Structural Optimization of Hydraulic Clamp

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Abstract- **This paper presents Structural Optimization of Hydraulic Clamp. Hydraulic clamping is preferred because it is flexible and simple to construct and operate. In the view of initial clearance a large deformation is required. Once disk deforms the clearance is eliminated and the engagement takes place. Any further hydraulic pressure gives the clamping force. The device must undertake large deformation more than 200 microns and still the stress should be within allowable limits. Otherwise induced stress goes beyond the yield limit and clamp will fail permanently.**

Criticality in design: In view of the large deformation, the clamp can get into large induced stress and cracks. It has to operate at a nominal hydraulic pressure. Thickness of the clamp members needs to be optimized, keeping in view of deformation and permissible stresses. FEM solution is used for design and optimization to compute the deflection field, stress field using iteration process and an optimum solution is obtained for better clamping device with allowable deflection and stresses. Also modal analysis is carried out to check the resonance condition of the hydraulic clamp for the working frequency of 100Hz. Results show safety of the hydraulic clamp for resonance as obtained natural frequencies are more than 30% away from the operating frequency.

Index Terms- Analysis of Hydraulic Clamp, Design and FEM solution of Hydraulic Clamp, Modal analysis of Hydraulic Clamp, Structural Optimization of Hydraulic Clamp.

1. INTRODUCTION

A clamp is a device used to join, grip, support, or compress mechanical or structural parts. Its opposing and often adjustable parts provide for bracing objects or holding them together. The hydraulic clamps ensure a powerful and consistent clamping force and enable components to be loaded and unloaded simply and quickly at the press of a button. Hydraulic clamps are one of the most powerful hydraulic tools designed for effective power work holding. Also Hydraulic clamps are acknowledged for its durability, sophisticated design and corrosion resistance. Hydraulic clamps are available in the varied sizes and dimension. Due to its perfect functioning and robust construction, it is sought after for machining operations. For better strength, hydraulic clamps are made of good quality material.

Hydraulic clamp is an ideal choice for construction of pipe-lines and fabrication of pipe-spools in workshops. They are ideal for punching and assembly operations or for transmitting force to a remote location via a rod. Three functions of Hydraulic clamps are (i) Position the component accurately. (ii) Support the component adequately.(iii) Clamp the component securely for machining.

Optimization involves evaluating the best results in terms of design, manufacturing, tooling and other structural, regulatory requirements. The various parameters are considered for the evaluation. By choosing some parameters as fixed, the other parameters are varied and the results are noted. The same is repeated by having different combinations, finally the results are compared and maximum contribution is noted.

II. METHODOLOGY

The basic design calculations are carried out for the minimum dimensions of the clamp system

•Geometric modeling of the hydraulic clamping system using Ansys mixed approach

•Division of the structure to ease map mesh (Map mesh gives better solution compared to the free mesh in the structures).

•Axisymmetric approach due to its geometric and loading nature.

•Element 8 noded quadrilateral element (Plane82) is considered for analysis due to its faster convergence in the nonlinear domain.

•Contact analysis is carried out to find the stresses and contact condition.

•The process is iterated till the geometry is optimized for all the parameters

•Results presentation.

III. GEOMETRY OF HYDRAULIC CLAMPING SYSTEM.

A. Description of the system.

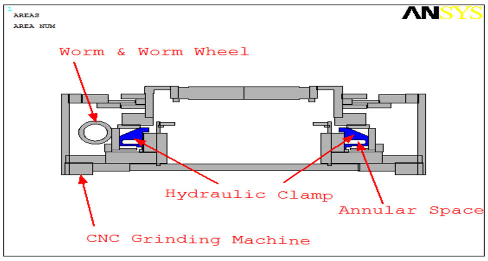

Fig.1: Hydraulic clamping system.

Figure.1 shows clamping system used in the rotary table assembly. The pressurized hydraulic oil is passed into the annular space of the clamp component as shown in figure. 1. Due to hydraulic pressure the member gets deflected and holds the rotating component against the stationary member and thus table gets locked in position.

Figure.2 shows hydraulic clamp representation using mixed approach. The geometry is split into regular areas to ease map mesh. Map mesh is best suitable for graphical representation and uniformity of the results. Three dimensional model is also shown by expanding the axisymmetric model.

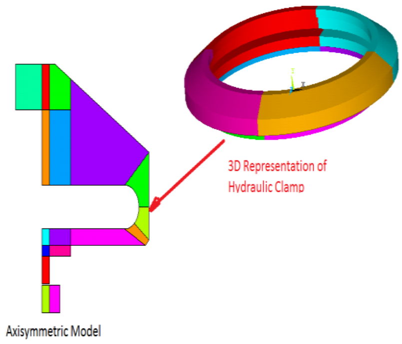

Fig.2: Ansys model of Hydraulic clamp

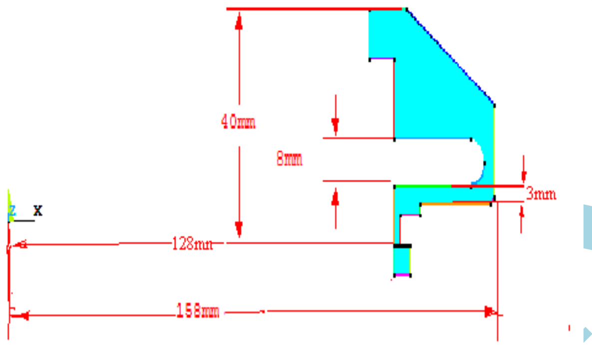

Fig.3: Dimensional plot of the Hydraulic clamp.

Figure.3 shows dimensions measured from the axis center. Maximum outer dimension is 158mm and inner dimension is 128mm with a height of 40mm. A fixed plate is created to define rigid contact region to find the stress conditions in the problem.

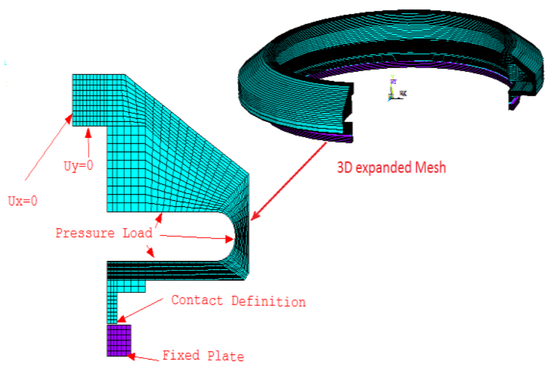

Fig.4: Boundary conditions of the problem

Figure.4 shows boundary conditions of the problem. The Axisymmetric problem is constrained at the left boundary in radial direction and supported at the component is bolted to a stationary member the nodes on the axis of the bolts restrained in all axis. Contacts pairs are created between bottom fixed plate and the hydraulic clamp. Pressure load is applied in the annular space. Three dimensionally expanded element plot is also represented. A Total of 546 elements with 1659 nodes are used for representation.

B. Geometric representation and optimization of the system.

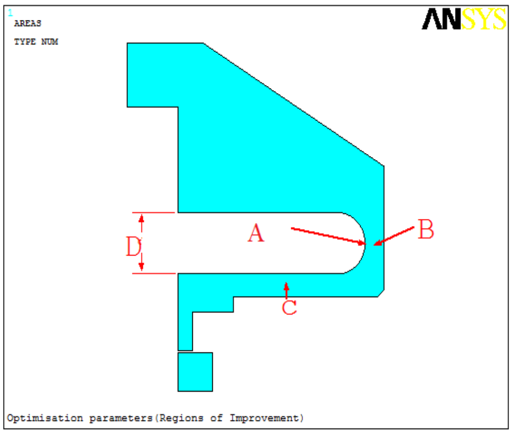

Fig.5: Regions of Optimization

The regions as shown in figure.5 by parameters are to be optimized for the stress condition. Here annular space can be altered along with the thickness of the clamp plates for complete structural integrity of the hydraulic clamping system.

The main criteria in fixing the dimension of component are:

1. The deflection of the component at clamping area should not be less than the 0.2mm. (By allowing a total clearance of 0.2mm between the flexible and rotating component)
2. The principal stress in the component should be within the allowable limits; for direct Harding alloy steel IS1570 40NiCr1Mo28 allowable stress is 295Mpa (hardened and tempered).

IV. RESULTS

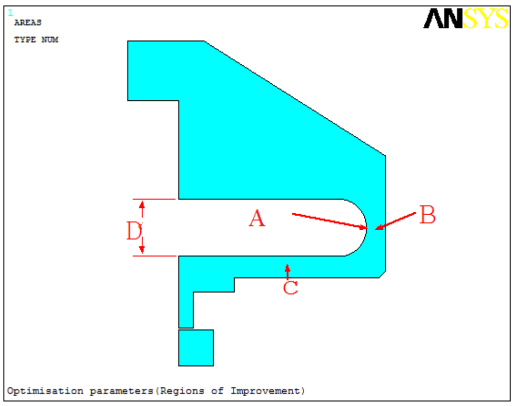

Fig.6: Shows the various design parameters that are changed during analysis

Table. 1: Deflection values for various plate thickness

SL.No	Plate thickness	Maximum deflection at clamping Nodes in mm
1	1mm	0.327
2	2mm	0.207
3	3mm	0.273

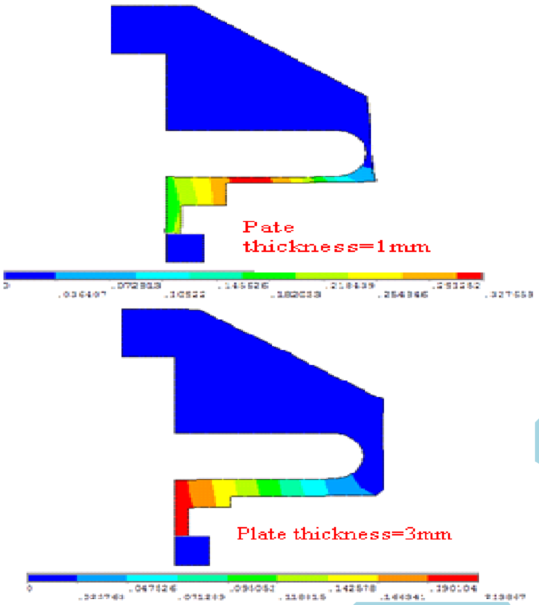

Fig.7: Deflections values of various plate thicknesses

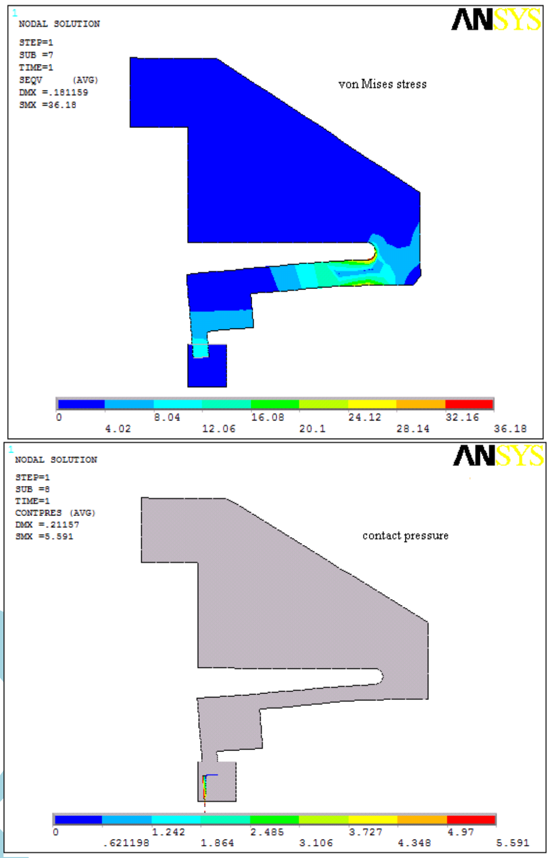

Fig.8: Sample: Iteration3: (A=1mm, B=5.8mm, C=3mm, D=2mm)

Table.2: Iterations for optimization of vonMises stress and Torque values

SL.NO	Parameters In mm				Von Mises Stress In MPa	Average contact Pressure In MPa	Torque N-m	Operated Pressure In MPa
	A	B	C	D				
1	4	1	1	8	663.70	72.88	627.84	2
2	4	3.8	1	8	441.45	65.90	574.67	2
3	1	5.8	3	2	354.92	18.81	18.01	2
4	1	5.8	2	2	331.56	24.755	21.985	2
5	3	3.8	2	6	338.69	31.558	14.91	2
6	2	4.8	2	4	321.81	31.627	28.08	2
7	2	4.8	2	4	331.56	24.755	28.08	2
8	2	4.8	3	4	286.18	10.661	10.74	2
9	4	4	2	8	275.49	18.2039	566.82	2
10	4	2.8	2	8	260.64	27.4289	270.8	2
11	4	3.8	2	8	260.24	33.56	575.02	2
12	4	3	3	8	222.06	10.634	19.45	2
13	4	3	2	8	260.24	27.419	12.54	2
14	4	2.8	3	8	247.47	19.72	345.13	2

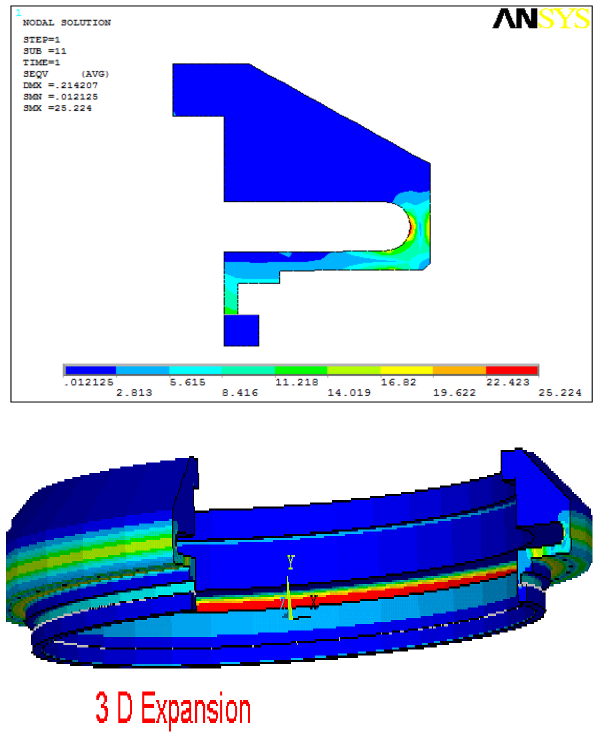

Fig.9: Sample: Iteration14: (A=4mm, B=2.8mm., C=3mm, D=8mm)

Table.3: Modal (Vibrational) analysis with Modal Frequencies.

Iterations	Modal Frequencies(Hz)
1	49.016
2	169.7

Table.3 results shows first modal frequency and second modal frequencies both are away from the working frequency 100Hz by more than 30%. So the system is safe for resonance condition.(30% variation for 100 Hz is 70Hz to 130 Hz and obtained frequencies are not in the same range).

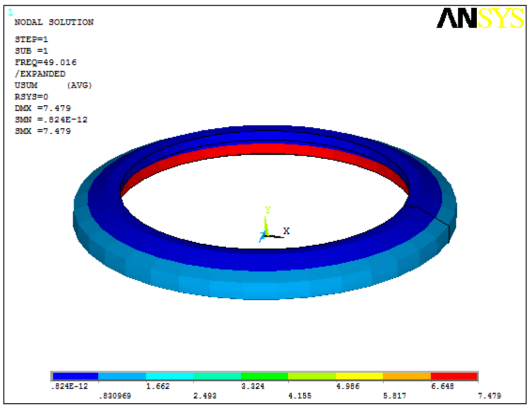

Fig.10: Mode shape for first fundamental frequency 49.016Hz

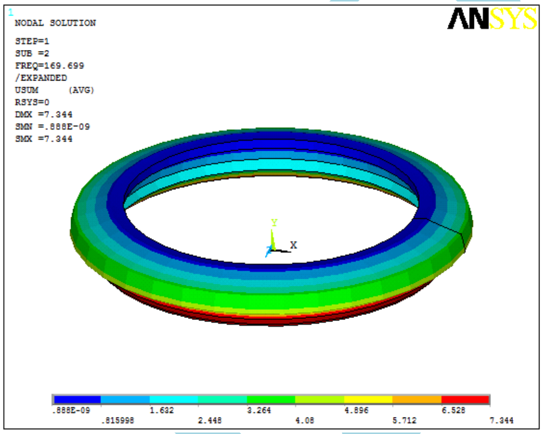

Fig.11: Mode shape for second frequency 169.7 Hz

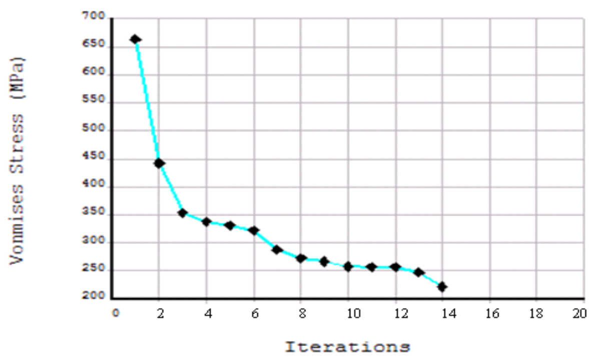

Fig.12: vonMises stress graph to number of iterations for problem optimization

Figure.12 shows graphically the vonMises stress induced for various design cases for the final design which is iteration 14 (fig.9) the stress induced is 247.47MPa which is within the allowable limits.

V. CONCLUSION

The deflection values at the clamping region for the plate thickness of 3mm (lower portion) were more than the required value (i.e. 0.2mm), and is retained for the bottom member.

The iteration 14 shows that the induced stress is 247.7Mpa which is less than the allowable value and the torque is 345.13N-m which is more than the design torque.for a nominal hydraulic oil pressure 2MPa only.

Theoretical torque calculation: The distance between spindle from column is 400mm and load acting on the spindle is 400N.

Torque = force *perpendicular distance
Torque = 400*0.4
Torque = 160 N-m
Taking factor of safety 2
Torque to be resisted each side of the column = 320N-m.
Finally iteration 14 as satisfied the requirements.

Further modal analysis is carried out to find the resonance in the problem. The obtained results shows complete safety of the Hydraulic clamp as the obtained frequencies are 30% away from the operating frequency of 100Hz. All the results are represented suitably in tabular form and graphical form.

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