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Design and Finite Element Optimization of Testing Fixture for Engine Brake System

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ABSTRACT

A testing fixture for brake testing operations is designed, analyzed and optimized for structural safety conditions using finite element analysis as well as theoretical calculations. Initially the theoretical calculations are carried out to find the initial thickness of the plate whose dimensions are specified as design constraints using shell deflection formulations. Geometry of the plate is built and analyzed under simply supported and uniformly distributed load conditions. The results show slight variation of theoretical and numerical results. Further the geometry is built for actual conditions and analyzed to find the deformation and stress. Similarly further geometries are built with rib structure for analysis. The design optimization is carried out using three design variables (plate thickness, rib thickness and rib height) and one state variable (deflection). 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 optimizer with 0.1 kg convergence tolerance. But the optimizer 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.

Keywords *- Fixture optimization Design sets Deformation FEA.*

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

Lot of literature is available on the fixture designs. Few of the salient literatures are as follows.

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 is 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 labour 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

The geometry of the fixture is as follows. Both cylinder mount and wall brackets are modeled.

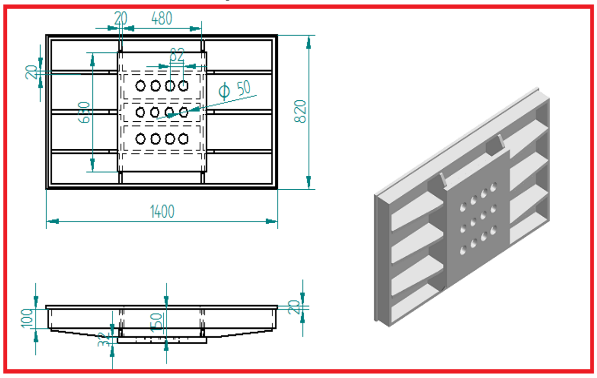

Fig1: Geometry of the Cylindrical Mount.

4. FINITE ELEMENT MESH

Mesh is the important aspect of finite element analysis. Mesh converts the geometrical problem to finite element problem. Also it reduces the infinite degree of freedom of continuum problem to defined or limited degree of freedom problem.

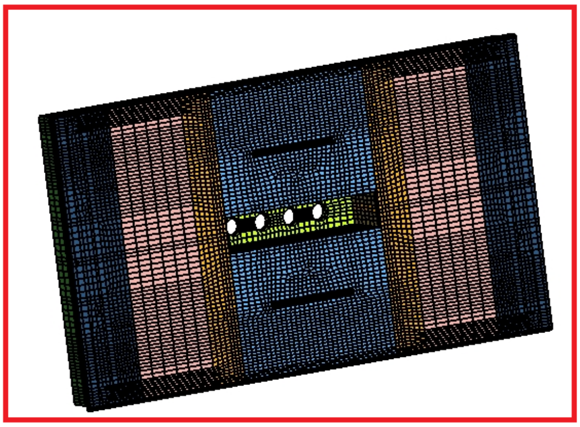

Fig2: Finite Element Mesh.

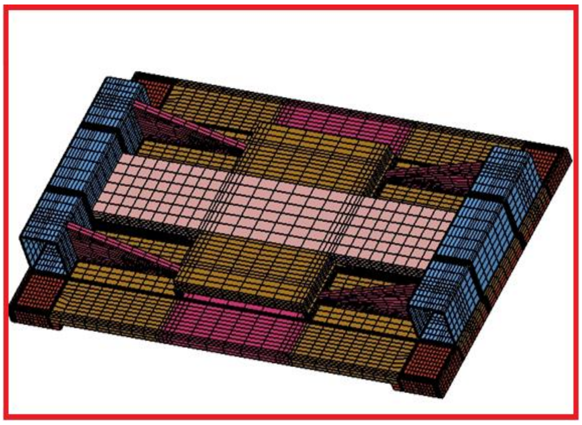

Fig3: Mesh of the Wall Bracket.

5. ANALYSIS RESULTS

Initially two dimensional analysis is carried out to find the optimum dimensions for the plate materials with and without ribs. Analysis has been carried out with 3 design variables and one state variable with weight as the objective function. The analysis is carried out with sub-problem approximation.

		SET 2	SET 3	SET 7	SET 8
		(FEASIBLE)	(FEASIBLE)	(FEASIBLE)	(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	SET 13	SET 14	SET 15
		(FEASIBLE)	(FEASIBLE)	(FEASIBLE)	(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			

Table 1: Design Sets.

6. RESULTS FOR FINAL OPTIMISED SET

The final set analysis results are presented as follows. The ribbed configuration von-Mises stress is captured and represented.

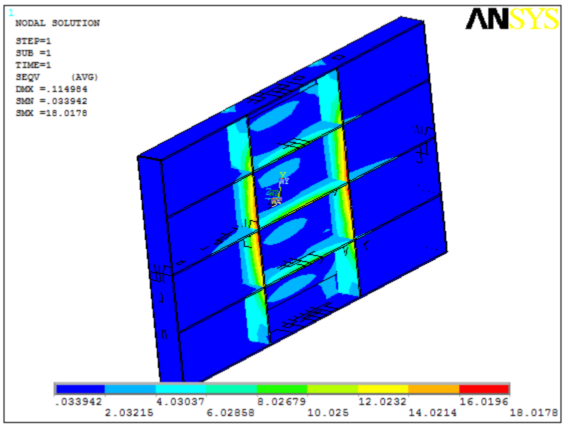

Fig 4: Vonmises Stress in the Final Set.

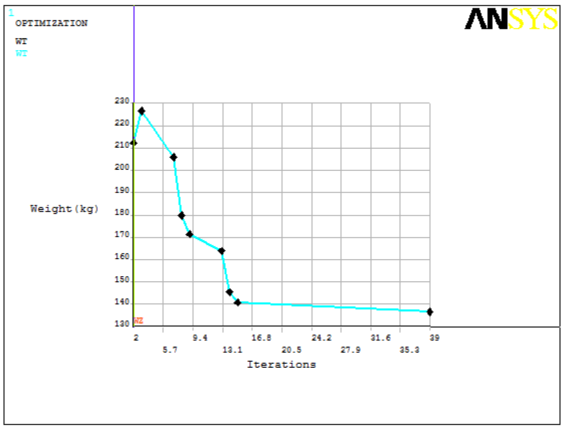

Fig 5: Iterations Vs Weight.

The graph shows dropping weight with the increased number of iterations. This can be attributed to reduced size of the cross section of the members.

7. ANALYSIS RESULTS FOR THREE DIMENSIONAL CYLINDRICAL MOUNT

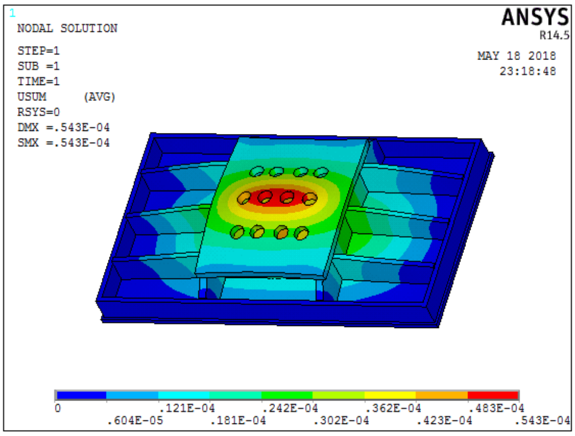

Fig 6: Displacement Plot for the Final Dimensions.

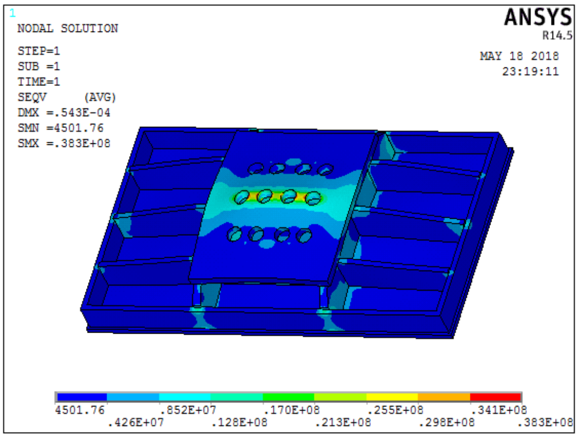

Fig 7: Vonmises Stress in the Cylindrical Mount.

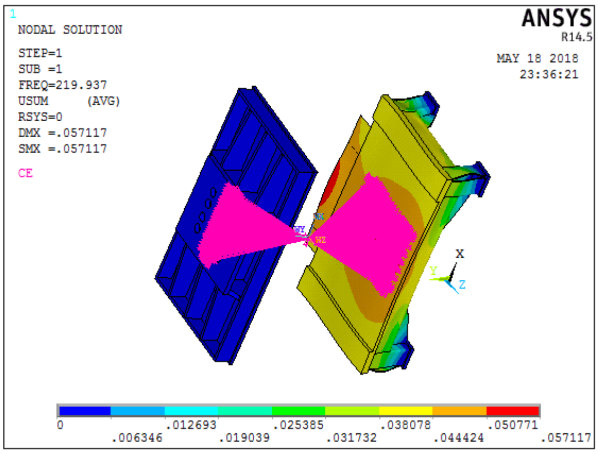

Fig 8: Mode Shape corresponding to the first fundamental Frequency.

Further dynamic analysis is carried out and mode shape is captured. The fundamental frequency value is much higher than the operational frequency and so no possibility for resonance in the system.

8. CONCLUSION

A testing fixture for brake testing operations is designed, analyzed and optimized for structural safety conditions using finite element analysis as well as theoretical calculations. Initially the theoretical calculations are carried out to find the initial thickness of the plate whose dimensions are specified as design constraints using shell deflection formulations. Geometry of the plate is built and analyzed under simply supported and uniformly distributed load conditions. The results show slight variation of theoretical and numerical results. Further the geometry is built for actual conditions and analyzed to find the deformation and stress. Similarly further geometries are built with rib structure for analysis. The design optimization is carried out using three design variables (plate thickness, rib thickness and rib height) and one state variable (deflection). 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 optimizer with 0.1 kg convergence tolerance. But the optimizer 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. Further three dimensional analyses is carried out for the same loading conditions. The results show maximum deformation limited to 54 microns due to the addition of top plate which is increasing the rigidity of the overall structure.

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