Journal of Engineering Research and Application www.ijera.com
ISSN : 2248-9622, PP 46-51

RESEARCH ARTICLE OPEN ACCESS

Design and F.E Analysis of Fixture for Front Axle Support

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ABSTRACT : *The paper is intended to Design a Machining Fixture for machining of Front Axle Support using HMC (Horizontal Machining Centre). The Front Axle support fixture for ESCOSRTS tractor is designed. The fixture is designed in such a way that stability is obtained during all machining operations. The paper consists of study of input data like Part drawing and Assembly drawing, followed by design and analysis. The fixture design begins with part modelling using CATIA V5 followed by analysis using ANSYS WORKBENCH Software package. In the study both Static as well as Dynamic analysis is carried out. The obtained results from ANSYS are later verified by analytical methods. The final design found to be safe and satisfactory to the need.*
Keywords* - *Static Analysis, Dynamic Analysis, part modeling.

I. INTRODUCTION

Jigs and fixtures are the core tools for any manufacturing industry in terms of ease of manufacturing and precision. Jigs and fixtures are the special purpose work holding and guiding tools utilised during manufacturing process, which help in mass production of components with at most accuracy. Quality of performance of a process is largely influenced by quality of jigs and fixtures used for this purpose.

A fixture can be used in almost any operation that requires precise relationship in the position of a tool to a work piece. Fixtures are essential elements of production processes. Fixtures must correctly locate a work piece in a given orientation with respect to a cutting tool or measuring device, or with respect to another component, as for instance in assembly or welding. Such location must be invariant in the sense that the devices must clamp and secure the work piece in that location for the particular processing operation. There are many standard works holding devices such as jaw chucks, Machine vices, drill chucks, collets, etc. which are widely used in workshops and are usually kept in stock for general applications. Fixtures are normally designed for a definite operation to process a specific work piece and are designed and manufactured individually. Jigs are similar to fixtures, but they not only locate and hold the part but also guide the part.

This paper is intended to design and develop a machining fixture for front axle support of a tractor. Machining fixture requires systematic design to clamp and hold the work piece during machining process. Using the design data and geometry of the component the fixture is designed.

As the name indicates front axle support in a tractor is used to support the front axle of ESCORTS tractor, it also helps in supporting the engine. Hence, it lies between the axle and the engine. Due to nature of its critical positioning, the front axle support needs to be manufactured with utmost precision and accuracy. This calls for the need of a fixture, which will hold work piece in its accurate position during machining operation. The design of the fixture should be such that it can withstand the high loads developed during the machining process.

This fixture is meant to support the ESCORT tractors front axle support during the machining operation. In doing so the machining process will become smooth and accurate.

Many papers have been presented on fixture design and analysis by many researchers on many different aspects of fixture design. Some have concentrated on contact points in a fixture as there area of interest while some have done extensive research on reducing the vibrations. Stiffness of fixture is also a very important area of research for many because of extensive load experienced by it during machining.

Y. G. Liao and S. J. Hu [1] presented a paper on surface quality prediction after machining was completed. For this purpose of machined surface quality prediction, they developed a methodology to integrate a FEA modal of the locator–work piece with the experimental stiffness of the fixture base and machine table. They showed that the magnitude of surface error is linearly proportionally affected by the magnitudes of the external loads like clamping and machining forces.

Haiyan Deng and Shreyes N. Melkote [2] presented a paper on determination of minimum clamping force required that ensures the dynamic stability of a fixture – work piece during machining. They made the following observation that particle swarm optimization technique was capable of finding the best set of clamping force. They also showed that consideration of fixture – work piece dynamics was very crucial when cutting force frequency was in vicinity of natural frequency. Cutting force frequency changes continuously during milling operation due to continuous loss of material. Another observation made was that material removal affects the fixture – work piece dynamics and clamping force required.

L. T. Nguyena & H.C. Mohringa [3] presented a paper on Stiff ness and damping properties of a swing clamp. In order to identify the modal parameters, a test fixture system composed of an aluminium workpiece and two swing clamps was investigated. Two types of experiments were conducted. First, the clamping-work piece-system was loaded with a quasi-static force to determine the parameters of the Valanis modal. In addition, harmonic excitations at various force levels and with two diff erent frequencies were applied. This experiment showed a good validation for the proposed modal.

C. Radha Madhavi, B. Ramu [4] presented a paper on design of machining fixture for turbine rotor blades. The rotor blades are of a gas turbine. In this paper they have designed and analysed the fixture. Hence, this paper is taken as a main reference to complete this paper.

B. Li and S. N. Melkote [5] presented a paper on Fixture Clamping Force Optimisation and its Impact on Work piece Location Accuracy. Here they show that the clamping force should be high enough to restrain the work piece motion but excessive force may cause work piece elastic distortion, which will affect the location and hence quality of machining. Therefore the clamping force should be of optimum level.

II. DESIGN OVERVIEW

The dimensions of the fixture were finalized based upon the dimensions of the front axle support and saddle.

A. Fixing the Length

Here the axis of the base and that of the front axle support (work piece) are to be placed perpendicular to each other to perform required machining operation. The width of the work piece is 540 mm and the overall length of the saddle is 1000 mm hence the fixture was made to be 1000 mm giving us enough clearance on either side to accommodate bracket at accurate positions.

B. Fixing the Width

The width of the fixture was based on the width of the saddle and length of work piece. The width of the saddle is 600 mm and the length of work piece is 505 mm. hence the width of the fixture was fixed to be 525 mm by giving a clearance of 10 mm on either side from work piece. The width of fixture was fixed based on the length of the work piece and not on the bases of saddle as there were no additional components to be placed on base.

C. Other Dimensions

The dimensions of bracket, clamp, clamp stud and heel pin are based on standard clamp dimensions with modifications done according to the input conditions.

III. DESIGN PARAMETERS

Material of front axle support = Grey cast iron
Power of motor = 10 Hp (7.5 Kw)
Diameter of cutter (D) = 120 mm
Depth of cut (ap) = 1mm
Number of teeth (z) = 10
Tool material = Carbide

IV. CALCULATION

At initial level based on industrial survey (for the given problem), Initial dimensions were fixed, based on which related stress calculations were carried out. It was found that clamp, stud, heel pin are the critical components. Hence following values were obtained for these components.

PARAMETERS	VALUES (MPa)
Tensile stress on stud	118.47
Torsional shear stress on stud	91.693
Tensile stress in strap clamp no. 1	230.84
Tensile stress in strap clamp no. 2	336.52
Tensile stress in heel pin	59.515

Table 1

Based on the obtained values the material chosen for Strap clamp no. 1, Stud and Heel pin was EN-8 since it has yield strength of 330 MPa. Similarly the material chosen for clamp no. 2 is EN-11 since it has yield strength of 420 MPa. This material combination makes the fixture safe under loading conditions.

V. SOLID MODELING

All the modals were prepared using CATIA V5 software. Fig 1 and Fig 2 shows the assembled view of fixture. Here there are different parts present in fixture such as Base, Resting pads, Bracket, Heel pin, Stud, Clamp, Std M16 nut.

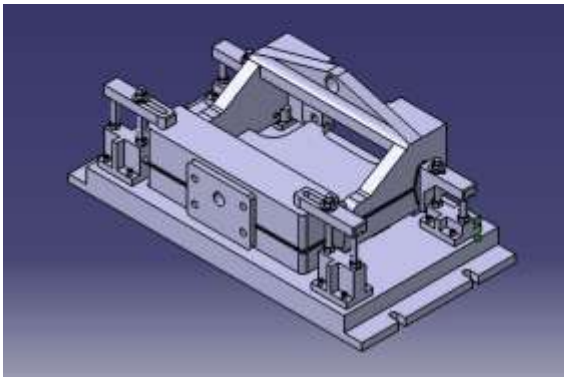

Fig 1 Fixture assembly with work piece

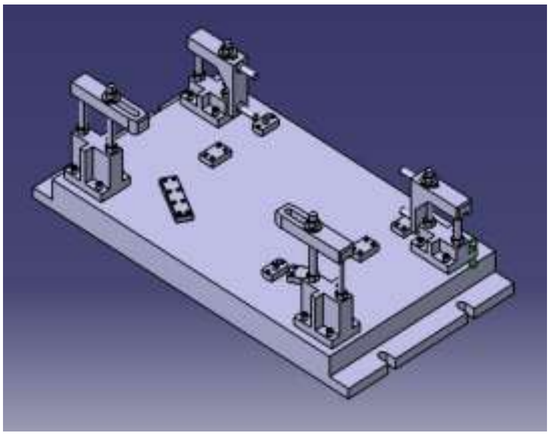

Fig 2 Fixture assembly without work piece

VI. ANALYSIS

In this paper we analyzed static, modal and Harmonic analysis of critical parts in fixture. All analysis were carried out using ANSYS 15 software.

A. Analysis of strap clamp no. 1

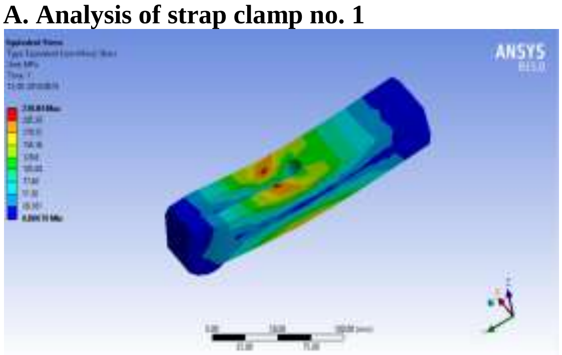

Fig 3 Von-Misses stress in strap clamp no. 1

Fig 3 shows the stress distribution in strap clamp no. 1 under bending condition. Here it is observed that the maximum stress developed is 230.84 MPa.

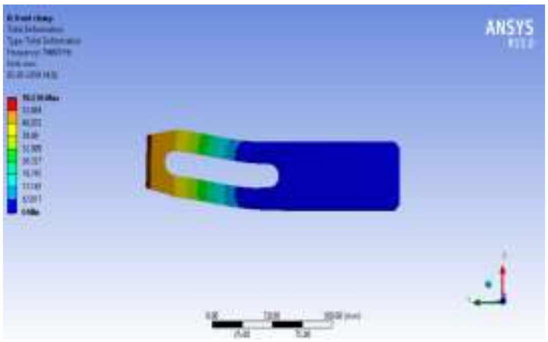

Fig 4 First mode shape

Fig 4 shows First mode shape for strap clamp no. 1 with maximum deformation at 59.236 mm. The natural frequency obtained is 1866.9 Hz. And Table 2 below shows the first 5 natural frequencies.

Mode	Frequency [Hz]
1.	1866.9
2.	1980.6
3.	2418.9
4.	2931.7
5.	4703.8

Table 2

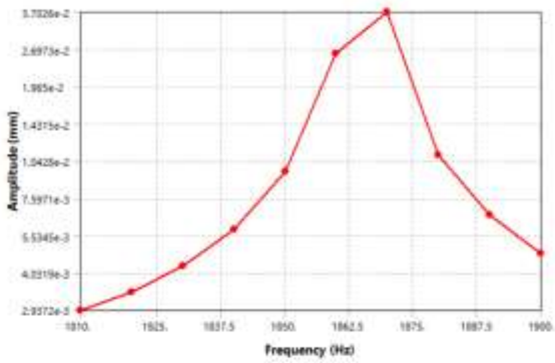

Chart 1

Above chart is obtained after harmonic analysis done for first mode. Here the maximum amplitude is obtained at 1870 Hz. The maximum deformation is 1.036 mm.

B. Analysis of clamp no. 2

The following are the results of clamp no. 2 under static, modal, harmonic analysis.

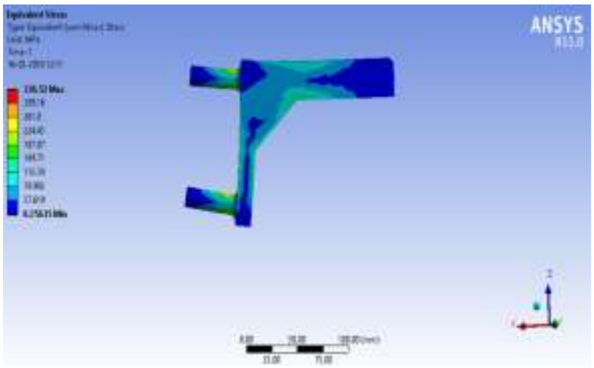

Fig 5 Von-Misses stress in clamp no. 2

Fig 5 shows the stress distribution in clamp no. 2. Here it is observed that the maximum stress developed is 336.52 MPa.

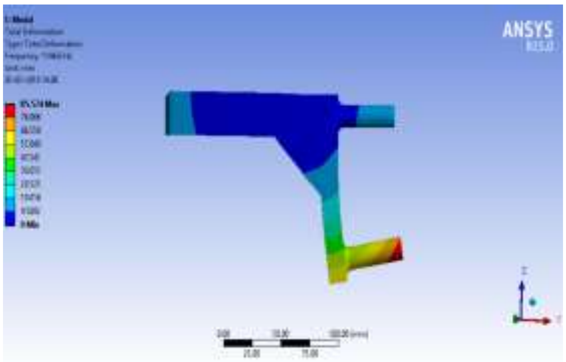

Fig 6 First mode shape

Fig 6 shows first mode shape for clamp no. 2 with maximum deformation at 85.574 mm. The natural frequency obtained is 1146.6 Hz. And Table 3 below shows the first 5 natural frequencies.

Mode	Frequency [Hz]
1.	1146.6
2.	1474.9
3.	1968.7
4.	2672.2
5.	2969.3

Table 3

The chart below is obtained after harmonic analysis done for first mode. Here the maximum amplitude is obtained at 1150 Hz. The maximum deformation is 2.146 mm.

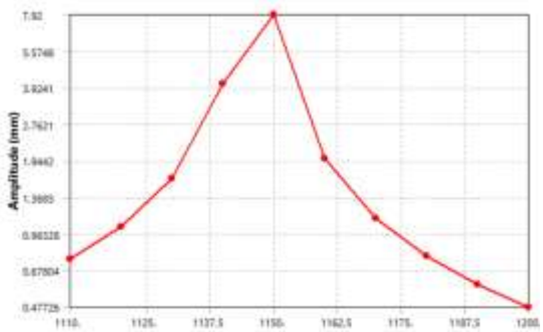

Chart 2

C. Analysis of stud

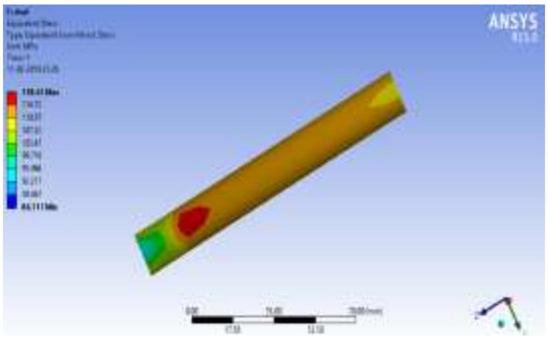

Fig 7 Von-Mises stress in stud

Fig 7 shows the stress distribution in stud in tension. Here it is observed that the maximum stress developed is 118.47 MPa.

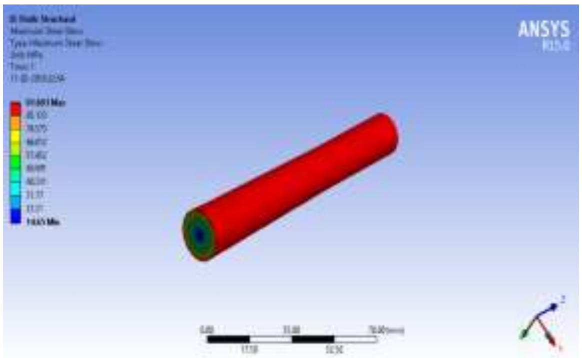

Fig 8 Maximum shear stress

Since stud also under goes torsion, fig 8 shows the maximum shear stress developed in stud. Here the maximum shear stress is 91.693 MPa.

Fig 9 shows first mode shape for stud with maximum deformation at 116.3 mm. The natural frequency obtained is 319.05 Hz. And Table 4 below shows the first 5 natural frequencies.

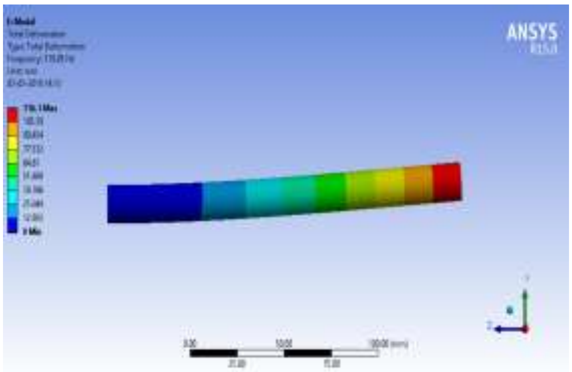

Fig 9 First mode shape

Mode	Frequency [Hz]
1.	319.05
2.	320.84
3.	1952.9
4.	1963.6
5.	4165.6

Table 4

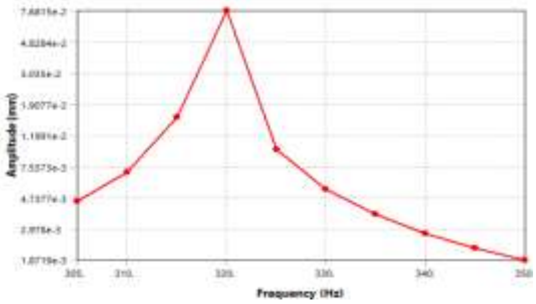

Chart 3

Above chart is obtained after harmonic analysis done for first mode. Here the maximum amplitude is obtained at 320 Hz. The maximum deformation is 0.0097 mm.

D. Analysis of heel pin

Fig 10 shows the stress distribution in Heel pin in compression. Here it is observed that the maximum stress developed is 59.515 MPa.

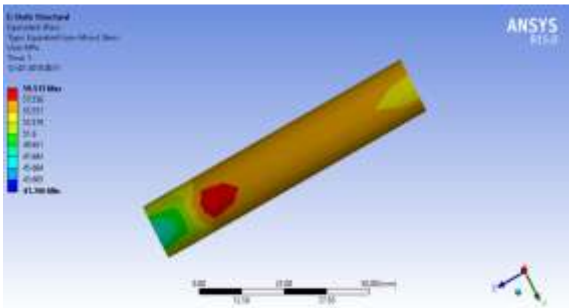

Fig 10 Von-Mises stress in stud

Fig 11 shows first mode shape for heel pin with maximum deformation at 138.22 mm. The natural frequency obtained is 635.86 Hz. Table 5 shows the first 5 natural frequencies obtained.

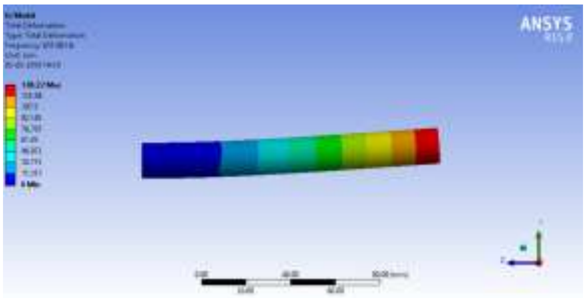

Fig 11 First mode shape

Mode	Frequency [Hz]
1.	635.86
2.	639.53
3.	3807.3
4.	3827.7
5.	5888.2

Table 5

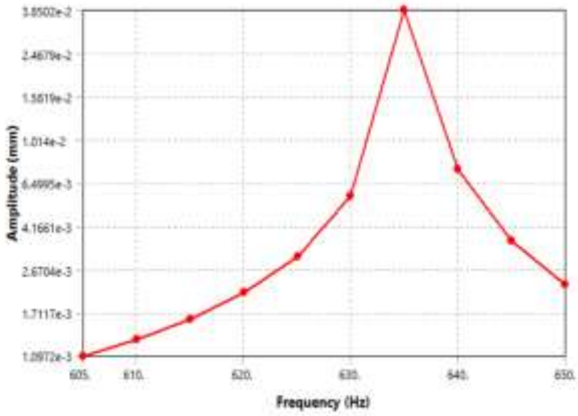

Chart 4

Above chart is obtained after harmonic analysis done for first mode. Here the maximum amplitude is obtained at 635 Hz. The maximum deformation is 0.01 mm.

VII RESULTS AND COMPARISION

At initial level based on industrial survey (for the given problem), Initial dimensions were fixed, based on which related stress calculations were carried out which fall under permissible limit as shown below in Table 6.

PARAMETERS	VALUES (MPa)	YIELD LIMIT (MPa)
Tensile stress on stud	118.47	330
Torsional shear stress on stud	91.693	350
Tensile stress in strap clamp no. 1	230.84	330
Tensile stress in strap clamp no. 2	336.52	420
Tensile stress in heel pin	59.515	330

Table 6

Finite Element Method (FEM) was used to determine stress effect for given fixture. Based on few assumptions, the numerical results are satisfactory. If rightly performed, more accuracy can be achieved. The table 7 gives the comparison between FEM results with the results when calculated analytically.

PARAMETERS	THEORETICAL VALUES (MPa)	ANALYTICAL VALUES (MPa)
Tensile stress on stud	118.47	111.4
Torsional shear stress on stud	91.693	86.19
Tensile stress in strap clamp no.1	230.84	240
Tensile stress in strap clamp no. 2	336.52	334.22
Tensile stress in heel pin	59.515	55.7

Table 7

The fixture is successfully designed and analyzed. As seen from table 7 the obtained design proves to be satisfactory.

VII. CONCLUSION

The fixture was successfully designed and analyzed as seen from result section. The main purpose of this fixture was to locate the work, support it properly and hold it securely, thereby ensuring the parts produced in same fixture will come within specified limits. Under the obtained theoretical and analytical values the purpose seems to be served. The benefits of clamping system used in this fixture are that they are simple to use, the design makes it easy to clamp and unclamp. The fixture is safe in static condition.

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