

Design and Structural Analysis of 3 Axis CNC Milling Machine Table

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ABSTRACT

In the field of Engineering, the solution of many complex problems is great limitless and usually impossible by analytical methods. For high exactness and repeatability, machine tools are used in industrial operation. Normally, several components such as base, knee, saddle, machine table, column and headstock, column are the main parts of the machine tools to get reliable performance. The work piece is held and supported on the machine table. A machine table should be enough rigid and must have good mechanical properties, to obtain a good finished and accurate work piece on a three axis CNC milling machine. A finite element analysis (FEA) gives a methodical study of failure principle which helps for additional progress of the 3 axis machine tables. In this paper, Static Analysis is performed on machine table to find out stresses generated in table, deformation of the table due to its weight. The finite element analysis is done by making 3D geometry in Solidworks software and analyse by using ANSYS software. The material comparison is shown in table and Grey Cast Iron is more dependable than other materials.

KEYWORDS: ANSYS 17, deformation, machine table, stress, strain, Solidworks

I. INTRODUCTION:

A machine table is used for the component to hold and support the work piece. To gain a good finished and precise work piece on the three axis CNC milling machine, a table should be adequate rigid and must have good mechanical properties. A finite element analysis (FEA) gives a methodical study of failure principle, which helps for further development of the three axis machine tables. While machining, three axis CNC machine table is the rectangular casting positioned on the base which supports the fixtures & the work piece. The working table establish on ways on the saddle. The top of the table is correctly finished and t-slots are good for clamping the work and other fixtures on it. The table fixed on machine structure takes vertical forces of work piece and fixtures. [1]

The dynamics of the specific machining process and nature of the forces involved, the appropriate design of machine-tool structures needs a exhaustive knowledge of their forms designs and properties of the material. Freshly, examinations have been shown in the field of upgrading of structural design of machine tools by improving stiffness and lightening weight which is especially urgent for the structural parts, such as base, knee, bed, column, worktable, headstock, etc. The prearrangement of stiffening-ribs in machine tool structures is a key feature for structural stiffness and material consumption. So the reducing design of stiffening-ribs is important for machining performance and energy saving. It is usually accepted that the precision of machine tools is resolute by their static, dynamic and

thermal characteristics. Specially, the dynamic characteristics show an significant role in high speed, precision machine tool structures, because vibration during the machining process results in chatter marks on the machined surface and thus creates a noisy environment.

High static stiffness in contradiction of bending and torsion, good dynamic characteristics as reflected by high natural frequency and high damping ratio. In production, good long term dimensional stability, reasonably low coefficient of expansion, low cost and low material requirements are the elementary properties of machine tool structures that engineers look for designing and constructing. At current the machine beds are made of grey cast iron material, which cause a number of problems in machine tools. Cast iron cannot with stand the sudden loads during operation whenever the load spreads ultimate loads it simply fails without any previous suggestion. Casting is only the manufacturing process used to produce the beds. This process leads to various casting defects in the component. So as to have high strength and high stiffness the weight of the machine bed should be high. [3]

II. Literature Survey

Parag R. Bhingardev et. al studied Static Structural Analysis is performed on machine table to find out stresses performed in table, falsification of the table due to its weight. The FEA is performed by making 3D geometry in CATIA software and analyse by using ANSYS software.

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Aleksandar Košarac et. al analysed dynamics characteristics of machine tools, especially modal parameters, have significant effect on the cutting procedure and cutting precision. Dynamic behaviour and purpose of modal parameter are shown for horizontal milling centres. For this purposes 3D CAD model of horizontal milling centre has been created using CATIA software, and modal analysis (natural frequencies and mode shapes of the machine tool structure) has been conducted by ANSYS Workbench and APDL. Results gained by FEM modal analysis are validate by experimental modal analysis. Modal parameters obtained experimentally and by FEM are compared, and results shows satisfactory matching.

Sagar Pandit Mahajan studied, the conventional structural materials used in precision machine tools such as cast iron and steel at high operating speeds develop positional errors due to the vibrations transferred into the structure. Faster cutting speeds can be developed only by structure which has high stiffness and good restraining characteristics. In this work, a machine bed is selected for the analysis static loads. Then investigation is carried out to decrease the weight of the machine bed without weakening its structural rigidity. The 3D CAD model of the bed has been created by using 3D modelling software and analyses were carried out using ANSYS Workbench.

Pratik Bhambhatt et. al studied by using practical data of CNC Router structure, equipped 3D CAD model for Finite Element Analysis in Solid Works 2015. From analysis result find value of von mises stress, strain and displacement (deflection) for optimize structure in strength and cost.

Sriranga V Deshpande et. al presented the design and fabrication of 3-axis milling machine. To produce pulse-width modulation (PWM) outputs in order to run the stepper motors that will be used in this work, Computer numerically-controlled (CNC) machine will be comprised the use of Arduino micro controller. A three-axis CNC milling was formerly used exactly surfaced designed for snapping of wood, plastic sheet and thin sheet of metal alloy by using a rotating drill bit which its accuracy was much lesser than using a lesser cutter technique this machine tool was transportable and it's controlled by the personal computer. Design and Construction of CNC with precision Stepper motors that contacted with the lead screw moment along three-axis.

Vedprakash et. al reviewed the sequence of works that have been carried out by different researchers on design, analysis, implementation and construction of a computer numerical controlled (CNC) mechanical systems. The main objective of this paper was to permit the future researchers to provide a passage into the work to improve the performance, accuracy, efficiency and the design of CNC machine.

Seyed reza besharati researched, reciprocal and simultaneous motion of the gantry and worktable was projected as the gantry machine's X-axis double motion mechanism. The double motion mechanism was designed based on a rack and pinion system. A new anti-backlash system is recommended to compensate for transmission error and backlash (simultaneously) and for use in the double motion mechanism. Due to manufacturing boundaries of the rack and pinion systems, a new double motion mechanism based on a ball screw system is proposed. The dynamic and static behaviour of the final CNC

gantry machine design is investigated via modal and static structural analysis using ANSYS software. The gantry's natural frequency was designed to be 202 Hz in the first vibration mode, making the machine capable of working at higher speeds of up to 11530 rpm, which is appropriate not only for rough cutting but also for finishing.

The final design of the new CNC gantry machine is updated according to the obtained results. The increase in natural frequency during gantry design modification affects complexity, increasing the weight and manufacturing cost of the gantry. As such, five different gantry designs are selected for comparison. Four parameters, i.e., the first four natural frequencies, total deformation due to mechanical forces, weight and manufacturing cost are measured performance indices. One is selected among five designs mathematically and improved by MOGA (multi-objective genetic algorithm) in ANSYS software. In the optimization process, the gantry's natural frequency is maximized, thus minimizing the total gantry weight and deformation against mechanical forces. CNC gantry machine documents for manufacturing are equipped, followed by modelling, casting, machining and assembly. To estimate and confirm the design and analysis, an investigational modal test is performed. The tentative results show less than 11% error between the dynamic analysis and investigational test.

III. Material and Method

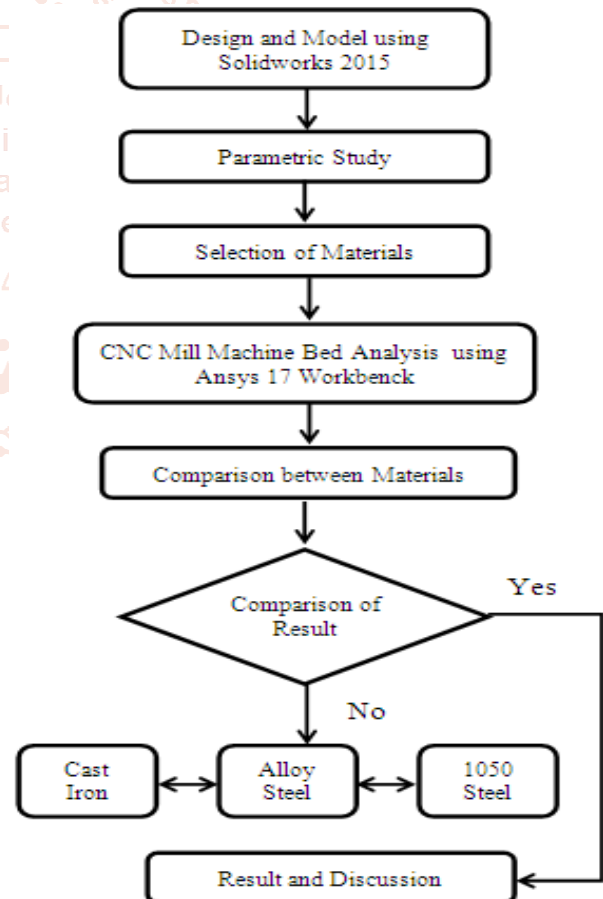


Fig. 1 Design Flow Chart

IV. MATERIAL USED FOR MACHINE TOOL STRUCTURE

The productivity and precision of the part manufactured in structural materials used in a machine tool have a significant role. Material selection is a significant of quality and cost. The properties of the material must be acceptable to meet

design necessities and service conditions. Most commonly used material for machine tool structure is cast iron and steel.

Cast Iron

Cast iron is mainly an alloy of iron, carbon, and silicon. From primary times cast iron has been the most commonly used material for machine tool structures. It may be cast into complex and complex shapes. It is easily machined and may be hand scraped and lapped to a high degree of accuracy. It has fairly good damping properties and also has reasonably good antifriction properties helped by the graphite contained in it. It can be given very good long-term dimensional stability by giving it a special long cycle stress relief annealing treatment. Cast iron should be preferred for complex structures subjected to normal loading, when these structures are to be made large in numbers.

Structural steel

The main condition in the selection and inspection of the steel is the tensile strength which is used as the basis of design.

Generally load carrying welded structures such as frames, beds, and column.

Steel

Steel is very widely used for machine components as it can be manufactured and processed into a number of different specifications each of which has a definite use. Two properties of steel apart from strength are of special significance in selection of proper grade of steel. First, the maximum hardness that can be attained and second, the harden ability which regulates the depth of hardened zone.

V. Design Consideration

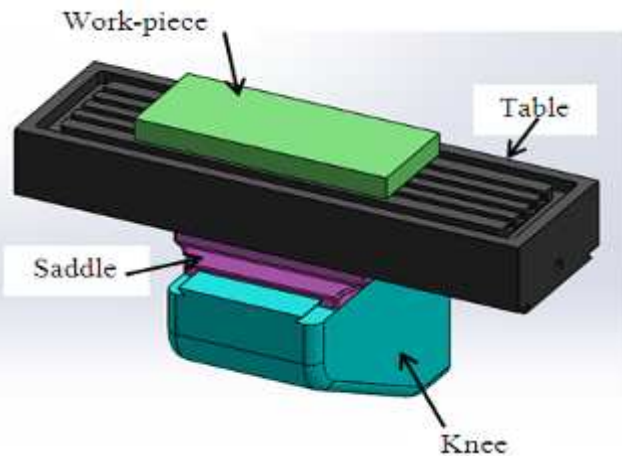


Fig.2 Isometric View of CNC Milling Table

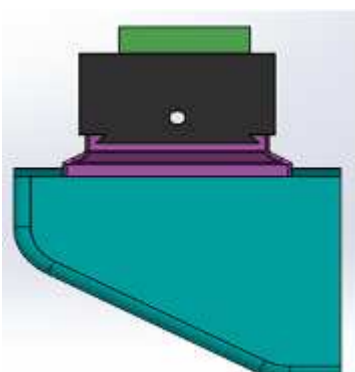


Fig. 3 Side View of CNC Milling Table

A 3D model of the CNC machine bed, its supporting rib and a workpiece for real time analysis was created in SolidWorks 2017 of the dimensions:

Table1 Dimensions of CNC Milling Machine Table

Model	Dimension (mm) Length × Breadth × Depth
Work piece	500 × 200 × 50
Table	1000 × 300 × 141.06
Saddle	381 × 350 × 78.14
Knee	304.8 × 500 × 396.875

VI. Design Analysis

Firstly, the design model is imported from Solid Works to ANSYS 17. Mesh size is 5mm and node points and element size are 4264771 & 2798773 respectively. Material is Grey Cast Iron. Display style is orthogonal quality and the 3D view of mesh, Total Deformation, Equivalent Stress, Equivalent Strain and Maximum Principal Stress are as follow:

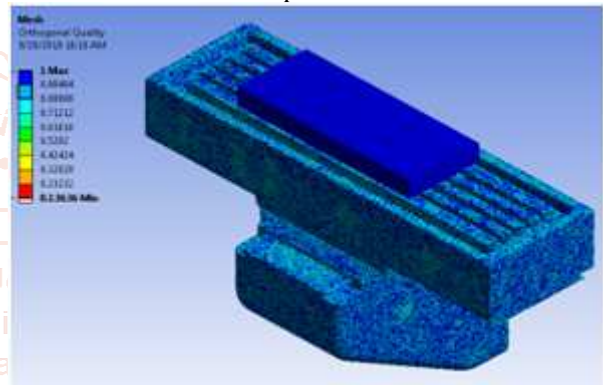


Fig.3 Mesh of a Milling Machine

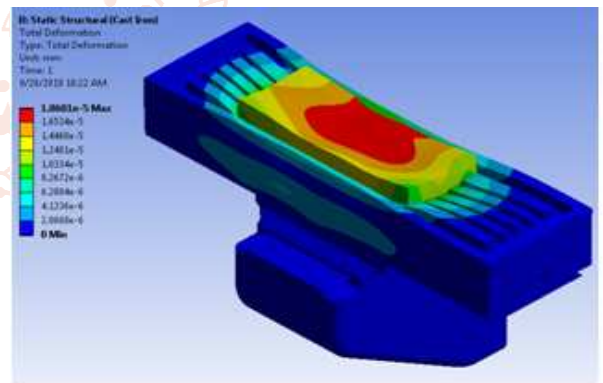


Fig. 4 Total Deformation of a Milling Machine

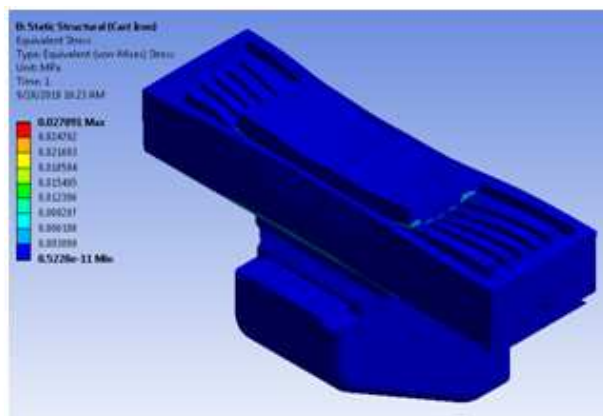


Fig. 5 Equivalent Stress of a Milling Machine

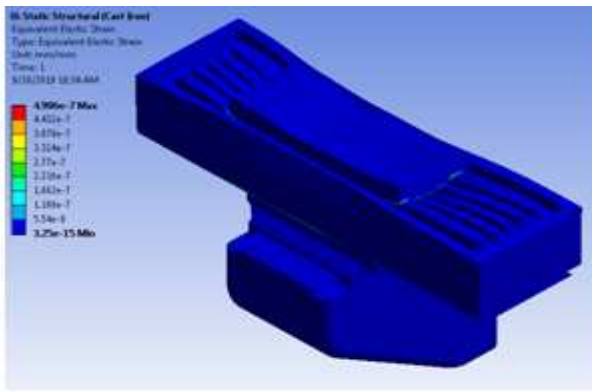


Fig. 6 Elastic Strain of a Milling Machine

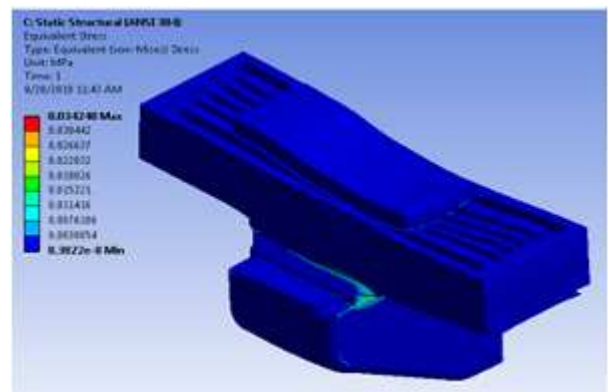


Fig. 10 Equivalent Stress of a Milling Machine

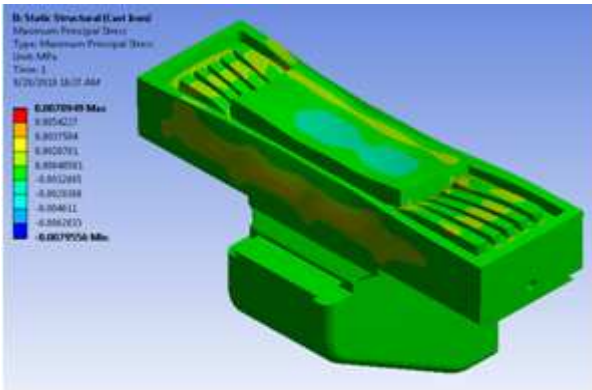


Fig. 7 Maximum principle stress of a Milling Machine

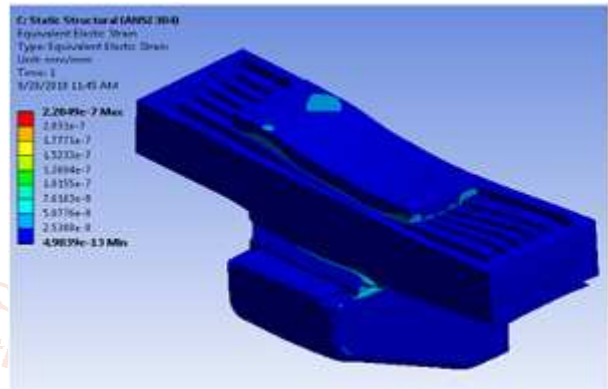


Fig. 11 Elastic Strain of a Milling Machine

Secondly, the design model is imported from SolidWorks to ANSYS 17. Mesh size is 5mm and node points and element size are 4264150 & 2798383 respectively. Material is Structural Steel (ANSI 304). Display style is orthogonal quality and the 3D view of mesh, Total Deformation, Equivalent Stress, Equivalent Strain and Maximum Principal Stress are as follow:

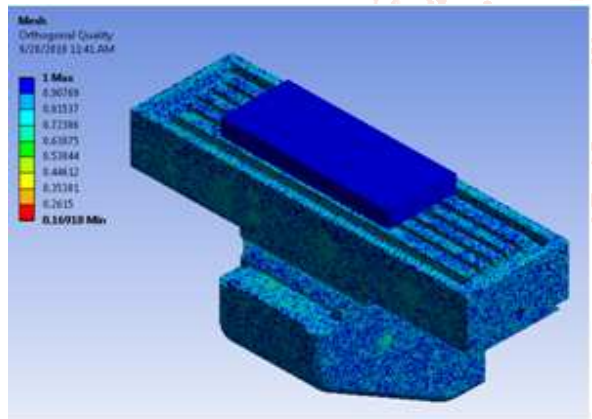


Fig. 8 Mesh of a Milling Machine

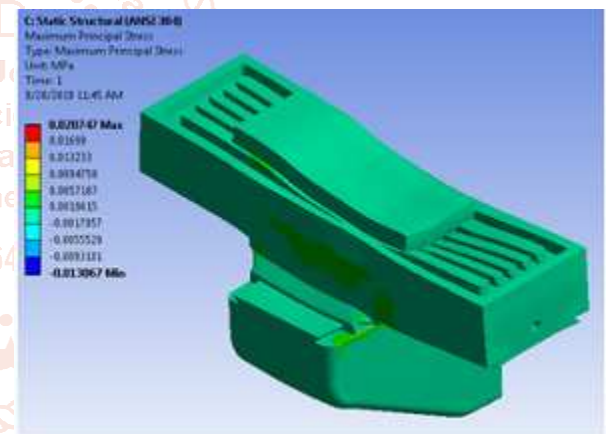


Fig. 12 Maximum principle stress of a Milling Machine

Finally, the design model is imported from SolidWorks to ANSYS 17. Mesh size is 5mm and node points and element size are 4260551 & 2795635 respectively. Material is Structural Steel (ANSI 1045). Display style is orthogonal quality and the 3D view of mesh, Total Deformation, Equivalent Stress, Equivalent Strain and Maximum Principal Stress are as follow:

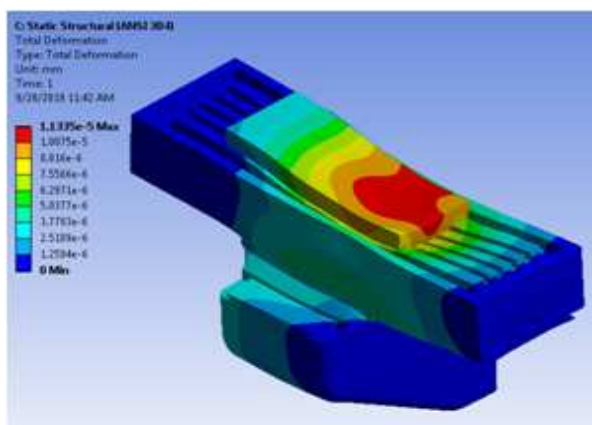


Fig. 9 Total Deformation of a Milling Machine

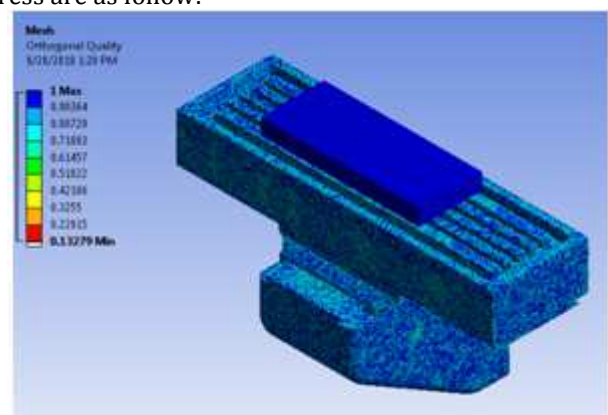


Fig.13 Mesh of a Milling Machine

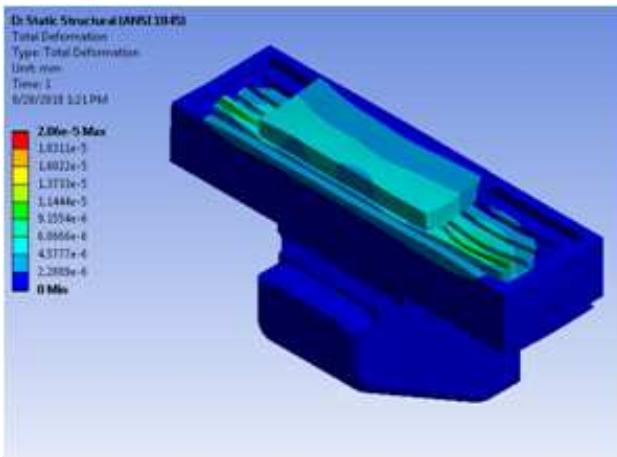


Fig. 14 Total Deformation of a Milling Machine

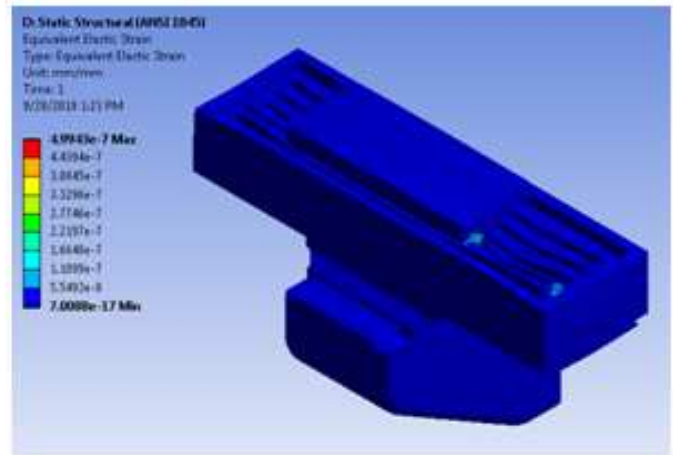


Fig. 16 Elastic Strain of a Milling Machine

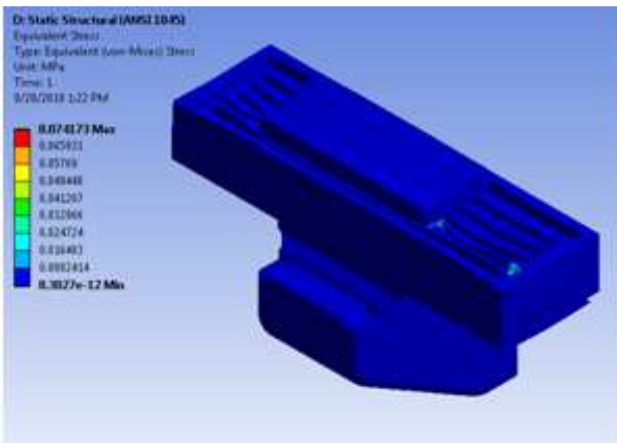


Fig. 15 Equivalent Stress of a Milling Machine

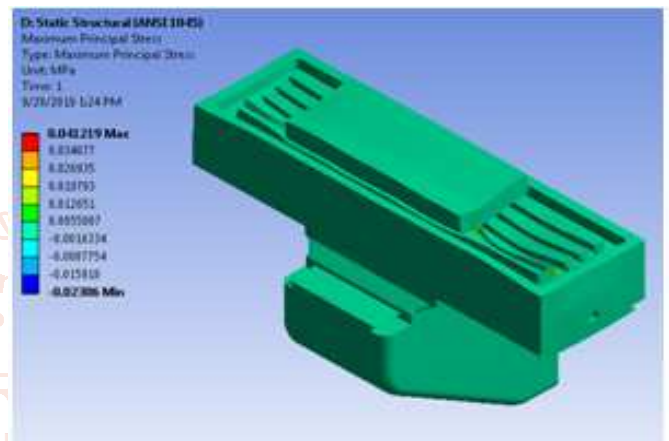


Fig. 17 Maximum principle stress of a Milling Machine

Table2. Comparison between Material

Sr. No.	Description	Result		
		Gray Cast Iron	ANSI 304	ANSI 1045
1.	Total Deformation (mm)	1.8601e-5	1.1335e-5	2.06e-5
2.	Equivalent Stress (MPa)	0.027891	0.034248	0.074173
3.	Elastic Strain (mm/mm)	4.986e-7	2.2849e-7	4.9943e-7
4.	Maximum Principal Stress (MPa)	0.0070949	0.020747	0.041219

VII. Conclusion

From the above tables and figures, the results are shown. As a result, Total Deformation of Grey Cast Iron is less than ANSI 1045 Steel but it is greater than ANSI 304 (Mild Steel). Equivalent Stress, Elastic Strain and Maximum Principal Stress are 0.02789, 4.985e-7 and 0.0070949 respectively. So, for CNC Machine Table, Grey Cast Iron is more reliable than other materials.

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