Cost Reduction of Fix Jaw of Rear Vice of Horizontal Band Saw Machine using Topology Optimization

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Abstract: *This paper is about cost reduction of fix jaw of rear vice by weight reduction. Rear vice of horizontal band saw machine used for clamping work piece during cutting operation. It has two jaws- Fix jaw and movable jaw. Movable jaw attached to hydraulic cylinder which applies force to hold work piece between these two jaws. Reduce weight of components help to minimize load on environmental resources .This efforts for reduction of weight by using topology optimization. fix jaws has been modeled using solid works First conducted analysis on existing jaws with calculating the forces acting on jaws in order to find out Max. Displacement and stress induced. These analyses were carried using Altair Hyperworks and solver used is optistuct. Again conducted topology optimization with applying manufacturing constrain like minimum member size and single type draw direction. Again prepare cad model as per topology result and carried analysis on optimized model. from that analyzed results, Displacement and stress are lower than existing model. From result it was found that current design is safe also save material and cost of component, Finally we reduced cost by 244/- and total reduced weight by 24 % of current fix jaw model. Topology optimization analysis is carried out in Hyperworks which yielded in weight optimized.*

Keywords: Horizontal band saw machine, rear vice fix jaw, Hyper works, Optistruct, Topology optimization

1. Introduction

Sawing machine is an important machine tool of mechanical workshop. A sawing machine is a machine tool designed to Cut off bar stock, tubing, pipe, or any metal stock within its Capacity or to cut sheet stock to desired contours. The sawing Machine functions by bringing a saw blade containing cutting Teeth in contact with the work piece to be cut and drawing the cutting teeth through the work piece. The sawing machine is much faster and easier than hand sawing. Sawing machine has two types:

1) Power hack saw
2) Band saw machine.[8]

Power hack saw machine uses a reciprocating cutting Action, while band saw uses a continuous band blade. For this work we have taken fix jaw of horizontal band saw. Rear vice used for clamping work piece during cutting operation. Rear vice has two jaws one is fixed jaw and another is movable jaw. Moving jaw attached to hydraulic cylinder. Hydraulic cylinder operated by a hydraulic power pack. Pressure dial gauge shows how much Pressure applying on hydraulic cylinder.[6]

Topology Optimization is defined as finding out the best possible material distribution in selected design space with considering the given sets of objective and design constraints. For solving any topology optimization problem have to specify parameters that are Design Variables, responses, Design objective and design constraints also consideration of manufacturing constraints.

Hence in order to accomplish the objective of cost reduction through weight reduction over existing design, Finite Element Analysis method is used. Since from last decade a powerful FEA packages have proven good to analysis. Hence we are going to use finite element analysis software

for weight optimization. In which Hypermesh is pre-processor. Optistruct is solver which now days much famous in industry and Hyperview is Post-processor. [1]

After will do FEA analysis of optimized model and check stress, displacement of optimized model do not to exceed magnitude of initial model.

This paper deals with 3D modeling of fix jaws. Calculation of force, Analysis, optimization, getting IGES model from optistuct (OSsmooth) and Make appropriate change in that model for manufacturing point of view and cross-check value of displacement within range(lower than Initial model).

2. Problem Definition

In which fix jaw of Rear vice is taking for project work. Rear vice jaw has two jaws one is fixed another is movable. Hydraulic cylinder attached to movable jaw which applies force to jaw to clamp the work piece. Fix jaw's weight is 12.1 kg. Fix jaw are made of ductile iron. Inner diameter of hydraulic cylinder is 80.125mm, while max. Pressure of hydraulic oil on cylinder is 22kg/cm2 .Maximum load applying on jaws is 10884N. [6]

3. Objective

The key objective of this effort is to carry out static analysis of fix jaw of rear vice and also perform topology optimization for achieving optimize the structural design of fix jaw of rear vice in order to reduce the material cost by reducing weight of Existing fix jaw without reduction in load bearing capacity.

- Determinations of the forces acting on fix jaw of rear vice during working conditions.

- Solid modeling of the fix jaw of rear vice.
- Determination of displacement and max. Disp. Node numbers of current fix jaw.
- Determination of Von mises stress of current fix jaw.
- Topology optimization setup with minimum member Size (8 mm) and single type draw direction..

4. Methodology

Prepare CAD model of current fix jaw
↓
Geometry cleanup & Meshing
↓
Run Analysis
↓
Find out max. Disp. And stress
↓
Setting Optimization (design variable, response, Design constraints, mfg. constraints, objective)
↓
Process submit
↓
Result visualization in Hyperview
↓
OSsmooth
↓
Redesign according to OSsmooth IGES ←
↓
Analysis optimized model
↓
disp. & stress lower than initial model →NO
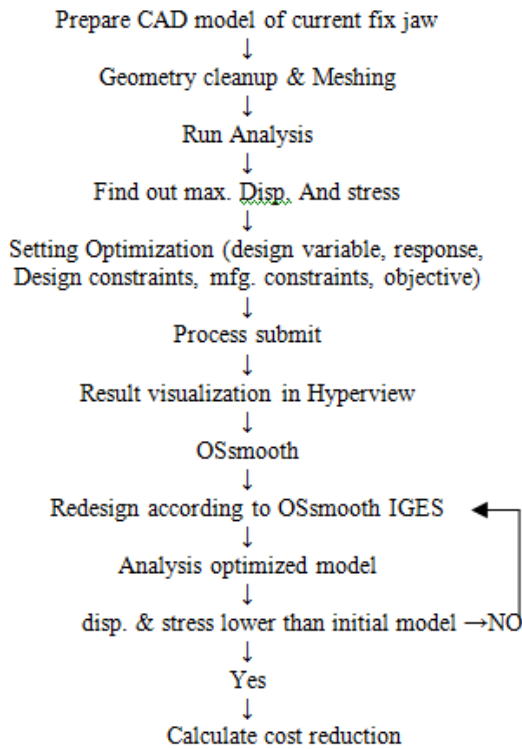↓
Yes
↓
Calculate cost reduction

Figure 1: Work flow diagram

In above diagram show that way of work. In order to proceed with this study various forces acting on fix Jaw. CAD model of fix jaw designed in solid works was imported in Hypermesh. Then geometric cleanup and meshing has done. Meshed model of fix jaw consist of 44053 nodes and 202579 elements. All are 3D Tetramesh (volumemesh).Tetra elements give enhanced result as compared to other types of elements, therefore the elements used in this analysis is tetra elements.
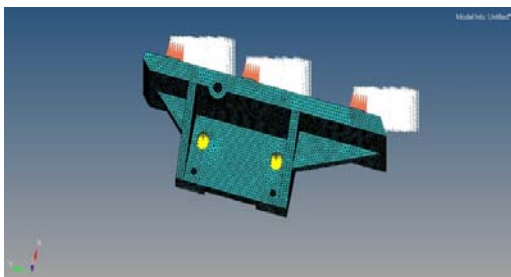
Figure 2: Fix jaw with meshing, loading & boundry Condition.

Ductile iron material has used for fix jaw. Calculated forces and boundary conditions were applied on meshed model in Hypermesh as shown in figure 2. Static analysis was performed by using optistuct. Viewed Result in Hyperview. All specification such as material property and result shown in table1.

4.1 Design parameters

1) Forces acting on jaws
Rear vice jaw has two jaws one is fixed another is movable. Hydraulic cylinder attached to movable jaw which applies force to jaw to clamp the work piece. Inner diameter of hydraulic cylinder is 80.125mm, while maximum pressure of hydraulic oil on cylinder is 22kg/cm2 .here we calculate total force applying on fix jaw [6].

$P=F/A$
$F=P*A$
$F=22*(3.142*(4.00625)2) =1109.44$ kg.
$F=1109.44*9.81 = 10884$ N
Maximum load applying on fix jaws is 10884N.
Considering factor of safety (F.S.) 1.5 then
$F= 10884*1.5 =16326$N.

Table 1. Material properties and specification of jaw

Parameter	Description	Fix jaw
E	Young's Modulus (Mpa)	170000
NU	Poisson's Ratio	0.275
RHO	Density (kg/m3)	7100
F	Force(N) factor of safety 1.5	16326
M	Wt. of jaw before optimization	12.1 kg

5. Results and Discussions

a) Static analysis
Static analysis was performed by using optistuct solver. From figure3, it is observed that the maximum displacement Developed is 0.116mm for fix jaw. Stress developed is 97.82 N/mm^2. Which is lower than the Yield strength. Hence, design is safe that is the values of maximum stresses are acceptable as compared to yield strength so design constraints For Optimized fix jaw is to maintain displacement value lower than 0.116 mm.

Table 2: Analyzed results for fix materials

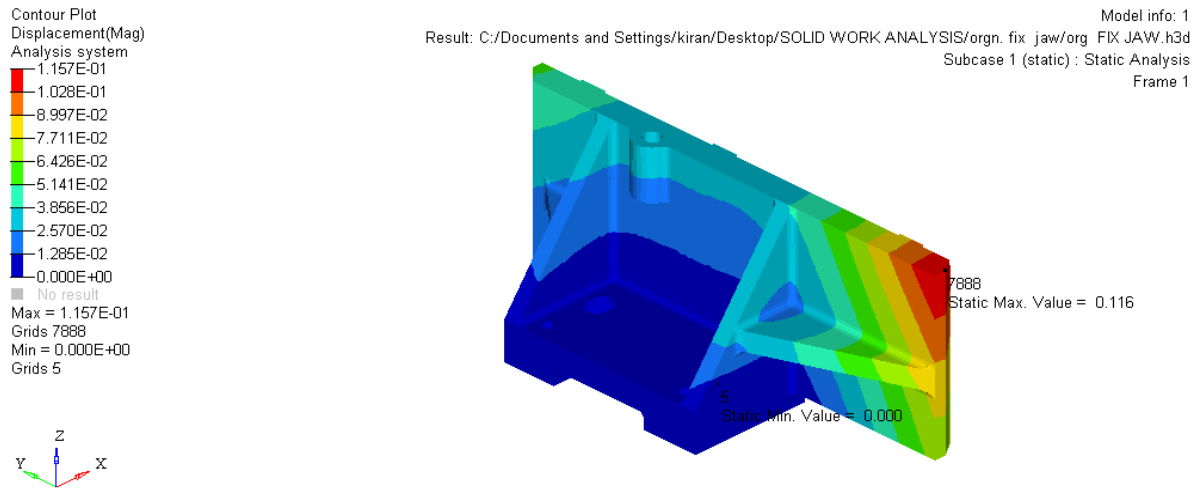| Description	Fix jaw
Max displacement in mm	0.116 at node 7888
Von Mises stress (N/mm^2)	97.82

Figure 3: Max. Displacement of fix jaw

b)Topology optimization

Topology Optimization technique gives an optimum material distribution within given design space [7]. The design space defined using solid elements. The topology optimization set up in which first is design variable selected as solid and setting up two manufacturing constraints 1. Minimum member size control (8 mm) 2. Draw direction type (single).Design response was volume Fraction, weighted comp., displacement. Optimization design constraints were volfrac for that upper bound 0.30 and Displacement constraint was upper bound 0.116mm for fix jaw.

Finally design objective was Minimum weight compliance. Run optimization by using optistuct Solver. Finally viewed result in hyper view.
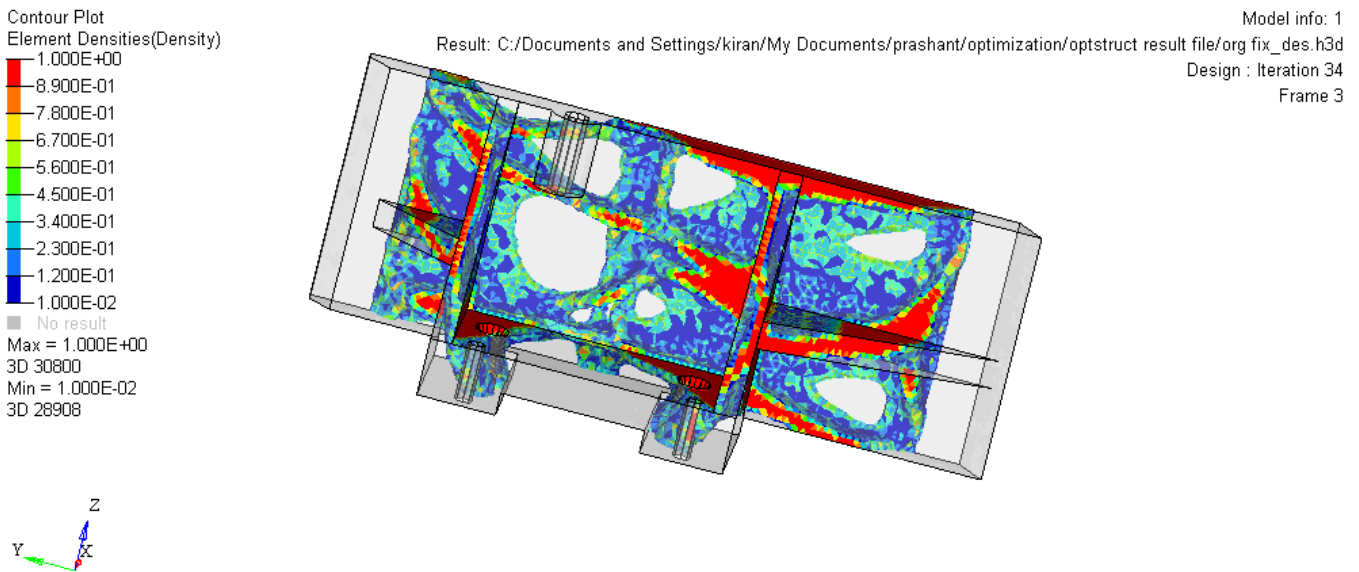

Figure 4: Hyper view element densities of fix jaw

Figure 4 shows element density for fix jaw. Optistruct identifies material distribution pattern throughout jaw and remove material from that region in successive iterations based upon set of objectives and constraints. This material removal is given by varying density of each element from 0 to 1. After numbers of iterations, when solution converges the density pattern of component a region with lower density indicate that it can be removed without hampering safety of component. So by removing the material from these design space of component objective of reducing weight of

component will be fulfilled with all design constraints. A conceptual design can be imported in a CAD system using An iso-surface generated with OSSmooth, which is part of OptiStruct. This IGES model imported in solid works makes changes as per manufacturing aspect. Figure 5 Shows CAD model of fix jaws resp.
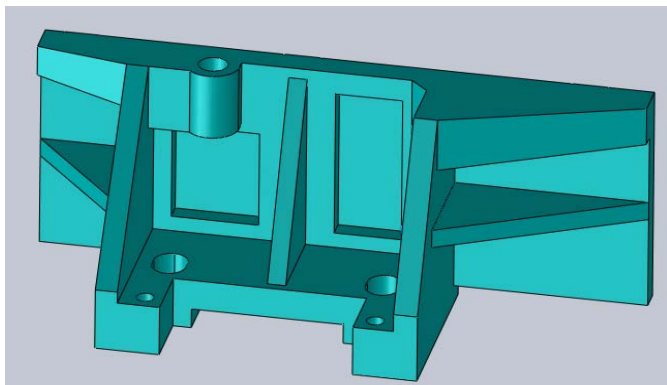
Figure 5: CAD model of optimized fix jaw

Again conduct analysis on newly optimized fix jaw model. Setup all meshing, boundary and loading condition. Cross Check that displacement and stress of optimized model do not exceed value Initial model. Figure 6 Shows displacement result of optimized fix jaw. Displacement of optimized fix jaw is 0.106mm (<0.116mm of current model). Then Check the magnitude of displacement and stress of optimized model has lower than initial model.
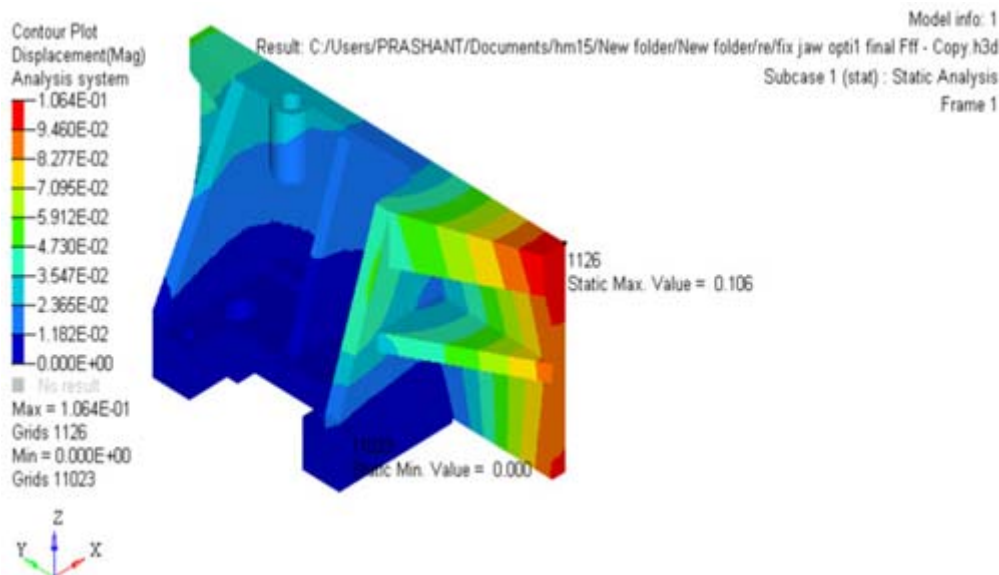

Figure 6: Disp. of optimized fix jaw 0.106mm

Table 3: Analyzed results for fix materials

parameter	fix jaw *before* optimized	fix jaw *after* optimized
Max. Displacement(mm)	0.116	0.106
Max. Stress (N/mm^2)	97.82	93.89
Weight optimization (kg)	12.1	9.23

Table 4: Total weight and cost saving

Design parameter	fix jaw after optimized
Weight reduced (kg)	(12.1-9.23)=2.87kg (24%)
Total cost saving/unit	2.87*85=244/-
Total cost saved/year	**244 *100 = 24,400/-**

6. Conclusions

In this work Forces acting on fix jaw of rear vice of horizontal band saw machine has been calculated with considering factor of safety. CAD model of jaws has been carried out using Solid works software. The static analysis as well as optimization of fix jaws has been carried out in Hyperworks. From the analyzed results, it is concluded that.

- The values obtained for the maximum displacement and von mises stress of optimized model are lower than existing model.
- Topology optimization generates an optimized material distribution for a set of loads and constraints within a given design space. This Optimization reducing weight, manufacturing cost of component fulfilled with all design constraints.
- Weight optimization of rear vice resulted to 24% of weight reduction than existing model. So that company saves 24,400/- per year.
- Finally we reduced cost of fix jaw by 244/- per piece.
- Though this work we can minimize load on resources.

7. Future Scope

We can apply this weight optimization method to all casting parts of horizontal band saw machine which are over design. So we can minimize total Manufacturing cost of machine and it will better to Increase sale in market

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