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Connecting Rod Test Fixture Design and Finite Element Optimization for Bush Pressing Loads

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Abstract

A Testing Fixture is designed and optimized using Finite element Analysis. Initially the thickness is calculated based on the standard deflection formulae for shell members. Later the loading is done to the real conditions and the geometrical parameters are obtained through finite element software Ansys. A geometrical structure composed of base plate, ribs are design optimised to find the best suitable dimensions for width, thickness and height. Three design variables are considered along with one state variable (deflection) for optimization. Since weight reduction is the objective, weight is considered as the objective function. The design optimization summary shows only 9 feasible sets and the weight has reduced from 289 kgs to 136 kgs. Also the design optimizer tool has recommended the dimensions for plate thickness, rib thickness and height of the rib. Transient analysis results shows stability of the structure for the given transient loading. Further three dimensional analysis results shows complete safety of the structure for the given loads. Further dynamic analysis, even brake cylinder is modelled as a single noded mass element and coupled to both cylinder mount and wall mount. The results shows very high natural frequency of the system compared to the operational frequency of 30 Hz.

Keywords—Fixture Design, FEA, Weight Optimisation.

1. INTRODUCTION

Fixture is a structural member for fixing the work piece or holding the work piece for further machining operations or assembly operations. The accuracy of machining or assembly mainly depends on the rigidity of the fixture used in the joining process. Improper fixture design results improper assemblies due to tolerance mismatching of the components. So proper care need to be considered during fixture design.

2. LITERATURE

Optimisation and stress analysis are the key parameters in the mechanical industry for building the better products. A better product should give the advantage of structural safety, cost, durability, ease of assembly etc. So optimizing all these parameters is a engineering challenge and human endeavor is always for taking the challenges arising due to industrial competitions. Lot of research has been carried out and available on the structural design and optimization techniques.

Duffin et al [1] is the founder of geometric programming techniques. He started his work on geometric programming in 1960 where no computer facilities are not available. But he has generated certain key programming aspects which are the back bone of present day design optimization techniques.

Dantzig et Al [2] starting programming based on multi-objective optimization. He is the founder of multi objective based programming. He has applied goal programming methods to achieve the multi objective programming. But he has limited his programming techniques to linear cases only.

Gattayly et al [3] discussed about selection concept and theoretical calculations. He discussed about the need of subject knowledge in deciding the parameters of optimization. Material concept, load concept, load transfer and knowledge in every stage of process are the main base for good optimization. Without the back ground of the subject, the design optimization can't be satisfied and efficient design can't be achieved.

S. Keith Hargrove [4] has discussed about usage of generic programming techniques in fixture design and planning. He has presented a brief review of development of prototypes built by researchers and its taxonomy. Various CAD/CAE tools are discussed for fixture design automation and process planning techniques. Also the type of industry has influence on the design of fixtures.

J. Cecil [5] discussed about automation of fixture design helps in faster production rates and reduces the labor costs. Since a fixture is a complex object to design due to its multiple functions, computer based design and automation can be better implemented to ease the complexity of the problem. As per him, the work progressed for automation is limited and lot of progress is required in integrating the cad environment with CIM environment.

Ian Boyle [6] has worked on magnetic fixtures which are very useful for automation of industrial fixture design and process automation and has developed a solution in the form of CAFIXD program. This program considers decomposition of the problem into sub problems and later a methodology will be developed to solve these sub problems. Finally all these methodologies are assembled to form a complete solution for the fixture design problem.

Z.M. Bi et al [7] developed methodologies for fixture design and its use in the automation. They discussed taxonomy of flexible fixture design concepts based on the existing fixture design concepts. They proposed verification method for the existing fixture designs. They propose new methods for shorter production cycle time, cost reduction, higher quality product with lesser process time for components.

Xiumei Kang et. Al [8] discussed about constraints on fixture planning and design. They have done lot of literature on fixture planning, work holding devices, locator principles etc. Designing and manufacturing is a costly process and consumes 10 to 20% of the total inventory of the company. So his advices methods to design higher flexible fixtures which are suitable for multiple operations in the production industry. A fixture design should be compatible with modern day competition in the industry for better products with lesser lead time.

3. GEOMETRY

A plate is considered as a start for the analysis. The geometrical modeling is done using Ansys preprocessor for the specified dimensions. Meshing and analysis is carried out for the given loads. The base metal considered is steel and the thickness is calculated based on the allowable stress on the members.

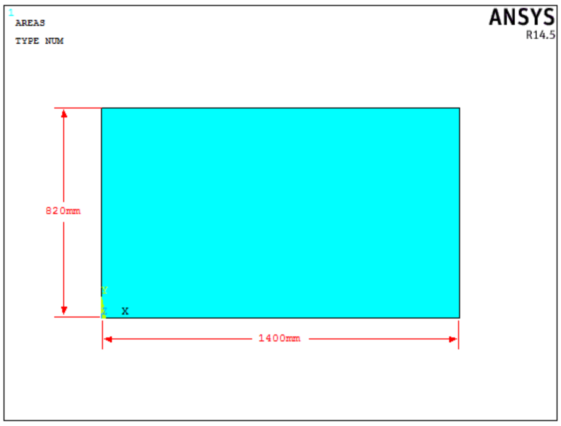

Fig1: Geometry of the Problem

4. FE Model

Mesh is the most important part of finite element analysis. Here the geometric model or continuum model will be converted to mathematical model. Without this conversion, the problem can’t be solved by finite element analysis. Mesh converts infinite degrees of freedom to finite degrees of freedom.

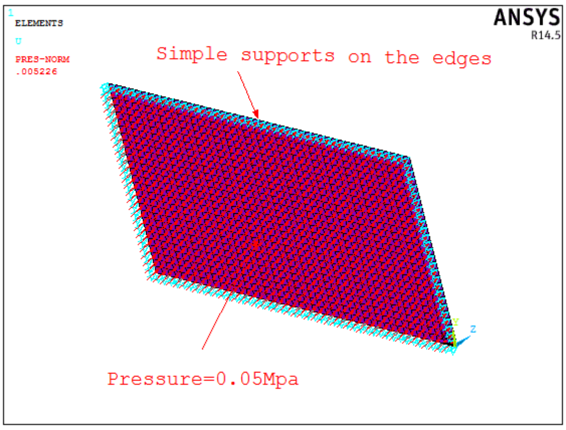

Fig2: Finite Element Mesh

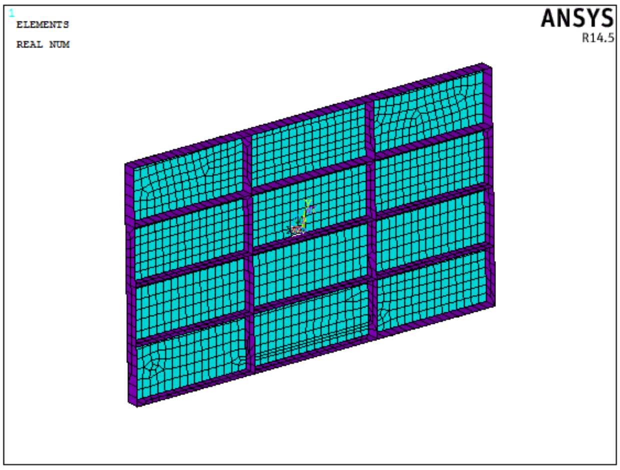

Fig3 : Mesh Plot of the Simplified Geometry

The figure 3 shows ribbed construction of the plate geometry. Shell elements are considered for analysis on the assumption of simply supported configuration.

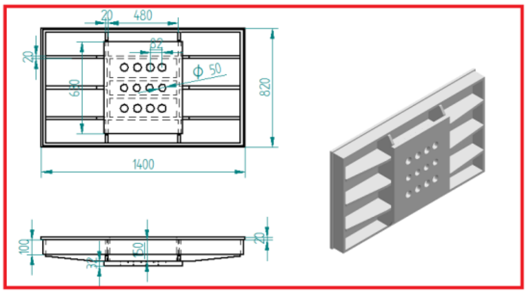

Fig4 : Three dimensional Geometry of the Cylinder Mount

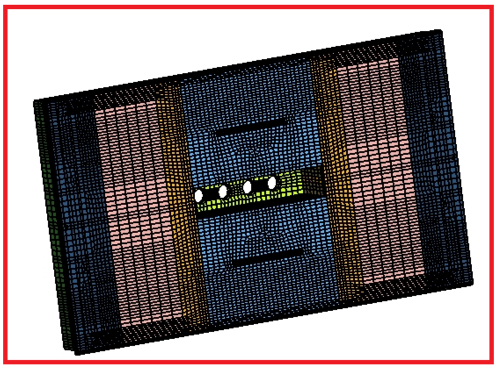

Fig5 : Mesh of the Cylinder Mount

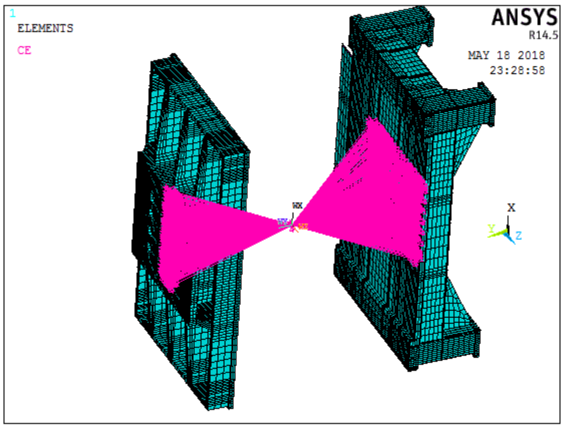

Fig6 : Loading Picture

The figure 6 shows loading through a mass element through RBE3 connections.

5. ANALYSIS RESULTS

After defining design variables, state variables and objective function, the design optimization is carried out using Optimiser module specifying subproblem approximation. The design sets are as follows. .

		SET 2 (FEASIBLE)	SET 3 (FEASIBLE)	SET 7 (FEASIBLE)	SET 8 (FEASIBLE)
MAXD	(SV)	0.73811E-01	0.92995E-01	0.67264E-01	0.92373E-01
H1	(DV)	86.246	72.313	90.895	97.262
T1	(DV)	16.858	18.063	16.068	13.370
T2	(DV)	8.8799	11.179	8.5096	7.6941
WT	(OBJ)	212.36	226.57	205.90	179.73

		SET 9 (FEASIBLE)	SET 13 (FEASIBLE)	SET 14 (FEASIBLE)	SET 15 (FEASIBLE)
MAXD	(SV)	0.70711E-01	0.69457E-01	0.94978E-01	0.84896E-01
H1	(DV)	98.997	98.739	97.599	97.495
T1	(DV)	12.539	11.798	10.509	10.145
T2	(DV)	7.4545	7.3501	6.5733	6.3972
WT	(OBJ)	171.45	163.83	145.54	140.85

		SET 39 (FEASIBLE)
MAXD	(SV)	0.94776E-01
H1	(DV)	96.838
T1	(DV)	10.130
T2	(DV)	5.9176
WT	(OBJ)	136.66

Fig 7 : Design Sets

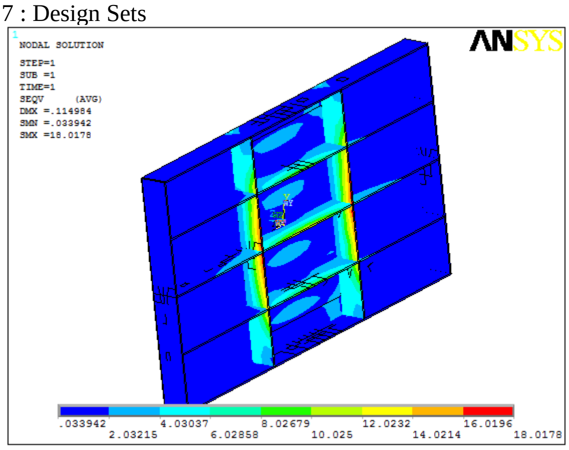

Fig8; Vonmises Stress Plot in the Ribbed Configuration

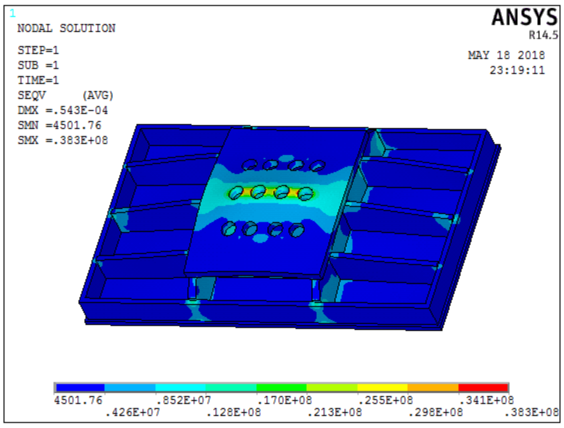

Fig9: Vonmises Stress in the cylinder mount

Set No	Natural Frequency(Hz)
1	219.94
2	229.82
3	247.28
4	313.40
5	323.39

Table1: Natural Frequency Summary

6. CONCLUSIONS

1. Since fixtures are designed mainly for deformation, deflection is considered as the state variables. Weight is considered as the objective function. Total of 50 sets with 30 infeasible sets are specified for the design optimiser with 0.1 kg convergence tolerance. But the optimiser is converged for 39 sets with 9 feasible sets satisfying the functional requirements. So the set number 39 has given the best possible dimensions for the cylinder mount for further manufacturing. But the final dimensions are altered based on the machining tolerance, corrosion tolerance and bearing clearance to place the hydraulic cylinders.

2. Further transient analysis is carried out using three load steps under impact conditions. The results show high rigidity of the structure under transient loading conditions.

3. Modal Analysis results complete rigidity of the fixture structure for the given resonance condition.

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