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Modeling, Analysis and Development of Industrial Plateau Honing Machine

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Abstract - Honing machines are used to generate the cross hatch pattern on the liners of the engine cylinders for improving their efficiency. This proposed work highlights on the structural modification of a Plateau Honing machine by scaling down the geometry of the machine to reduce the overall size of the machine and also to reduce the cost while keeping its functional components undisturbed. Structural design is a key component that contributes to increased efficiency in manufacturing processes, as well as other advantages such as reduced rejection. Modeling of the structure is done to easily identify and arrange its functioning components, as the manufacturing industries suggest newer and creative designs. The scope of the work focuses on testing the structural integrity of the modifications performed by using Finite Element Method analysis to verify the changes and optimizing the size and shape of the machine. Relatively working on the functional aspects of the machine Parameters like honing pressure and speed. For the above redesigning of honing head will be done to check its strength as well as working on material optimization.

Key Words: Plateau Honing machine, structural integrity, FEM analysis.

1. INTRODUCTION

This Honing is an abrasive machining technique that involves scraping an abrasive grinding stone or grinding wheel against with a piece of metal in a regulated route to achieve a precise surface. Honing is generally used to increase a surface's geometric shape, although it may also be used to optimize the finish. Typical applications include cylinders for internal combustion engines, air bearing shafts, as well as gears. Hone comes in a variety of shapes and sizes, but they all include one or maybe more abrasive stones that are pressed against the surface they're working on. Honing is a somewhat costly procedure since it is a high-precision technique. As a result, it's only utilised in components that require extreme accuracy. It's usually the last step in the production process before an item is sent to a client. The object's geometrical size is determined by previous processes, each of which is generally grinding. The component is then sharpened to increase a form feature like roundness, flatness, cylindricity or sphericity.

A spinning tool containing abrasives scrapes metal out from internal surface of a bore or cylinder during the honing process. The main goal is to achieve a certain dimension and geometric cylindricity on the surface. It's generally supplementary machining processes that complete a product, relieves tension, or validates a flaw like out-of-round tapers or misalignment of bores. Drill, ream, heat treat, then hone seems to be a conventional manufacturing cycle. Drilling and honing may be all that is essential in some cases. In a procedure that works successfully as a finishing process with boring as well as grinding, the honing operation generally eliminates between 0.001 to 0.010” (0.03-0.3mm) of material.

Honing rates are sluggish in comparison to grinding, however this does not indicate that metal is removed slowly. To calculate metal-removal rates and geometric correctness, the size of the abrasive and length of stroke are combined with food rate, rotation, and spindle speeds. This is frequently less than 0.000040" or one micron. In the cutting procedure, two major forces are associated: torque from its abrasive's pressure upon its surface being cut throughout tool rotation, and forces again from hone or workpiece chop and forth activity.

The finish of cylinders for internal combustion engines, air bearing spindles, and gears are examples of typical uses. There are different kinds of hones however all of them are made up for even stones that will be more abrasive are pressed in comparison to the surface operating on. When it comes to sharpening knives, honing steel doesn't truly hone blades; it just realigns the metal across the edge. Lapping and super finishing are two more procedures that are comparable. Because honing stones resemble grinding wheels, it's easy to mistake it for a low-tech kind of grinding. It is more accurate to conceive of it as a self-truing grinding procedure. The wheel follows a basic route during grinding. When plunge grinding a shall, for reference, the wheel goes in around the part's axis, grinds it, but instead moves back out. Any errors in the geometrical parameters of the grinding wheel should be transmitted into the component where every cutting of the wheel continually touches the very same segment of the material. As a result, the resulting workpiece geometry can only be as accurate as the truing dresser. As the grind wheel wears, the precision suffers even more, necessitating frequent truing to restructure it.

1.1 Principle of Honing

Honing works on the idea of obtaining a rotary motion and also a translatory motion while employing a high feed rate. It is necessary to provide a 0.2 mm tolerance in the hole size just so the bore may be completed quickly with medium grit honing sticks before moving on to fine grit honing sticks. The technique necessitates the continual flushing out of spent abrasive grain with honing sticks in order to avoid the abrasive grains becoming lodged in between the grain and results in the honed surface becoming glazed.

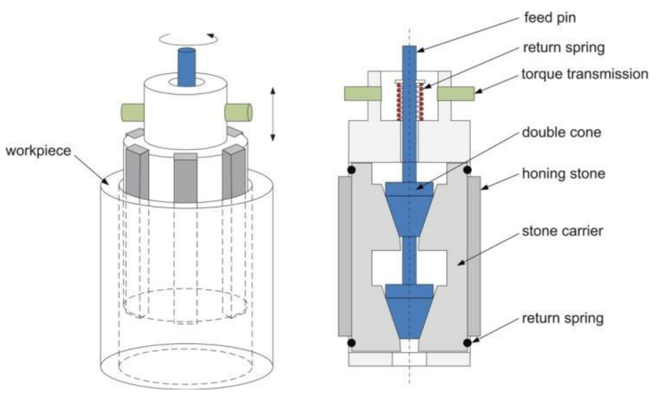

Fig -1.1: Honing Principle

1.2 Honing Stones

To obtain a precise surface, honing utilises a specific instrument called an honing stone or an hone. The hone is made up of abrasive grains which are adhered along with a glue. Honing grains are unevenly shaped and range in size from 10 to 50 micrometres in diameter (300 to 1,500 mesh grit). Smallest particle sires result in a flatter work piece.

A honing stone is similar to a grinding wheel in many ways, although honing stones are more brittle and adapt to the geometry of the workpiece as they wear in. Honing stones can be handled with wax or sulphur to extend their life and reduce their friability; wax is typically chosen for environmental reasons. A honing stone can be made out of any abrasive substance, although the most popular are silicon carbide, corundum, diamond and cubic boron nitride. The properties of the workpiece material typically influence the selection of abrasive material. Corundum or silicon carbide are suitable in most situations, although exceptionally hard workpiece elements must be polished with super abrasives in some cases.

In most cases, the hone is rotated in the bore as it is pushed in and out. Machines might be transportable, basic manual machines, or completely automated based on what measuring the design is done. Cutting fluids with special properties are utilized to produce a clean cut and to eliminate a bended piece of material. Modern abrasive advancements have made it feasible to remove far more material than had been previously conceivable. In several situations as through machining is possible, these have displaced grinding. On shafts, external bones serve the similar purpose.

1.3 Cylinders Honed

The main purpose of the honing toll is used to design the piston cylinders in the engines, the cylinder's interior surface should be honed in such a way that it should with and the lubrication inside the cylinder and the cylinder should not undergo friction. So the honing tool operates the two operations in a single tool, one is roughing operation and one more is surface finishing operation. If one operation is done in the clock wise direction i.e. If the tool rotates in the clock wise direction, the other operation is done in the counter clock wise direction i.e. the toll rotates in the counter click direction, so that the diamond shaped pattern is obtained inside the cylinder surface, hence the lubrication holds in long period of time, because the lubrication oil flows in the zig-zag direction.

Fig -1.2: Cross hatch pattern on a cylinder

1.4 Cross Hatch Pattern

A cylinder liner is a cylindrical component that fits within an engine block to make a cylinder. It's amongst the most crucial components of an engine's interior. The cylinder liner is replaced on certain engines if it wears out or gets damaged. On engines with no replacement sleeves, the cylinder could be fixed by boring out the old liner and replacing it with a new smooth and round liner (despite the fact that the cylinder's diameter has been marginally increased). Because it lowers the amount of oil movement up and down the cylinder, cross-hatch is utilised while using low tension oil rings, for example. The simpler the rings can adapt and the quicker they will adhere to the cylinder, the rounder and truer the cylinders must be.

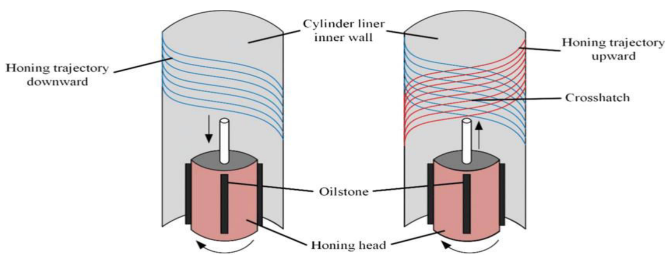

Fig -1.3: Tool movement to achieve cross hatch pattern

To maintain adequate lubrication for round seal of pistons inside the cylinders, "cross-hatch" design is employed to keep oil or grease in place. Scuffing of the piston ring and cylinder can be caused by a smooth glazed cylinder wall. On braking rotors and flywheels, the "cross-hatch" design is utilized.

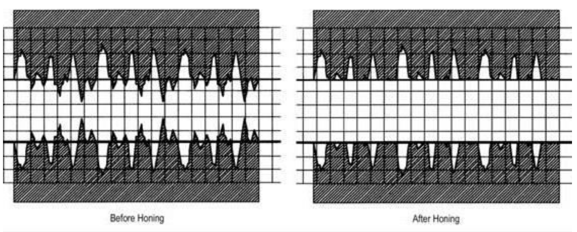

Fig -1.4: Graph of honing process

2. MODELING AND ANALYSIS

This work highlights on the structural modification of an Honing machine by scaling down the geometry of the machine to reduce the overall size of the machine While keeping its functional components undisturbed. The scope of the work focuses on testing the structural integrity of the modifications performed by using FEM and validating the Changes and optimizing the size and shape of the machine. Working on the functional aspects of the machine parameters like honing pressure, no of cycles and feed rate and speed. For the above, redesigning the honing head and validate for the strength as well as work on material optimization. The body of the paper consists of numbered sections that present the main findings. These sections should be organized to best present the material.

For modelling the component we used SOLIDWORKS 2016 software, solidworks is the industry standard in 3D CAD, with cutting-edge productivity tools that encourage optimal design practices while also guaranteeing compliance with industry and business standards. This 3D CAD programme is robust, user-friendly, adaptable, and scalable, so we choose this software to design the honing component.

2.1 Model of the Plateau Honing Machine

This is the structural model of the plateau honing machine it is designed to show that it is having the cantilever type section to hold the functional components and to carry out the analysis for this model.

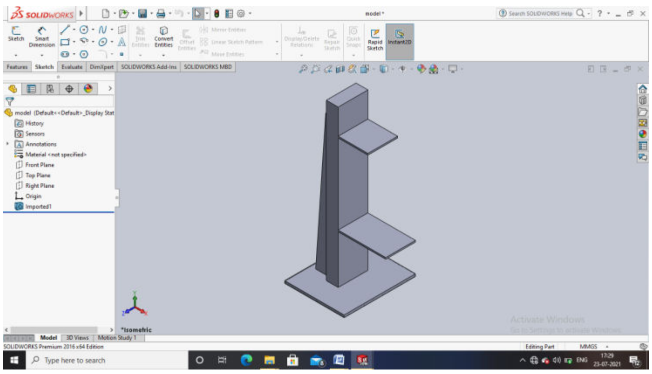

Fig -2.1: Model of the Plateau Honing Machine

2.2 New Structural Design for Plateau Honing Machine

This is newly designed model for the plateau honing machine by considering the problems occurred in the previous model and this will be evaluated by doing analysis.

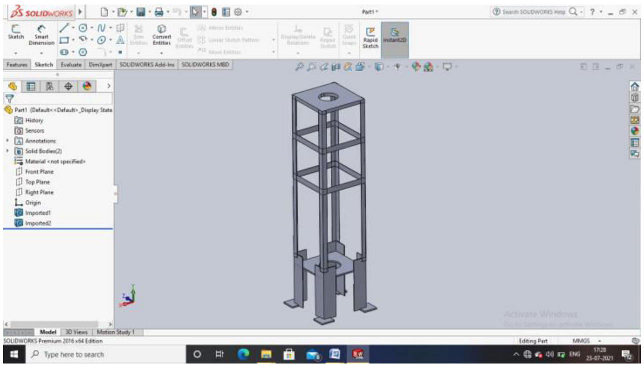

Fig -2.2: New Structural Design for Plateau Honing Machine

2.3 Drafting of the New Structural Design

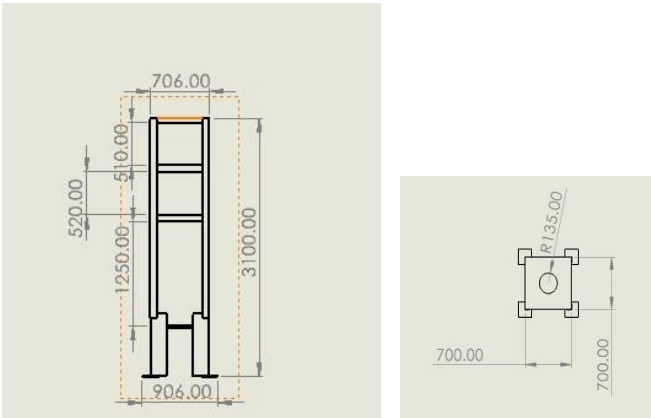

Fig -2.3: Drafting of the New Structural Design (dimensions in mm)

2.4 Models of Honing Head

The measurements are taken in different measuring instruments such as, vernier caliper, Screw gauge, and CMM machine, since the dimensions are very important to do modeling.

Fig -2.4: Honing Head – Sai Pavan Hydraulics and machines

2.5 Honing Head

Assembly is the combination of the different components or tools to form the main tool or the component. It includes the different subassemblies to form the main assembly, compared the main measurements of the honing tool component, which we took from different measuring instruments and compared with the draft copies which were took from the modelling software, so that the different components should match the measurements such as diameter, radius, length etc.

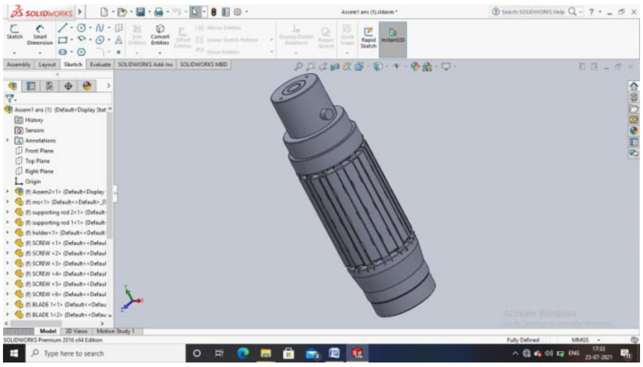

Fig -2.5: Honing Head Assembly

2.6 Analysis of Plateau Honing machine structure

It will either be linear or non-linear in nature. The linear model presupposes that the material somehow doesn't deform plastically (permanent deformation). When straining material beyond its elastic capabilities through into plastic region, or bending more than 10% of the model length, non-linear models are used to separate contact situations (contact with lift-off) (large deformation). Material characteristics alter at this stage, and stresses in the material fluctuate depending on the degree of deformation. Vibration analysis is frequently used to evaluate for natural, resonant frequencies (a loud muffler or other problems, such as the Tacoma Narrows bridge), random vibrations, shock, and impact in models. Each of these events may have an effect on the model's inherent vibration frequency, causing resonance and ultimate collapse.

Some of the Static Load Assumptions are:

1. All acting loads has to be independent of time.
2. Loads are considered to be static or applied gradually at a moderate rate.
3. The load considered will be constant.
4. During the research, it is assumed that no change in the direction of load.
5. Inertial and damping forces are created by impact or dynamic loading, that are disregarded.
6. Periodic loads with such a frequency much lower than the model's inherent frequency could be analyses as static loads.

Analysis is done for the structure the fig 2.6 shows the meshing has been done of the entire structure number of nodes is 16446 and number of elements is 8241. The fig 2.7 shows the load applied on the structure and the load applied is 3000N.

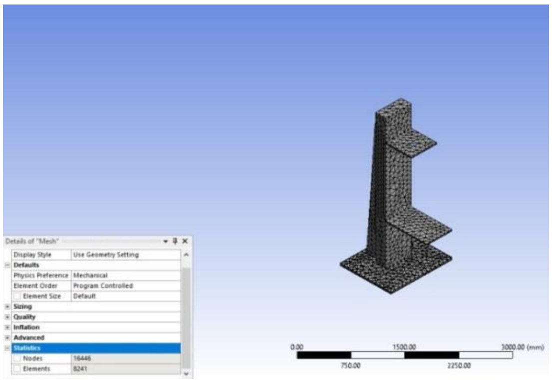

Fig -2.6: Structure model being meshed

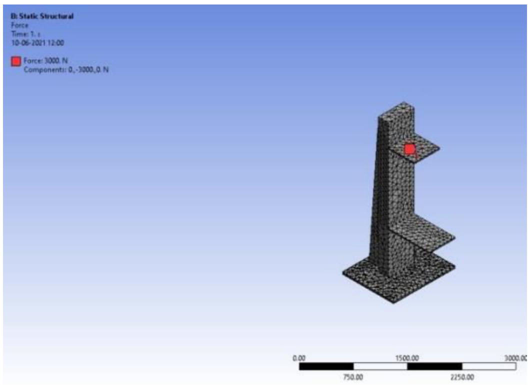

Fig -2.7: Load applied on the model

2.7 Stress and Total deformation

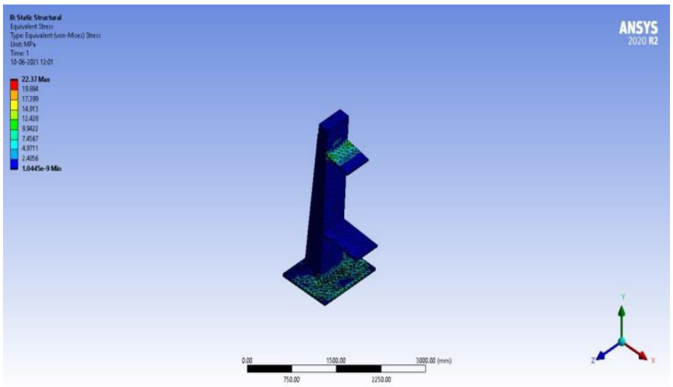

Fig -2.8: Von-mises Stress for model

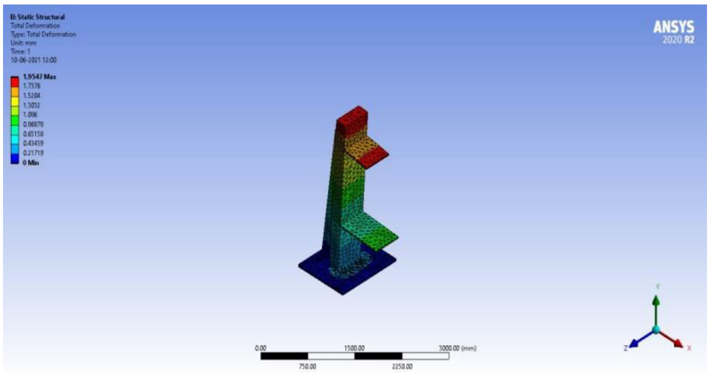

Fig -2.9: Total deformation for the model

2.8 Analysis for the new structural design of Plateau Honing Machine

Analysis is done for the new structure designed for the Plateau honing machine. The design is completely change from the previous model where it has been meshed and the fig 2.10 shows the number of nodes is 29305 and number of elements is 12464. In fig 2.11 load has been applied on the structure to shown the stress and total deformation because to conclude the design is safe.

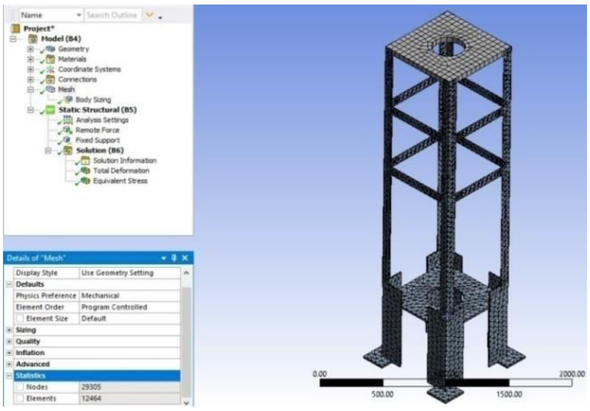

Fig -2.10: New structural model meshed

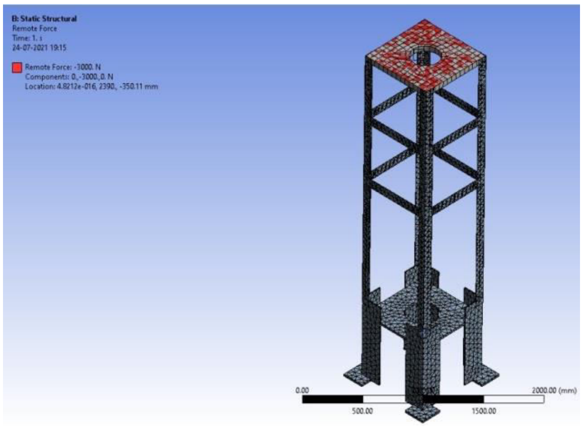

Fig -2.11: Load applied on New structural model

2.9 Stress and Total deformation

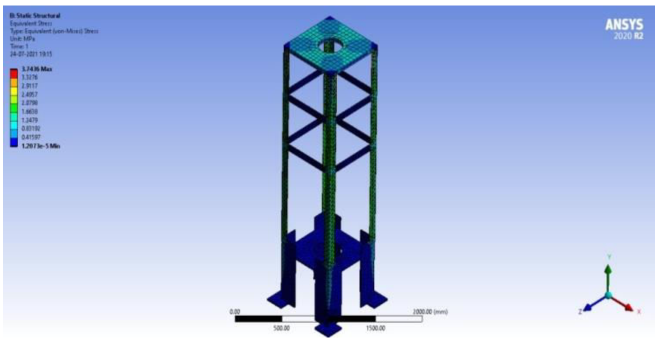

Fig -2.12: Von-mises stress on new structural model

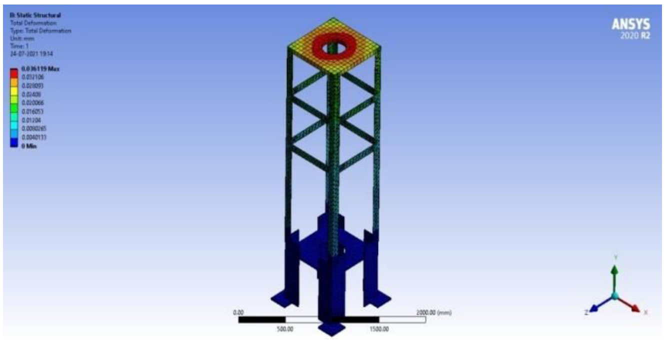

Fig -2.13: Total deformation on the new structural model

2.10 Modal Analysis

Modal analysis is very important in bridge building, where the engineer has keep natural frequencies distinct from the frequencies of people walking across the rail. Because it may not be possible, it is advised that groups of people, such as troops, stop their stride while walking down a bridge to avoid possibly high excitation wavelengths. Various natural excitation frequencies might exist and stimulate the natural modes of a bridge. Engineers (at least inside the near term) tend to learn from such experiences, and more contemporary suspension bridges account for the possible impact of wind through the design of the deck, It may be constructed in such a way that it pulls the deck down against the structure's support instead of allowing it to lift. Such aerodynamic loading concerns are addressed by decreasing the area of the structure exposed to the approaching wind and reducing wind-induced oscillations in suspension bridge hangers.

In this work the modified frame structure is considered for the modal analysis.

High speed motor which runs at 3000 RPM is used but the speed has to be stepped down due to slow RPM of the honing head and applied pressure on the liners. The L section Hardened steel material is considered to develop a structure for the above the motor load is concentrated on top of the structure with the help of a plate.

So the structure designed need to be validated for minimum 5 mode shapes and natural frequencies. The model is meshed in modal analysis module of Ansys Work Bench and the support conditions are enabled without any other external loads.

As a result, the stability and mode shapes are based on 5 natural frequencies.

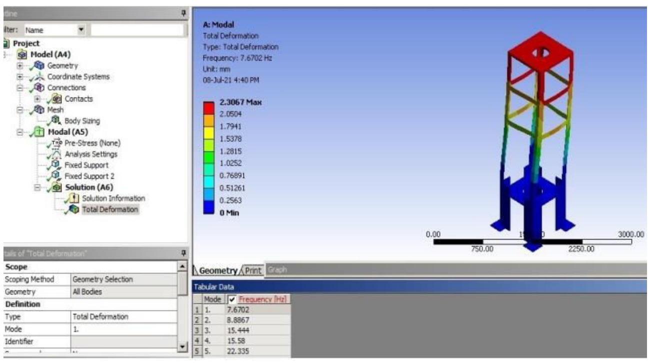

Fig -2.14: Modal Analysis model 1

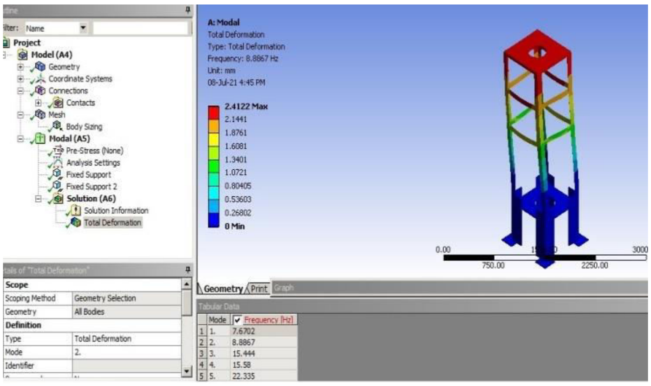

Fig -2.15: Modal Analysis model 2

After performing the analysis we have got 5 natural frequencies with their displacement mode shapes. As shown below

1. 7.67 Hz
2. 8.88 Hz
3. 15.44 Hz
4. 15.58 Hz
5. 22.33 Hz

At each natural frequency mode shapes have been plotted, the displacements vary from 2mm to 25 mm. Hence it is suitable to consider the first two modes for the design confederation and suggested that the vibration of the motor and the other components should not go beyond 10 Hz during the operation, if the need requires it is necessary to design suitable damping system based on the mode shapes.

2.11 Analysis of Honing Head

This is the complete assembly of the honing head which is subjected to analysis for the toque, pressure and force and the number of nodes is 153194 and elements are 76956.

The main thing before the analysis is all individual components which has been assembled has be featured with Bonded option in the software which shows every component is bonded with each other because the analysis can be done accurately.

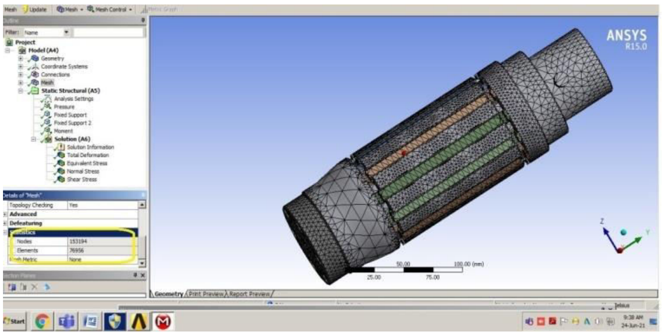

Fig -2.16: Honing head meshed

2.12 Total deformation and Stress

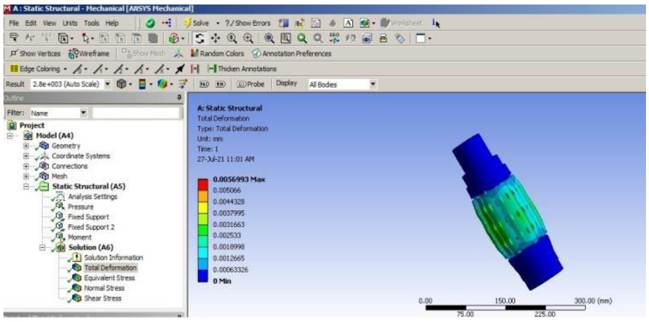

Fig -2.17: Total deformation of honing head

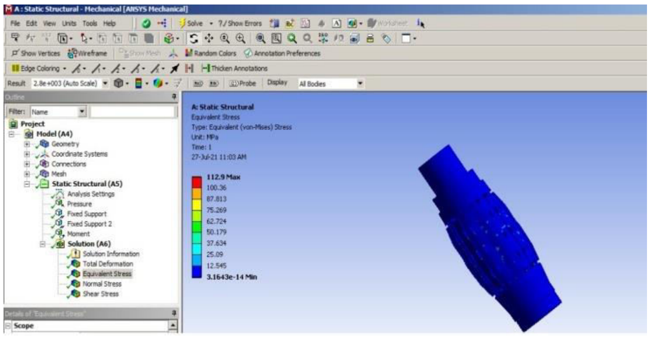

Fig -2.18: Analysis to determine von-mises stress

2.13 Calculation

1. Normal Force Calculated from cone force at an ideal tool.

$$\mathbf{F_n = \frac{F_k}{m.tan\gamma}}$$

$$\mathbf{F_k = P_k \cdot A_k}$$

$F_k = 29.42 \text{ x } 3115.66$

$F_k = 91662$ N

$F_k = 91$ KN

$$\mathbf{A_k = \pi . r^2}$$

$A_k = \pi \text{ x } (\frac{63}{2})^2$

$A_k = 3115.66 \text{ mm}^2$

$\mathbf{P_k} = 31 \text{kg/cm}^2$

$P_k = 29.42$ bar

Normal Force

$$F_n = \frac{91}{m.\tan(2.5)}$$

$$= \frac{91}{12.\tan(2.5)} = \frac{91}{0.52}$$

F_n= 175 N

2. The cutting pressure from the cone force considering Negligible Friction.

$$P_n = \frac{1}{m.bh.\tan\gamma} \cdot \frac{F_K}{Lht}$$ m = 12 Nos

$$= \frac{1}{12\,.\,8\,.\,\tan(2.5)} \times \frac{91}{120}$$ b_h= 8mm

P_n = 180 Bar

3. Torque calculation for the honing head.

N = 300 rpm

P= 7hp

Horse power to convert in to kw $P = \frac{7}{1.341} = 5.21$ kw

$$T = \frac{P}{2} . \pi . N$$

$$T = \frac{5.21 \times 1000}{2} . \pi . 300$$

T= 165.47 Nm or 165470 Nmm

Pressure on the circumference of the honing head to be 2 bar for the material removal Is applied on the circumference.

2.14 Nomenclature

1. F_n = normal force between honing stone and workpiece.
2. F_k = axial feeding force on the cone.
3. P_k = hydraulic pressure at the feeding cylinder.
4. A_k = piston area of the feeding cylinder.
5. P_n = cutting pressure at the honing stone.
6. L_{ht} = contact length between honing stone and workpiece.
7. b_h = width of one honing stone.
8. m = number of tool sticks.
9. N = speed
10. P = Horse power of the Motor

3. RESULTS AND DISCUSSION

The results from the FEM Analysis for the plateau honing machine is tabulated and interpreted as follows.

A. Structure Modification

The existing structure of the plateau honing machine is big and that leads to machining errors though the design and stability is within the limits. FEA validation is done to check for the same, as the entire honing head assembly was overhung and structure was also subjected to vibrations on a long run there were issues found. As a result the new modified structure will be designed where the weight is distributed equally and the honing head is centrally placed and weight of the structure is reduced to almost 50 percent and it is found that the deformation and the stresses were within the allowable limits.

1. **Table -1:** Existing Plateau Honing Model

Sl. No	Load (N)	Total Deformation (mm)	Stress (MPa)
1	3000	0.2171 (Min)	$1.0445*10^{-9}$ (Min)
2	3000	1.9547 (Max)	22.37(Max)

2. **Table -2:** New designed structural model

Sl. No	Load (N)	Total Deformation (mm)	Stress (MPa)
1	3000	0.00401 (Min)	$1.2073*10^{-5}$ (Min)
2	3000	0.036119 (Max)	3.7436 (Max)

From the above table we can see that the results are within the limits. Thus the new designed structure validates the design and suggested for mplementation.

B. Honing Head

Honing head is designed by reverse engineering concept and modified for the required diameter, checked for the assembly constraints and clash between the parts, also calculated the feed rate, pressure and normal force as per the current dimensions and performed static structural analysis on the honing head to evaluate the deformations and stresses on the tool as the tool has to undergo repetitive cycles of operations, the circumferential stresses and deformations are evaluated and found to be within the allowable limits.

Table -3: Analysis of honing head

Sl. No	Total Deformation (mm)	Normal Stress (MPa)	Von-mises stress (MPa)	Shear Stress (MPa)
1	0 (Min)	-25.867 (Min)	$3.1643*10^{-14}$ (Min)	-22.453 (Min)
2	0.005699 (Max)	103.95 (Max)	112.9 (Max)	30.89 (Max)

The results show that the deformations are very low and the stresses are within the allowable limits of hardened steel which validates the design, the manufacturing drawings are released and suggested for manufacturing as these honing heads were outsourced from different vendors, so the company wanted to indigenize for their requirement for varying applications.

C. Modal Analysis

Further efforts were made to perform modal analysis to confirm that there is no vibration effect which will alter the results. The structure is considered as the main feature for the structural stability

So the modal analysis is performed and has worked on 5 mode shapes and modal frequencies. The modal frequencies are in the range of min 7hz to max 22 hz.

Table -4: Modal Analysis of New designed structural model

Sl. No	Frequency (hz)	Deformation (Min) mm	Deformation (Max) mm
1	7.6702	0.2563	2.3067
2	8.8867	0.2680	2.4122
3	15.444	2.1036	18.933
4	15.58	0.3979	3.5815
5	22.335	2.8167	25.35

It shows that the first two modes are in the safe modes and the deformations also very low up to 2mm. The structural variation also is very low at these frequencies and the maximum deformation at 22 hz is 25 mm which is considerable safe mode to work.

3. CONCLUSIONS

The structure of the existing plateau honing machine is big and it appears like the cantilever structure where all the functional components are placed. Due to the excessive vibration occurred in the machine it results in poor performance and inaccuracy. To overcome this new plateau honing machine structure is designed by scaling down the parameters and testing is done for the medications performed by FEM. Analysis is done for the existing and new structure and by doing comparison of the total deformation and stress results of both the designs the new designed structure is safe. Modal analysis is done to check the vibration in the new structure and the analysis is done for 5 natural frequencies, the displacements vary from 2mm to 25mm. The vibration of the motor and other components should not go beyond 10 Hz during the operation. Hence the first 2 modes of frequencies are considered. Honing head is modified for the required diameter and also calculated feed rate, pressure and normal force as per the current dimensions and the analysis is performed. Total deformation and stress found during the analysis is within the allowable limits of hardened steel.

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