
LM guide ways X-axis	HSR	35
Z-axis	HSR	35
MAIN SPINDLE (Standard)		
Spindle motor power	kW	7/9 or 5.5/7.5
Spindle bore diameter	mm	40
Spindle front bearing diameter	mm	80
Spindle nose		A2-5
Maximum bar capacity	mm	27
Spindle speed - Standard	rpm	4000
- Optional	rpm	5000
TURRET		
No. of stations	Nos.	8
Maximum boring bar capacity	mm	32
Tool cross section	mm	25×25
TAILSTOCK		
Quill diameter	mm	60
Quill stroke	mm	60
Thrust (maximum)	Kgf	350
Quill taper		MT3
COOLANT		
Tank capacity	ltrs	100
Pump motor capacity	kW	0.25
MACHINE SIZE		
Weight (approximate)	Kgs	3300
Dimension (L×B×H)	Mm	1730×2000×1500

III.METHOD AND METHODOLOGY

There is a need to minimize the mass of the Lathe Bed, topology **and size optimization** technique will carried out without affecting the strength, stiffness and stability requirements.

This project deals with the **topology and size optimization** of structural component of a CNC Lathe Bed using Altair OptiStruct for the given loading conditions. The objectives of the Project are:

- Based on the results obtained in static analysis, at the locations of low stress, below the yield point stress level, the material is minimized by optimization techniques.
- **Topology and size optimization** is carried out using optimization techniques to reduce the mass of the component.

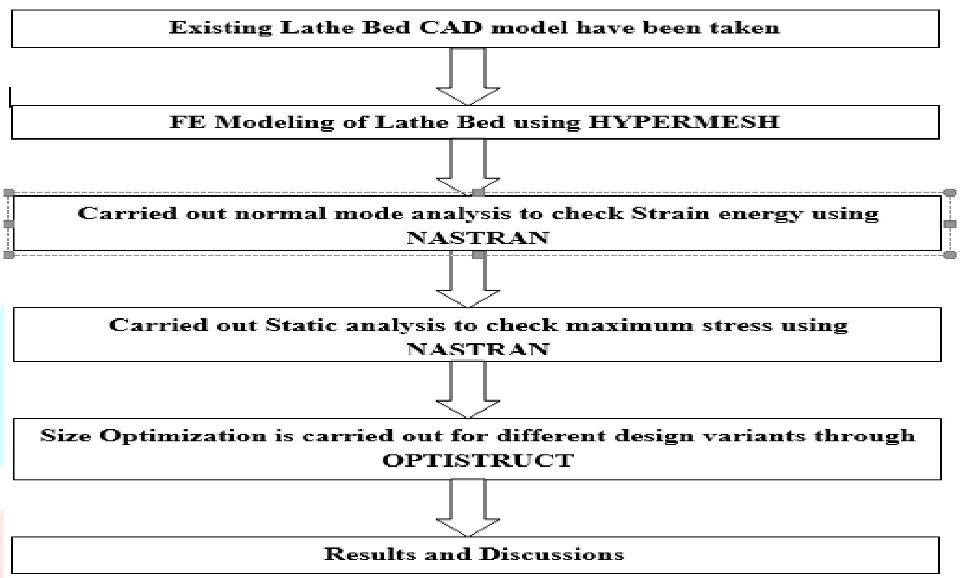

Fig 4: Project Methodology

IV. RESULT AND DISCUSSION: OPTIMIZATION OF LATHE BED

The Lathe Bed

The base of the lathe that supports the headstock, tailstock, carriage and the ways is called the lathe bed. The lathe bed being the main guiding member of the tool, for accurate machining work, must satisfy the following conditions,

1. It should be sufficiently rigid to prevent deflection under tremendous cutting pressure.
2. It must be massive with sufficient depth and width to absorb vibration.
3. It must resist the twisting stress setup due to the resultant of two forces.
4. The bed should be seasoned naturally to avoid distortion.

The main requirement made to the bed of a machine tool is that it maintains the proper relative positions of the units and parts mounted on it over a long period of service under all the specified working conditions. This is achieved by designing, locating datum surfaces on the bed for the principle units whose positions remained unchanged under the above mentioned conditions. The locating datum surfaces for the traveling or adjustable units and parts are straight line bearings called ways or guides, or ways along which the unit can be adjusted.

It follows that, along with the requirements of strength, predictability, low metal requirement and sufficiently low cost, the most important requirement made to beds, bases and columns is shape invariability. This property depends upon

1. Proper selection of bed material and the manufacturing process.
2. The provision of static and dynamic rigidity at which the deformation of bed, under the action of maximum forces during operation, is within limits confirming to the machining tolerances.
3. A sufficiently high wear resistance of the ways.

The configuration of a bed is determined primarily by

1. The arrangement of ways on it for various units of the machine tool.
2. The weight, dimensions and length of stroke of main units and parts.
3. The necessity of housing of various mechanisms inside the bed.
4. The necessity of providing various openings, apertures, etc., in the bed walls for assembly, disassembly, inspection, adjustment and lubrication of various mechanisms of the machine, and pads, bracket and lugs on the bed walls for mounting various devices.

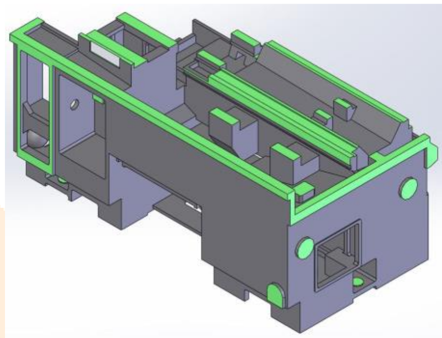

Fig: 5 Lathe bed

Cast bed design should be complied with the general foundry requirements. Their aim is to facilitate molding and reduce shrinkage stresses. As mentioned above a bed must be sufficiently rigid. Ribs connecting the bed walls or cast on the walls greatly affect the rigidity. The efficiency of ribs in increasing the rigidity of construction depends upon their arrangement, quality, shape and size.

The arrangements of the ribs and their shape have a pronounced effect on the horizontal rigidity of a bed. The most advantageous are diagonal ribs and in certain cases crossed ties between the longitudinal walls of the bed. Ribbing in the form of horizontal shelves or a diagonal network has a favorable effect on the horizontal rigidity, especially if it is combined with partitions. Diagonal ribbing increases the torsional rigidity of the bed as well.

Function of Lathe

The main function of lathe is to remove a metal from a piece of work to give it the required shape and size. This is accomplished by holding the work securely and rigidly on the machine and then turning it against cutting tool which will remove metal from the work in the form of chips. To cut the material properly the tool should be harder than the material of work piece, should be rigidly held on the machine and should be fed or progressed in a definite way relative to the work.

What Materials to Use to Make a Bed Lathe?

A lathe can be made from various materials for each component such as the lathe bed. When making a lathe, you start by building the lathe bed. Choosing the right material to use is important for its stability and durability.

Vibration Reduction

The materials that you use must be suitable for repeated use and durability. One of the primary considerations is damping. Working with a lathe causes vibrations that are caused by noise, mechanical oscillations or alternating currents. Damping reduces vibrations by dissipating the energy.

The following goes over each material type you can use, its damping quality and its advantages and disadvantages.

Cast Iron

Cast iron is commonly used for machinery housings or bases due to the stable structure of the material. It is also known for holding its shape when it is subjected to contraction and expansion due to temperature fluctuations. This is ideal for a lathe bed and is also why it is used for pans for cooking.

This material offers good damping, it is easy to machine and can be made in various sizes. Aging of the material can take up to a year and it can be more expensive than other materials available.

A variation of cast iron is Durabar. It has some of the same properties of regular cast iron however the material is pre-aged which makes it more expensive. It comes in standard sizes which can make it impractical for home use.

Wood

A wood lathe bed is constructed like a hollow box. It is easy to assemble and inexpensive to make. The material provides some natural damping.

Wood has some disadvantages as constructing a lathe bed requires drilling and tapping many holes. Wood can also warp when exposed to extreme temperature or moisture.

Aluminum

Aluminum is an easy material to work and can be made in various sizes. Its lightweight property allows for the lathe to be easier to transport, however it provides poor damping.

Steel Shaft

Using a steel shaft provides the lathe bed with a rigid and stable design. Sizing can be adjusted and it is quick and easy to assemble. Its cost is moderate and it does provide some damping.

You will need to do some precise boring of the tail, headstock, tail support and carriage if you use this material for your lathe bed.

Concrete Tube

A concrete tube typically comes in a rectangle shape. This shape allows it to be very stable and rigid and come in various sizes. Lathe components can be attached easily. To provide damping, the hollow inside of the tube will need to be filled. The most effective method will be with concrete.

Granite

Granite is an inexpensive material for a lathe bed. It is very rigid and stable and provides good damping. However, as it is a natural stone, there may be defects within the stone that are unfore-seen. For any lathe attachments, it will require anchors to be used.

Materials for lathe Bed

The metals are employed for various engineering purposes such as structural members, roofing materials, damp proof courses, pipes, tanks etc. Out of all the metals, iron is the most popular metal and it has been used in the construction activity since prehistoric times. Following are some of the ferrous metals which have been employed in the construction of machine structures.

Grey Cast Iron

Grey cast iron commonly used cast iron and the most widely used cast material based on weight. It is the least expensive of all the metals that could be used for castings and hence is considered first when a cast metal is being selected. Other metals are selected only when the mechanical and physical properties of grey cast iron are inadequate. Most cast irons have a chemical composition of 2.5 to 4.0% carbon, 1 to 3% silicon, and the remainder is iron. Elastic modulus of cast iron is only 0.9 to 1×10^4 kgf/mm^2 as compared to 2.1×10^4 kgf/mm^2 of steel. Even then major structural components of machine tools such as bed, saddle, headstock, tailstock body, base, column, slides, gearbox body as also the smaller components such as brackets, housings, covers, pulleys, etc., are made of grey cast iron in preference to steel due to its excellent castability and better damping properties against vibration. Grey iron castings have a tendency to warp and distort. This is mainly due to internal stresses generated by uneven cooling of the casting in the foundry, as well as due to redistribution of stresses in the machine shop during machining. Uneven cooling can be reduced by avoiding abrupt changes in sections and also by having the thickness of walls as uniform as possible. Grey iron castings are often stress relieved by annealing. Grey cast iron Grade 15 of IS 210 is used for brackets, covers, etc., Grade 20 is used for bed, column, saddle, headstock, etc. and Grade 25 is used for components subjected to severe loading. The slide ways on the column, bed, etc., are generally cast integral with the structures and are normally hardened either by flame or induction hardening to HB 450-500.

Steel

Steel is an alloy made by combining iron and other elements, the most common of these being carbon. Depending on the carbon content it is classified as low carbon steel (carbon content less than 0.3%), medium carbon steel (carbon 0.3 to 0.6%) and high carbon steel (more than 0.6%). With respect to vibration proof properties, beds of welded steel construction are not usually inferior to cast iron beds. Cast iron is having more capability of damping vibrations than steel. Other advantages of grey cast iron include high rigidity, resistance to rust and wear, feasibility, high melting temperature and also the low cost characteristics is yet another criterion in selecting cast iron over steel for machine tool structures.

Table: Material properties of grey cast iron are tabulated below

Material name	Young's Modulus in "N/mm2"	Density in "kg/mm3"	Poisons ratio	Ultimate Strength in "N/mm2"
Grey cast iron	130000	7250×e-9	0.30	200

Introduction to optimization

The ever increasing demand on engineers to lower production costs to withstand competition has promoted engineers to look for rigorous methods of decision making such as optimization methods, to design and produce products both economically and efficiently.

Optimization techniques have reached a degree of maturity over the past several years are being used in a wide spectrum of industries including aerospace, automotive, chemical, electrical and manufacturing industries.

With rapidly advancing computer technology, computers are becoming more powerful and correspondingly, the size and the complexity of the problems being solved using optimization techniques are also increasing.

Optimization methods coupled with modern tools of Computer Aided Design are also being used to enhance the creative process of conceptual and detailed design of engineering systems.

Conventional design processes are iterative in nature. In each step various relevant analyses are performed. The various yielded results, for example; displacements, stresses, fatigue analysis etc. characterize the performance of that particular design. These results are used to modify the design and thereafter the new design is reanalyzed once again. This loop has to be repeated until the demands like economic efficiency, a desired weight or wanted fatigue properties are fulfilled. The number of iterations depends on the experience of the designer.

Optimization is an act of obtaining best results under given circumstances. In design, construction and maintenance of any engineering system, engineers have to take many technological and managerial decisions at several stages. The ultimate goal of all such decisions is either to minimize the effort required or to maximize the desired benefit. Since the effort required or the benefit desired in any practical situations can be expressed as a function of certain decision variables, optimization can be defined as the process of finding the conditions that give maximum or minimum value of a function.

It can be seen from the Figure 6 that if a point x^* corresponds to minimum value of a function f(x), the same point also corresponds to the maximum value of the negative of the function –f(x).

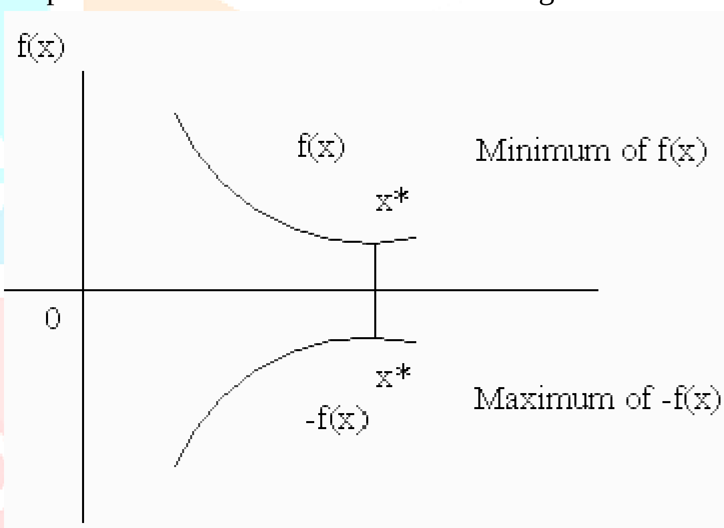

Fig:6 Optimization overview

Statement of an optimization problem

An Optimization problem can be stated as follows:

$$\textbf{Find } X = \begin{Bmatrix} x_1 \\ x_2 \\ x_n \end{Bmatrix} \quad \text{which minimizes } f(x)$$

Subjected to constraints

$g_j(x) <= 0, \quad j=1, 2, 3,......m$

$l_j(x) = 0, \quad j=1, 2, 3......p$

Where X is an n-dimensional vector called the design vector, f(x) is termed the objective function, and $g_j(x)$ and $l_j(x)$ are known as inequality and equality constraints respectively. The number of variables n and the number of constraints m and/or p need to be related in anyway.

Design vector

Any engineering system or component is defined by a set of quantities some of which are viewed as variables during design process. In general, certain quantities are usually fixed at the outset and these are pre-assigned parameters. All the other quantities are treated as variables in the design process and are called design or decisions variables.

x_i = 1, 2, 3… n. the design variables are collectively represented as a design vector:

$$\text{Find } X = \left\{ \begin{matrix} x_1 \\ x_2 \\ . \\ x_n \end{matrix} \right\}$$

Design constraints

In many practical problems, the design variables cannot be chosen arbitrarily, rather they have to satisfy certain specified functions and other requirements. The restrictions that must be satisfied to produce an acceptable design are collectively called design constraints.

Constraints that represent limitations on the behaviour or performance of the system are termed behavioural or functional constraints.

Constraints that represent physical limitations on design variables such as availability, fabric ability and transportability are known as geometric or side constraints.

Objective function

The conventional design procedures aimed at finding an acceptable or adequate design which merely satisfies the functional and other requirements of the problem. In general there will be more than one acceptable design and the purpose of optimization is to choose the best one of the many acceptable designs available. Thus a criterion has to be chosen for comparing the different alternative acceptable designs and for selecting the best one. The criterion with respect to which the design is optimized, when expressed as a function of the design variables is known as the criterion or merit or objective function. The choice of the objective function is governed by the nature of problem. For example, the objective function for minimization is generally taken as weight in aircraft and aerospace structural design problem.

Optimization techniques

Optimization techniques can be broadly classified into three techniques; they are as follows:

- Mathematical programming techniques.
- Stochastic process techniques.
- Statistical methods.

Mathematical programming techniques are useful in finding minimum or maximum of a function of several variables under a prescribed set of constraints.

Stochastic process techniques can be used to analyse problems described by a set of random variables having known probability distribution.

Statistical methods enable one to analyse the experimental data and build empirical models to obtain the most accurate representation of the physical situation.

Structural optimization

New competitive products must meet the growing demands of the market. They must be light-weighted, resource- efficient, durable, and stable and have an affordable price. At the same time, the product must be introduced quickly to the market. These demands can only be met if structural optimization tools are used in addition to established CAE, CAD, DMU and PDM systems. Improvements can be carried out on the digital prototype at a very early stage. Accordingly, the number of required prototypes can be reduced which results in possible time and cost savings.

Conventional design processes are iterative in nature. In each step various relevant analyses are performed. The various yielded results, for example; displacements, stresses, fatigue analysis etc. characterize the performance of that particular design. These results are used to modify the design and thereafter the new design is reanalyzed once again. This loop has to be repeated until the demands like economic efficiency, a desired weight or wanted fatigue properties are fulfilled. The number of iterations depends on the experience of the designer and in complex structures or multi body systems may be high and process time consuming. Structural optimization problems are difficult to solve by analytical method hence we go for numerical methods and FEM is one of the important numerical approach.

Finite Element-Based optimization techniques were first developed by UCLA Professor, Lucien Schmitz in the 1960s. He recognized the potential of combining optimization techniques with finite element analysis for structural design.

Today, there are three types of finite element-based optimization approaches for structural optimization. They are:

- Size optimization
- Shape optimization
- Topology optimization

Size optimization

Size or parameter optimization typically uses element cross-sectional properties as design variables. These include parameters such as plate thickness, area and moment of inertia of a beam cross section.

Size optimization involves the modification of the cross-section or thickness of finite elements. The optimization is carried out by mathematical programming techniques with different objective functions for example maximum stiffness or minimum weight. Many mathematical programming approaches have been tested and implemented in finite element programs (e.g. MSC/NASTRAN, PERMAS, COSMOS/M) and special optimization programs (e.g. MBB-LAGRANGE, STARS, ADS). During the optimization, the element properties are modified on FE level. Due to easy calculation purposes even realistic problems can be handled. Today these approaches can be considered as state of art.

Shape optimization

Shape optimization involves determining the optimal profile (or boundary) of a structural component. The design variables are related to the amount of deformation.

Compared to size optimization, shape optimization is more complex. The coordinates of the surface are regarded as the design variables which will be modified during optimization. Surface modification is also used to reduce the stress peaks found in a design proposal. The resulting component shape is optimally adjusted to the strain resulting from the specified loads and boundary conditions. Thus the reliability and life of a component can be increased.

Topology optimization

Topology optimization involves the optimal distribution of material within the structure. Unlike shape and sizing optimization, topology optimization does not require an initial design. Typically, the design process starts with a block of material called the design domain. The design domain is comprised of large number of candidate elements, and topology optimization process selectively removes from the domain those unnecessary elements.

Aircraft components are often stability designs and topology optimization methods still completely lack the ability to deal with buckling criteria. The present work therefore uses the traditional compliance based topology optimization method to suggest an optimal design configuration which is engineered to provide the design with some stability.

V.CONCLUSION

Optimization in its broadest sense, can be applied solve any engineering problems. To indicate the wide scope of the subject, some typical applications from different engineering disciplines are given below;

- Design of aircraft and aerospace structures for minimum weight.
- Finding optimal trajectories for space vehicles.
- Design of civil engineering structures such as frames, foundations, bridges, towers, chimneys and dams for minimum costs.
- Minimum weight design of structures for earthquakes, wind and other types of random loading.
- Design of water resources system for maximum benefit.
- Optimal plastic design of structures.
- Optimum design of linkages, cams, gears, machine tools and other mechanical components.
- Optimum design of electrical networks.

VI. REFERENCE

1. **S. Syath Abuthakeer, P.V. Mohanram and G. Mohan Kumar,** structural redesign of a CNC Lathe bed to improve its static and dynamic characteristics.
2. **B. Malleswara Swami,** Design and structural analysis of CNC vertical milling machine bed.
3. **Kunal Gajjar,** Machine tool structure has great influence on the precision of machine tool's operations.