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CNC MACHINES – CASE STUDY AND PART ANALYSIS

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ABSTRACT

Computer numerical control setups have begun to pop up in the manufacturing industries across the world due to their high efficiency and minimal dependance on human labor. In this research paper, we aim to understand the in depth functioning of CNC machines, perform different analysis and finally suggest a vast no. of ways in which these manufacturing marvels can be implemented into different industries. Under the analysis aspect of this research paper, we have performed the analysis of miller beds with the basematerials as Cast Iron, Stainless Steel and Carbon reinforced polymer using state of the art analysis software like Ansys and we have tried to understand the differences between these materials using their Stress and Strain analysis on Ansys. After understanding the role of CNC machines and the efficacy of different materials, we have provided multiple future applications of the CNC technology in varied industries.

I. INTRODUCTION

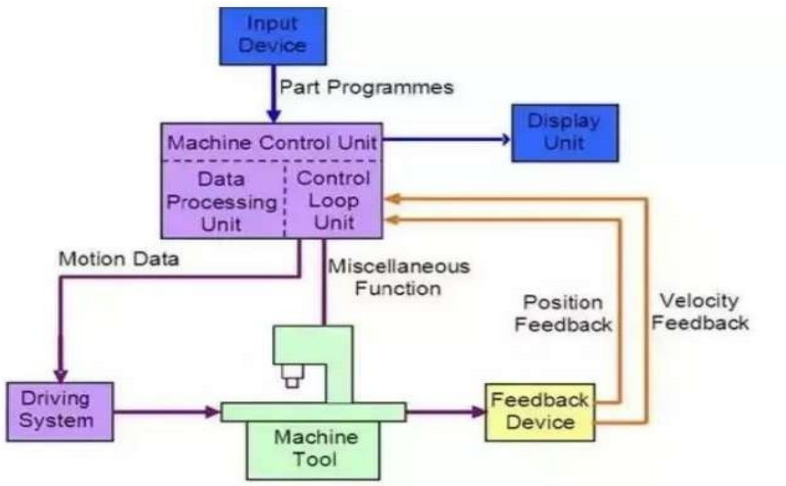
CNC machining is a manufacturing process in which pre-programmed computer software dictates the movement of factory tools and machinery. The process can be used to controla range of complex machinery, from grinders and lathes to mills and routers. With CNC machining, three-dimensional cutting tasks can be accomplished in a single set of prompts. When a CNC system is activated, the desired cuts are programmed into the software and dictated to corresponding tools and machinery, which carry out the dimensional tasks as specified, much like a robot. The programs for CNC machines are fed to computers though small keyboards instead of heavy-duty systems. CNC programming is retained in a computer's memory. The code itself is written and edited by programmers. Therefore, CNC systems offer far more expansive computational capacity. Best of all, CNC systems are by no means static, since newer prompts can be added to pre-existingprograms through revised code. Abbreviated as CNC, the Computer Number Control processes run in contrast to and much more efficiently than manual control, where live operators are absolutely necessary to operate the machining tools via levers, buttons and wheels. To the layman, a CNC system might not look very visually different from a generic computer system, but the software programs and the state-of-the-art components employed in CNC machining makes it stand out from all other forms ofcomputation.

1.1. Parts of a typical CNC Machine:

The CNC machine comprises the following parts:

INPUT DEVICES: These are the devices which are used to input the program in the CNCmachine. There are three commonly used input devices and these are the punch tape reader, the magnetic tape reader and computer via RS-232-C communication.

Machine Control Unit (MCU):

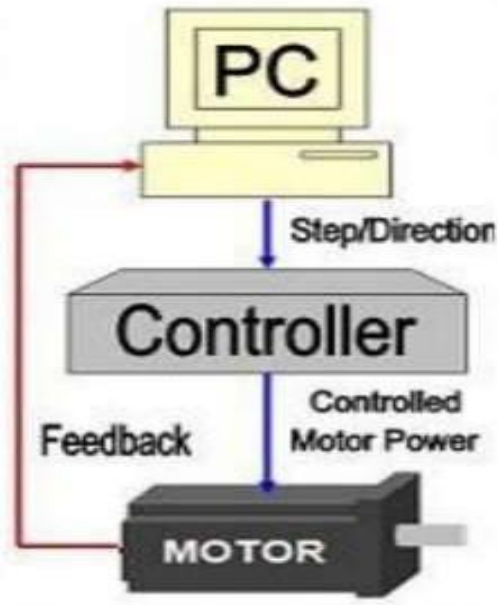


This part is inarguably one of the most essential parts of the CNC machine. It is responsible for all the controlling action of the CNC machine. The MCU is also responsible for the following tasks:

1. It reads the coded instructions fed into it and alsodecodes them.
2. It helps to send the proper instruction to everypart of the machine.
3. It can recognize interpolations (circular, straight,and helical) to form axis transfer commands.
4. It holds the reviewed signals of location and velocity for each drive axis. 5. It implements the auxiliary control functions such as coolant or spindle on/off and tool change.

MACHINE TOOL: Machine tools are hands down an essential component of a CNC machine. They make the manufacturing process possible, helping us craft perfect custom machined parts and products. In layman terms, if the MCU unit is the brain of theCNC system then the machine tools are the limbs converting the code to actual work

DRIVING SYSTEM: The driving system of a CNC machine consistsof amplifier circuits, drive motors and ball lead screw. The MCU provides the signals of position and speed of each axis to the amplifier circuits. The control signals are then amplified to run thedrive motors.



FEEDBACK SYSTEM: This feedback system consists of transducersthat act as sensors. It contains position and speed transducers that continuously monitor the position and speed of the cuttingtool located at any instant. The MCU receives the signals from these transducers and it uses the difference between the referencesignals and feedback signals to generate the control signals for correcting the position and speed errors.

1.2. The Working of a typical CNC Machine:

In order to improve the functioning of a typical CNC machine, one must understand itsoverall working. The working of a typical CNC machine is as follows:

1. First, the part program is inserted into the Machine Control Unit of the CNC machine.
2. In MCU, all the code is decoded and then the MCU dictates the driver system to run thedifferent processes.
3. The drive system works as the motion commands are sent by MCU. The drive systemcontrols the working of the machine tool.
4. The feedback system records the position and velocity measurement of the machine tool and sends a feedback signal to the MCU where the MCU compares the received signals with the standard signals to alter any processes if required
5. A display unit displays all the commands, programs and other important data on themonitor. It acts as the eye of the machine.

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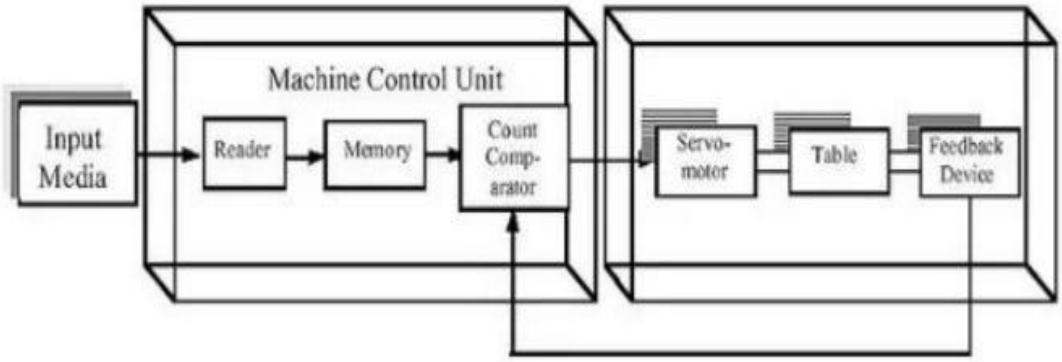

1.3. Detailed Overview of the CNC Process:

The basic mechanism of a CNC Machining process is:

1. Designing the CAD Model: The CNC machining process begins with the creation ofa 3D solid part CAD design either by the producer himself or by outsourcing it to a CAD/CAM design service company. The CAD software allows designers and manufacturers to produce a model of their parts and products along with essential specifications, such as dimensions and geometries, for producing the part or product. This is an extremely essential step as the final product will depend heavily on the CAD model. Hence, one must employ an extremely skilled professional for this role.

2. Conversion of CAD File: The formatted CAD design file runs through a computer- aided manufacturing (CAM) software, to extract the part geometry and generates the digital code which will control the CNC machine and operate the available toolsto produce the required part. There are two types of these codes: G codes: A G code in CNC programming controls the movements of a machine M codes: An M code in CNC programming controls miscellaneous machine functions, including starting and stopping specific actions or programs.

3. Setting Up the Machine: Before the CNC machine is put into action, it is essential to prepare it for operation. These preparations mainly include inserting the workpiece directly into the machine, onto the machinery spindles and attaching the required machine tools, such as drill bits and end mills, to their respective components.

4. Execution: On initiating the CNC machine program, and the program guides the machine throughout the process as it executes the necessarymachine operations to produce a custom-designed part or product.

The vast majority of today's CNC arsenals are completely electronic. The mostfrequently used machines in CNC systems include the following:

1.4. Types of CNC Machines:

There are majorly two categories of CNC machines in modern day industries:

1.4.1 Conventional Machines:

Milling: Milling is a process performed with a machine in which the cutters rotate to remove the material from the workpiece present in the direction of the angle with the tool axis. It is a very universal fabrication method with great accuracy and tolerances. Milling is suitable for a variety of materials and is also very quick. The ability to manufacture a wide range of complex parts is a great advantage. Basic mills consist of a three-axis system(X, Y and Z), though most newer mills can accommodate three additional axes.

Turning: Turning is a form of machining, a material removal process, which is used to create rotational parts by cutting away unwanted material. Turning is pretty much the opposite of milling. This means that instead of the cutting tool, the workpiece is rotating.

Grinding: Grinding, on the other hand, is a machining process that involves the use of a disc-shaped grinding wheel to remove material from a workpiece. If a workpiece has a coarse surface, grinding can make it smoother. The achievable surface quality is very high.Therefore, it is used as a finishing operation rather than creating the final piece from raw materials.

Drilling: While milling equipment can also produce holes, drills are meant for only that job. While milling tools use cutting edges around the cutting head's periphery, drills usethe tip of the tool to produce a hole. CNC drilling machines are commonly used to automate this job, provide better accuracy and a more cost-effective solution.

1.4.1 New Age CNC Machines:

Plasma Cutters: A plasma cutter is a commonly used CNC tool for cutting metals for a wide variety of purposes. It is an excellent tool for quickly cutting through sheet metal,metal plates, straps, bolts, pipes, etc.

Electrical discharge machines: Electrical discharge machining, or EDM, is a non- traditional method in which material is removed from a workpiece using thermal energy.Much like processes such as laser cutting, EDM does not need mechanical force in the removal process.

Laser Cutting Machines: Laser cutting machines are a tool used in a wide range of industries for precision cutting and designing projects. The laser cutting machine emits ahigh-powered laser beam to either cleanly cut or etch a specific design on materials such as steel, plastic or wood.

Routing: CNC routers are seemingly similar to CNC milling machines. Here also the rotating piece is the cutting head. The main difference lies with the materials suitable for cutting. Routers are a perfect fit for cutting softer materials (not metals) that do not require very high accuracy. The reason for that is its lesser output power.

II. MODELING AND ANALYSIS

A simulative analysis on Material Selection of a CNC Milling machine's Bed

The transfer of high speed as well as the high cutting speed of machine tools is very essential for the improvement of productivity. It ensures not only faster cutting rates but also lesser cutting force. Faster cutting speeds can be acquired only by structure which hashigh stiffness and good damping characteristics. Clearly the life of a machine is inversely proportional to the levels of vibration that the machine is subjected.

A 3D model of the CNC machine bed was created in the SOLIDWORKS 2019 software and saved in the iges format and imported into Ansys workbench. The analysis was carried out on three materials cast iron, stainless steel and carbon fiber polymer. The forces inthe front are the weight of the machine bed and cutting forces that are applied to the guideways. The forced at the back of the bed are mainly due to the motors that are present in themachine.

There are two types of analysis that this machine bed undergoes:

1. Statical Analysis - A static analysis calculates the effects of steady loading on a struc- ture, while ignoring inertia and damping effects, such as those caused bytime-varying loads.

2. Normal Stress Strain analysis - A normal strain results from tensile stress and is a strain computed from relative displacements that are measured perpendicular to two refer-ence planes.

Machine Bed supports all elements like column, work table and servo motors. Whateverthe cutting force induced in the machining process is simply transformed to machine bed, and machine beds absorb the vibrations induced in the machining process. Machine bed contains hole for accommodating the lead screw which drives the work table. So that workpiece canbe moved as per the user programming code. It also supports the column on the rear end ofit with the help of lead screws. Machine beds withstand the various forces generated duringthe cutting.

OBSERVATIONS AND INFERENCES

Total deformation of carbon polymer composite machine bed is less than the deformation due to both Steel and Cast Iron due to its high Young's Modulus than both Steel and Cast Iron.

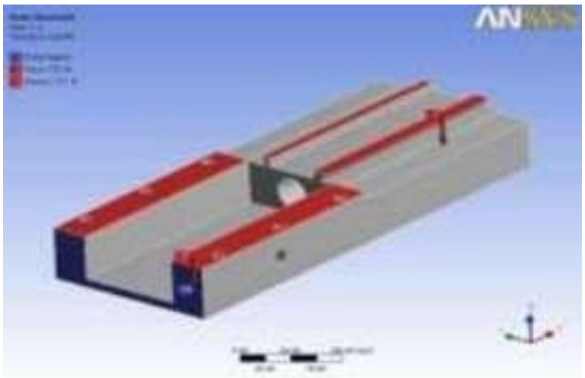

Figure 1: Miller Bed In Ansys

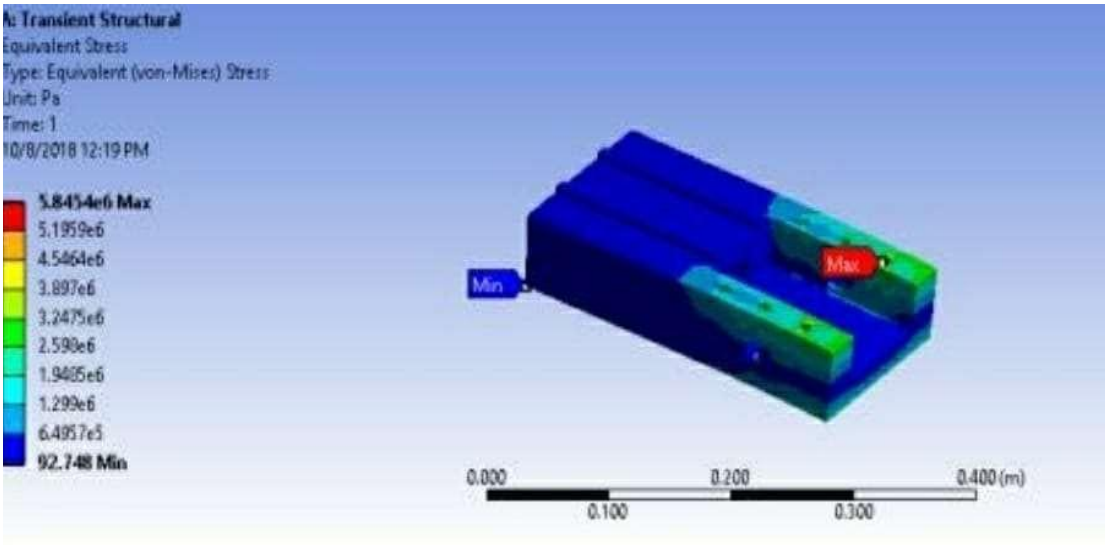

Figure 2: Normal Stress On Miller Bed Made Of Castiron

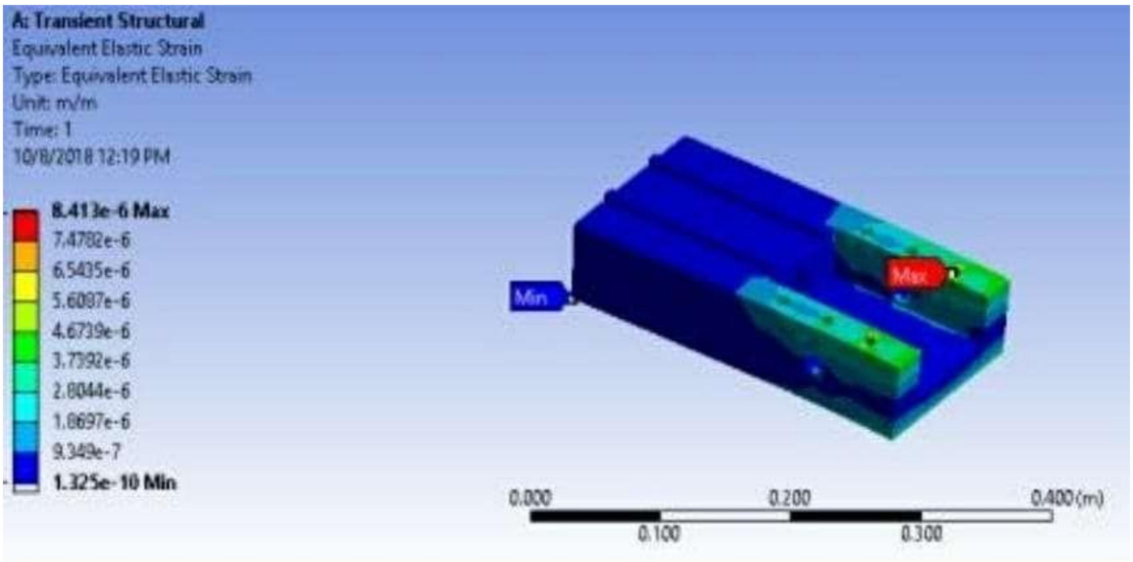

Figure 3: Normal Strain On Miller Bed Made Of Cast Iron

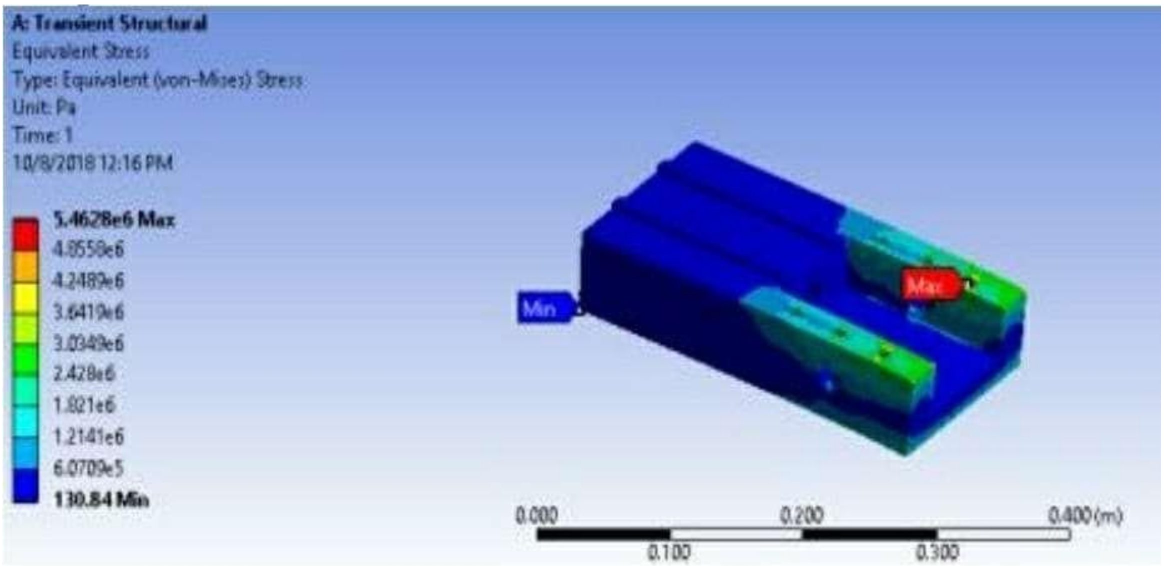

Figure 4: Normal Stress On Miller Bed Made Of Stainless Steel

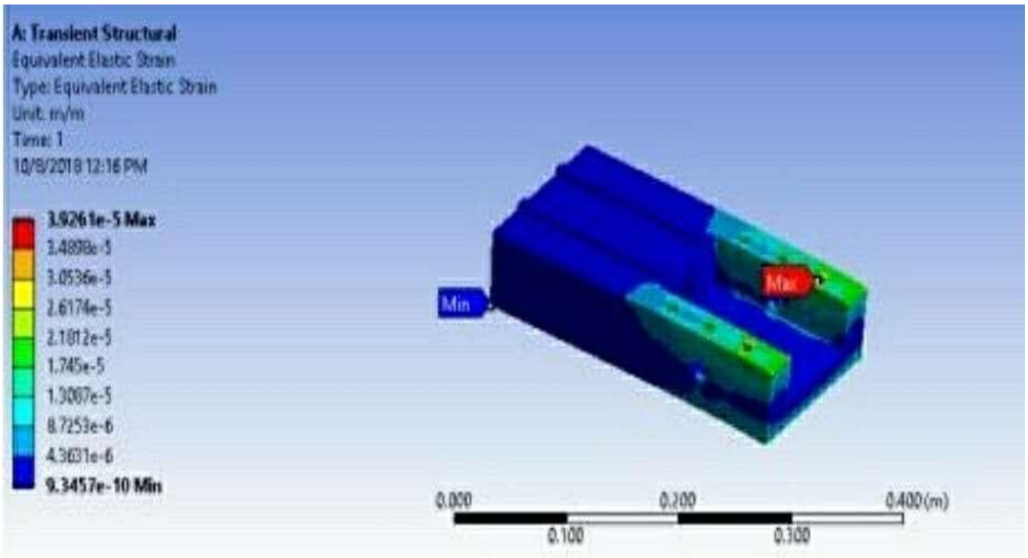

Figure 5: Normal Strain On Miller Bed Made Of Stainless Steel

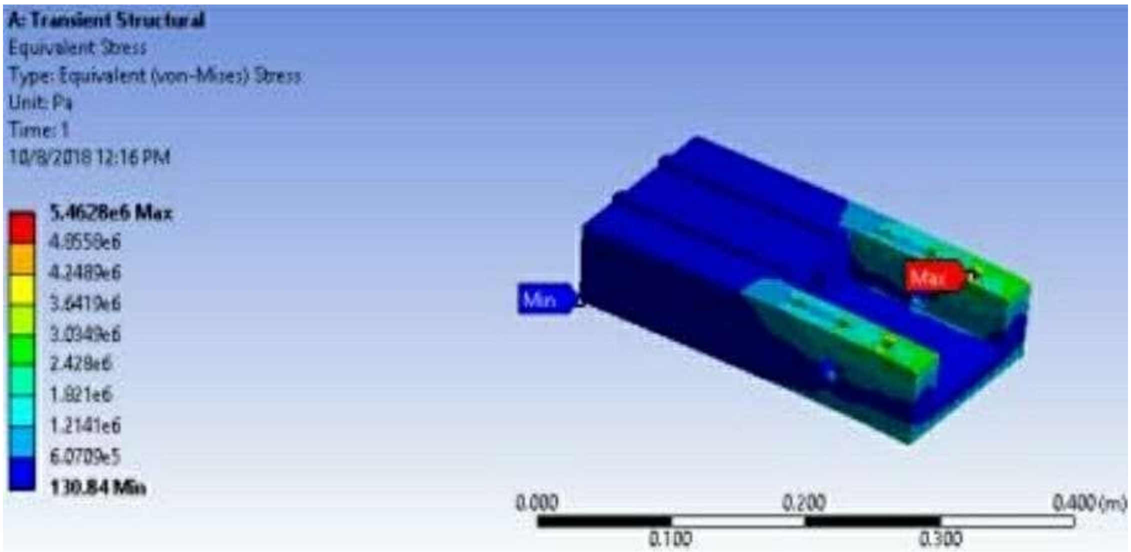

Figure 6: Normal Stress On Miller Bed Made Of Carbon Fibre Polymer

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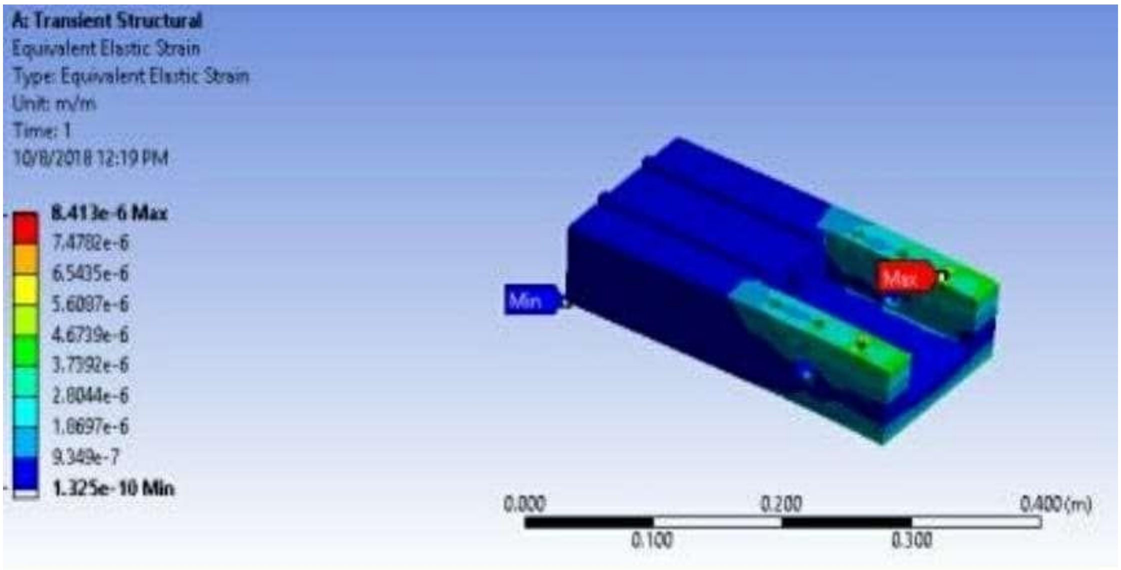

Figure 7: Normal Strain On Miller Bed Made Of Carbon Fibre Polymer

Since stress is independent of Material Property, hence stress induced all the machine beds is approximately same because there is no design modification.

Normal Strain of carbon polymer composite machine bed is less than the both Steel andCast Iron due to its high Young's Modulus than both Steel and Cast Iron.

Table 1: Comparison of Different Materials

	Cast Iron	Steel	Carbon Fibre Polymer
Total Deformation (mm)	3.9567×10^{-5}	2.887×10^{-5}	2.0543×10^{-5}
Normal Stress (mpa)	0.040325	0.036949	0.040435
Normal Strain (mpa)	2.5335×10^{-7}	1.4113×10^{-7}	1.3193×10^{-7}

This composite material offers high accuracy and precession of the component manufactured in such machine tools made of composite materials. By considering all the results, the induced deformation and strain in carbon polymer machine bed is less than conventional cast iron machine beds because specific strength and specific rigidity of carbon polymer machine bed is more than cast iron. The work suggests that carbon polymer material is best suited for CNC milling machine bed.

Finite element analysis of CNC Lathe: The Spindle

Machine tool industry is the key industry of machinery manufacturing industry, to pro-vide equipment for the manufacturing industry. The machine tool spindle is the key compo-nents of the machine tool spindle, a chuck mounting the front end of the workpiece or tool directly involved in cutting performance, especially the low order natural frequency has a great influence on the performance of the machine tool. Especially for CNC machining it requires both high precision and high efficiency requirements, it is necessary to carry out and finish machining process, but also some rough machining, therefore, put forward higher requirements on the static and dynamic characteristics of the spindle. In this paper, the finite element machine spindle based on ANSYS analysis, provide a reference for the design of the spindle.

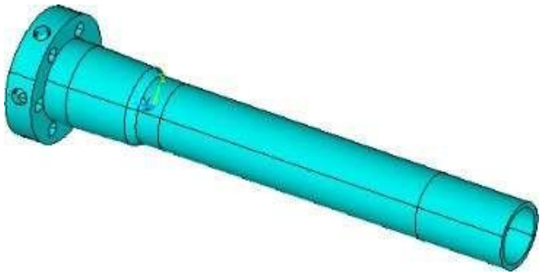

Figure 8: Model of a Spindle

OBSERVATIONS AND INFERENCES

The harmonic motion is observed in the spindle of the lathe as the frequency of a normal turning operation is increased at stated intervals of time.

Every increase in the frequency is referred to as order and each order changes with an increase in the rotation frequency. The spindle here undergoes 4 orders Starting from 1 to 4.

The vibration of the structure can be expressed as a linear superposition, including low order modes than the effect of higher modes of vibration on the structure. The dynamic characteristics of low order modes of structure play a decisive role, it analyzes the vibrationcharacteristics of structure. The natural frequency of the spindle is high enough, the spindle static stiffness canmeet the design requirements of high stiffness. The first critical speed calculation of 60×338.52=20311.2r/min according to the natural frequency of spindle. Modal analysiswas done far greater than the working speed of spindle (less than 1600r/min), indicatingthat the work spindle speed can effectively avoid to ensure the machining precision of thespindle resonance. The spindle should be stiff enough to carry operations without any bending and with increasing speed of the CNC lathe the job was done more precise and accurately then a manual one.

Order	Natural Frequency
1	338.52
2	339.53
3	820.59
4	1043.90

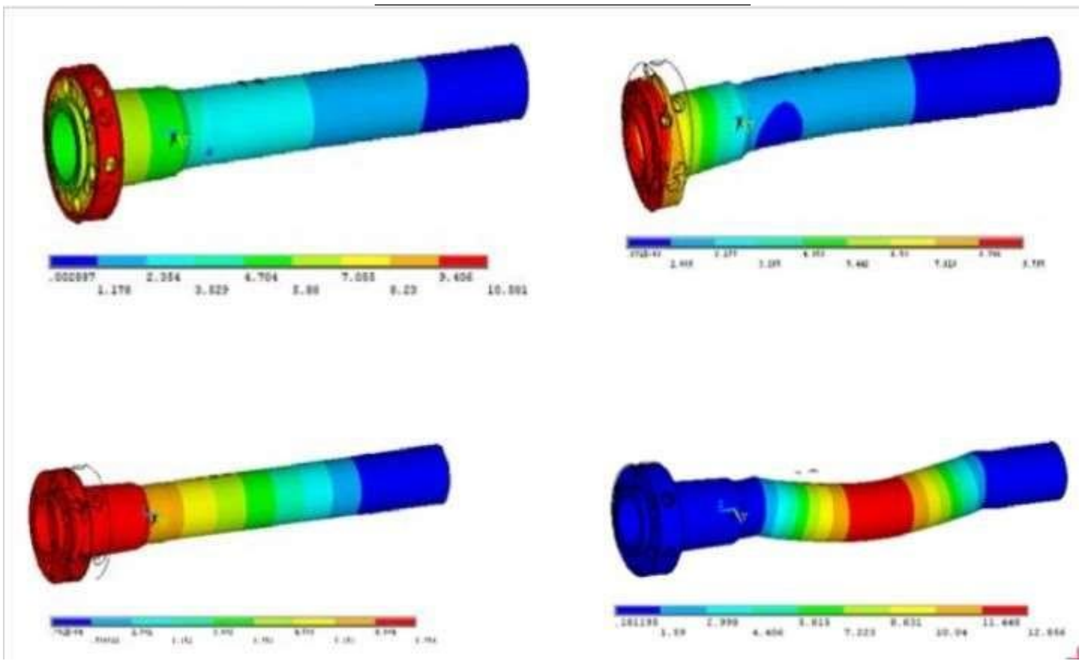

Figure 9: Ansys Analysis of Spindle

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III. APPLICATION

Applications of CNC Machines

CNC machines are used to create various complex parts for a large number of industries.Although mass production can also be used in some fields, others require custom-made parts for certain purposes. Industries tend to use CNC machines since it provides the ability to create precise parts with the help of a computer. From medical to military fields, all rely on machining parts. Since the technology has vastly improved over the years in both machines and computers, using CNC machines makes it easier to produce complex and intricate parts as compared to the conventional methods.

Medical Industry

This is an industry involving life and death and hence precision is of utmost importance. High precision and high rate of production are needed to meet the demands in this field. The CNC machines are easily able to cope up with stipulations due to a variety of materials and techniques.They can easily create intricate and custom parts in large volumes. The approval of the Central Drugs Standard Control (CDSCO) is also required in this industry. Since a computer is used for manufacturing, it enables the engineer to check the part prior to machining and the margin of error. There may be some parts which combine to form a device and, in such cases, high accuracyis needed to prevent device failure and incorrect results.

Transportation Industry

The need and use of CNC Machines is very similar to the aerospace industry. The testing and analysis during the prototyping stage requires parts and any changes needed can be quickly implemented through the computer and new modified parts can be obtained. The properties required in this field are slightly different to those in the aviation industry. There we require high speed strength and stability but here we need and durable parts. Since a CNC Machine can work with a variety of materials, it can be used to create almost every part, from engine to brakes.

Aerospace Industry

This is another field where there should be minimum margin for error, sometimes as low as 0.00004 inches. This is because the devices in this industry have to face intense pressure and great speeds and every instrument must be precise to prevent any possible harm. The smallest of problems can cause major failure. The abilities of CNC Machines have allowed major developments in the aerospace industry which could not have been possible without it. Various parts for prototypes and testing stages are manufactured through CNC Machines and since the 3D image is available to the engineer through the computer, any changes that are required can be easily made. This provides parts for testing the mass production of parts at a rapid rate is made possible through CNC Machines.

Oil and Gas Industry

The machinery required in this industry is built up of a large number of parts that need to be accurate so that they can properly fit together. In case of a mismatch, there could occur a leak or some functions may not work as intended. Hence, a CNC machine is needed for high accuracy. Generally, oil and gas plants are set up at locations far away from major towns and cities and hence the parts of the machinery should be robust and have high they should be able resist various natural forces because if they fail, production will stop for a long time.

Military Industry

Much like the oil and gas industry, the military requires parts that are tough and sturdy and there can be no compromise in accuracy. The government sets strict regulations on military products that need to be followed and these are conveniently complied with while using a CNC Machine since it can easily make intricate parts with high precision. Although the working and operation of all procedures related to the military are kept private, the CNC Machines are an entity that cannot be ignored for manufacturing processes given its quick and accurate production.

Electronics Industry

This is an industry where at times a CNC Machine becomes a necessity because the level of precision and accuracy that is required cannot be achieved by humans. Some require laser precision a few micrometers. Tinier the parts, smaller becomes the room for error and computer-controlled machining it. The machines can be used to create parts for heat sinks, amplifier housings, radio frequency interface shielding and electrical insulation.

IV. FUTURE SCOPE

Future Prospects of CNC Machines

The development of CNC Machines transformed the design and manufacturing industry. Their attributes of providing complex parts with great accuracy and precision at high production rates made their importance unprecedented. However, the question of whether there is room for improvement or if production should continue as it is, still persists. One opinion was that the human programmers operating on this machine would soon be replaced by Artificial Intelligenceand Machine Learning, which have taken massive strides in recent years. This could be possible since it is believed that machining through CNC Machines is highly adaptive and a closed-loop andcomputers these days have the ability to study and learn from the past operations and quickly implement them through Artificial Intelligence and Machine Learning.

CNC and Robotics

The idea here is to create an environment of machines that requires minimal human influence andcontinues the process in an efficient manner. Projects are being carried out to incorporate CNC Machines and robots to work together. The CNC Machines will make the parts as they currently do but robots will be used for packing and moving of these parts. The plan will be to create such a software that allows the CNC operator to easily control this system of machines to achieve maximum efficiency with minimum effort. With the growing advancement of Artificial Intelligence and Machine Learning, this collaboration of CNC Machines and robots could happen in the near future.

Digitalization

This involves simulating an object or a process in a virtual environment to get a better insight on the situation. It basically involves collection of data and processing it to help in analysis and simulation. It is a trend that is being adopted by various industries and shall soon make its way intothe machining world. This will increase productivity and help new ideas come to life. The idea is to collect as data as possible because it would make the "virtual twin" more accurate and hence its simulation will also be more precise. The design engineers can use the findings of the simulation togreat effect to plan and the machining process.

Personalization of CNC Machines

Over the years, CNC Machines have become cheaper, smaller and easier to use. Companies that manufacture them are trying to make them more to increase not only industrial but personal use as well. Just like 3D printing has become very popular these days, CNC Machines can have similar demands if the machines are made compact and easy to use and are made available for an affordable price. People can keep them in their personal workshops. No one thought that computers would be so widely used and could even fit in our pockets when they were invented. A similar situation with CNC Machines is likely on the cards with growing efforts to these machines.This will birth new ideas and innovations.

V. CONCLUSION

Computer numerical control (CNC) is a strategy for robotizing control of machine instruments using programming installed in a microcomputer connected to the apparatus. CNC machines are utilized to make an assortment of items utilizing various cycles. With appropriate preparing, a human administrator can utilize CNC machines to make exact parts with diminished danger of mistake. Subsequent to taking this class clients ought to have the option to depict regular parts of CNC machine instruments and controls. CNC machining assumes a fundamental part in the advancing universe of current assembling. On account of ongoing headways in innovation, gone are the times of abrasive plant life. Laborers today utilize their machining abilities in a perfect, proficient setting with cutting edge and forefront innovation. Laid out above are the essentials of the CNC machining measure, different CNC machining activities and their necessary hardware, and a portion of the contemplations that might be considered by makers and machine shops when choosing whether CNC machining is the most ideal answer for their specific assembling application. In this existence where there is no time at all to squander, CNC machining is the most ideal approach to be productive and on schedule with substantially less mistake than a human worked machine. With developing age and innovation, the necessities of utilizing such machines have been prime and acknowledged around the world. This guarantees less work exertion with more prominent exactness.

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