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Design and Development of Stamping Bracket of Snowmobile Using Computer Aided Engineering

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Abstract: *Development of new products is extremely essential for the success and smooth running of every industry. Companies have to constantly inject innovations and design efforts to make the design processes easy and to attract consumers in a constantly in a evolving and highly competitive market with best quality . Keeping ahead of the competition by bringing new and exciting products to market fast, and at the necessary level of quality, presents a major engineering challenge. A new casting bracket in place of old stamping brackets in snowmobile chassis development process is described, which introduces advanced FEM and Optimization technology into the concept development phase. Detailed predictions of interacting parts in a mechanism assembly are made possible through use of value engineering based process and material selection and advanced simulation technology. Design optimization is then employed using the modeling as a virtual testing ground for design variants. The approach provides clear design direction and helps to improve performance and reduce the unnecessary welding efforts of bracket manufacturing. Design is an intelligent activity that begins with design requirements and ends with a product description. Using Altair Optistruct was able to significantly reduce design time by sub modeling with structural optimization. The resultant casting bracket design showed superior performance characteristics. And finely the manufacturer had to put less efforts in stamping and part welding , which reduced the manufacturing time and cost also.*
Keywords: *CAE, Topology Optimization, Sub-modeling, Product Design, Cost saving.*

I. Introductions

The level of increasing competition between automotive manufacturers has focused the development of new products to focus upon more efficient design. By defining the the most efficient sub modeling and topology optimization structural target can be achieved fewer design iteration, therefore leading to reduce cycle time and lower the development costs . The optistruct software from Altair suits provides environment which relishes this method by providing a ‘ right first time approach ‘ to chassis design or part design. The use of topology design to structural design provides a very fast rout ensuring the vehicle’s new modification.

For example Carl Reed [1] presented an insight-full development of an efficient body structure subjected to various load cases . Based on the topology load path , which optistruct defines . And his paper has presented the reliability of on CAE software. By this it has enabled the development of a body across a structural target in one design iteration instead of traditional mathods which took 10 iteration in more time and efforts from many engineers. Dave Huson [2] developed a virtual design of vehicle within 12 month that requires no full prototype testing . This has done during the Roewe 550 development program . Physical testing of vehicle has latterly proven that the performance prediction from CAE were accurate enough to achive an effective design. SAIC with Altair product design has demonstrated that aggressive vehicle program time scale can met through effective engagement of a CAE design driven process combined with the utilization of timescale reduction and optimization technology. Mohhammad Chodat & Search leech [3] has described the design optimization which has then employed using the modeling as a virtual testing ground for design variants. The approach provides a clear design direction and helps to improve performance. This approach has been adopted on the Unilever project and has included advanced non linear CAE to accurately predict concept performance, and drive new design concept with optimization. Andrian Chapple [4] presented eDICT (evolutionary design in chassis technology) which is an innovative structural process flow for the design of optimal structure. By this optimization capability of optistruct software with a set of custom tool to guide and translate a design into a production feasible sheet metal solution . The critical eDICT is to determine the optimal solution from the outset and place material only where it is needed . And the presented technique from thyssenkrupp are leading the way in translation of optimum topology solution into feasible design . A.K. chitle and R.C. Gupta [5] has described about the SAMUEL EILON model in their book of product design. That is a mathematical model of profit volume analysis and it is a useful tool t determine whether the additional investment of monetary units (due to process change , design change and material change) is desirable or not.

This paper is presenting the complete methodology for designing a new product by using of CAE , sub modeling , Optimization and economic calculations.

II. Objective

The objective of this exercise is to develop a methodology for finding a correct design solution which requires both material and process change, with the help of CAE (FE Analysis , Sub-modeling, Topology Optimization) and economic study. The new design should be in such a manner that it will require very less efforts for manufacturing and it is effective cost saving product also.

The load transfer bracket which has used previously consist of two stamping parts . so there are 8 manufacturing processes which is require to create this product. The real challenge for the designer is to replace this Load transferring bracket with such a product which requires less manufacturing processes. And the total cost of this product should less with same or improved performance. Fig. 1 is showing the load transferring brackets made with two stamping parts.

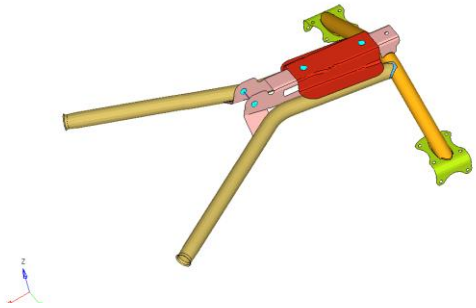
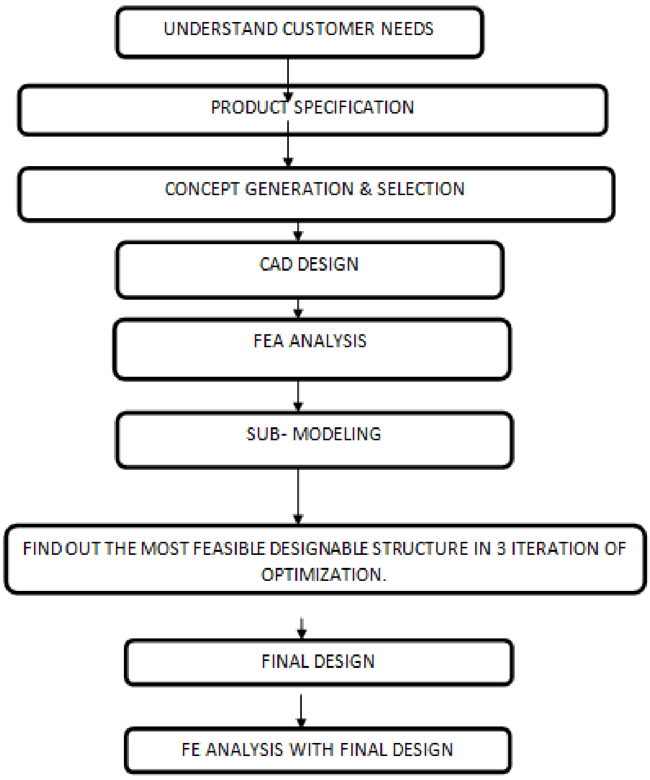


Figure 1: Load transferring bracket assembly of a snowmobile chassis

Material of stamped part : **Steel GR-50**
Yield stress Limit = 345 Mpa
Ultimate stress limit = 450 Mpa
Young's Modulus = 2.1e5 Mpa
Density = 7.8e-9 tons /mm3
Poisson's Ratio = 0.30



III. Methodology

4.1 Material and Process Selection

Here the material and process has done by the brainstorming and discussion .Brainstorming in value engineering is define as "an organized creative approach which has for its purpose, efficiently identification of unnecessary cost i.e. which provides nighters quality nor use ,life, appearance or customer features". it is very comprehensive . Based on function analysis the process concentrates on the detailed examination of utility , rather than on a simplistic examination of components and component cost . collateral gains productivity, parts, availability, lead time and quality . one engineer must understand the relation between the production and design interact. In the past because of the limited number of materials and processes a product engineer could prepare the majority of designs, Geometric designs were evaluated initially with the material and process which were available. This approach is no longer acceptable and the design method of the past must necessarily be update. Any product design today particularly through value engineering take a rigorous study of the material and process possibilities.

It must realize in today's product design concept "process selection save rupees while optimization save paisa. There are many factors which affect the process and material selection like shape requirement, material requirement and process characteristics.

4.2 Process Selection

Process selection requires a broad and extensive knowledge of various manufacturing process. It is the initial selection of manufacturing processes , which in combination with a geometric design and material fulfils the design requirement, The component which has showed in this paper need processes :

- 2 stamping
- 2 cutting
- 4 bending
- welding

This much processes requires lots of time , if this all process can replace by any one casting process that will be reduce the manufacturing cost. This process selection reduce the excessive need of manufacturing firm, and the designer and production engineers . There are many parameters which controls the process selection exercise.

- Geometry
- Material
- Production value.

4.3 Material Selection

The selection of the sound economic material for product designs in itself a difficult problem. In many situation development work on the creation of new material selection is choosing one material from the many available. It is essential that the material requirements be specified in terms of product function and end use.

The determination of what of what alternative are to be considered is done largely institutionally. In the initial evaluation of material alternatives , may can be rejected on the basis of absolute product parameters such as strength , conductivity, , magnetic permeability etc. this is fairly strait forward in that , either the alternative meet some absolute requirement or it does not. Ones the material which does not meet the requirement have been eliminated, the problem is far more difficult . though all the remaining alternatives are acceptable , the question is how good they are compare to one another. The decision matrix is used in the final evaluation of specific alternatives.

There are various parameters for material selection like :

- Function
- Reliability
- Service life
- Environment
- Productebility
- Cost

4.4 Role of CAE in Design Process

In the traditional design process, computer aided design (CAD) and computer aided engineering (CAE) tools are used sequentially. The designer creates the geometry in CAD and verifies it using CAE. With the simulation driven design approach, CAD and CAE are deployed in parallel. CAE, using intelligent technology, automatically determines the optimum geometric configuration, allowing engineers to reach the best performing design, faster.

FE Analysis

FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. A company is able to verify a proposed design will be able to perform to the client's specifications prior to manufacturing or construction. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition. There are generally two types of analysis that are used in industry: 2-D modeling, and 3-D modeling. While 2-D modeling conserves simplicity and allows the analysis to be run on a relatively normal computer, it tends to yield less accurate results. 3-D modeling, however, produces more accurate results while sacrificing the ability to run on all but the fastest computers effectively. Within each of these modeling schemes, the programmer can insert numerous algorithms (functions) which may make the system behave linearly or non-linearly. Linear systems are far less complex and generally do not take into account plastic deformation. Non-linear systems do account for plastic deformation, and many also are capable of testing a material all the way to fracture.

FEA uses a complex system of points called nodes which make a grid called a mesh . This mesh is programmed to contain the material and structural properties which define how the structure will react to certain loading conditions. Nodes are assigned at a certain density throughout the material depending on the anticipated stress levels of a particular area. Regions which will receive large amounts of stress usually have a higher node density than those which experience little or no stress. Points of interest may consist of: fracture point of previously tested material, fillets, corners, complex detail, and high stress areas. FEM is fast growing technique now a days, Various companies in India is adopting FEM base software work. This method has reduced the time of new product designing , testing. There is no more need to make many prototypes for testing , if you are getting a good correlation with one of the FM model and real testing prototype than further design iteration is possible from FEM model only. Thus it saves lost of material cost, testing equipment cost etc.

Sub-Modeling

In Any simulation software the solution time depends on type of analysis, Number of nodes and elements , total DOF. If the number of nodes of FE models are more than it will take more time to solve the analysis. Many times it happens that we have our area of interest in very small reason of any full model ,and there is no need to analyze full model. In such cases full model solving is very time consuming process. Sub-modeling is a nice technique to reduce the total simulation time for such cases. In sub-modeling it is possible to make separate to the desired reason of the model. And the Forces and displacement can apply with the help of concept of Free Body Diagram (FBD). All the forces and all the moment will be balance Fx .Fy, Fz, Mx, My, Mz. And this sub model can save your run time by 50 to 98 % (depends on reduction of Number of Elements, nodes ,DOF).

TOPOLOGY Optimization

Optimization is a mathematic based technique, for which a programmed software can work easily. And Optistruct is the one of the optimization software, which is based on various mathematical calculations. World’s well known company Altair engineering is the owner of Optistruct. Freeform optimization (or topology optimization) is a mathematical approach used in finite element analysis to determine the optimum material layout for a given design space which takes into any number of design constraints. By defining a design space that the engineer has to work in and applying boundary conditions such as predefined loads and fixture positions, topology optimization can suggest the ideal layout of material to meet defined performance targets. Freeform optimisation can be used at the concept level of the design process to arrive at a conceptual design proposal that is then fine tuned for performance, weight and manufacturability. This process replaces time consuming and costly design iterations and hence reduces design development time and overall cost while improving design performance. It is important to note that design proposals from a freeform optimization study will present an optimal layout of material distribution which may be at odds with the manufacturing processes employed. As such there is still a need for the engineer to interpret the output from the study into a final manufacturable model that can be tested further. However, some new advances in manufacturing techniques such as additive layer manufacturing or 3D printing, has the potential for parts to closer resemble the freeform results.

IV. First Step and topology results

5.1 FE Analysis and Optimization

Analysis work had been distributed in 4 stages. In the first stage FE analysis of full chassis completed. The load transferring bracket have the material property of Steel GR-50**.** The material details are described below the figure 2. Analysis has done for the 4 load cases i.e. Bending, Left hand Torsion, Right hand Torsion, shock. The details of all these loading and Geometry has taken from L&T Technology services, vadodara but it is not shown here to publish it in detail. But it will not affect our objective of describing a CAE based approach.

And then in second step Sub model prepared with a small structure which has only 3 pipes ,2 stamping bracket and connectors. After value engineering for material and process selection a model of the stamping parts has been replace by a design volume. This design volume(Fig. 2) had extracted carefully for outer surfaces, which should not interfere with other components. And Optimization has done for three iteration with different setups.

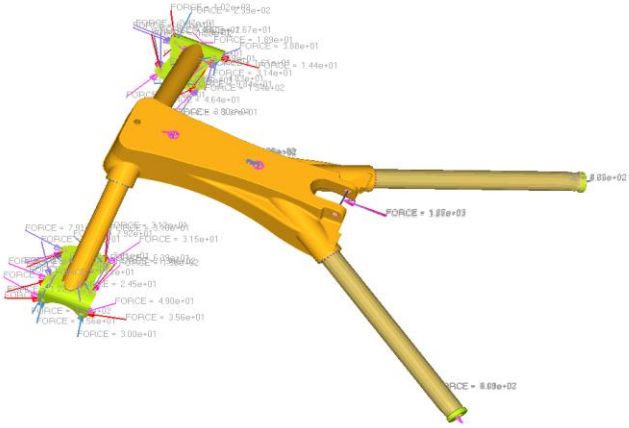


Figure 2: Extracted Design Volume with the FBD loads

Aluminium-365

Yield stress Limit = 125 Mpa
Ultimate stress limit = 170 Mpa
Young's Modulus = 7e4 Mpa
Density = 2.8 e-9 tons/mm3
Poisson's Ratio = 0.33

ITRATION 1

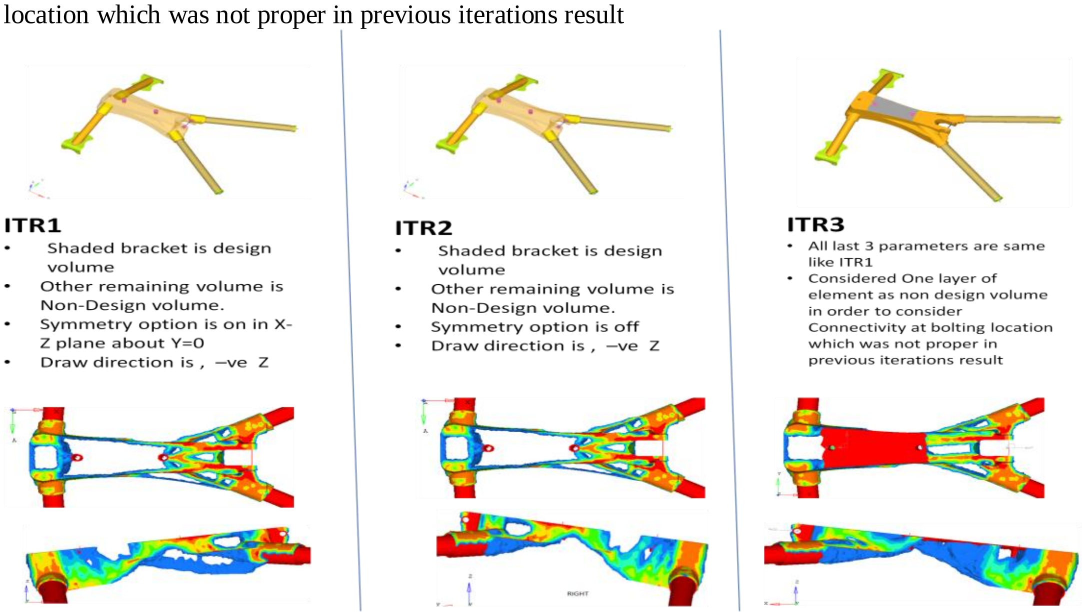
- Symmetric option in X-Z plane about Y=0
- Draw Direction is negative Z

ITRATION 2

- Symmetry option off
- Draw Direction is negative Z

ITERATION 3

- Symmetry option is on in X-Z plane about Y=0
- Considered One layer of element as non design volume in order to consider Connectivity at bolting location which was not proper in previous iterations result



Optimization with this 3 iteration is our 3rd stage , first two iterations are not giving completely manufacturable design ,so some extra non design volume has added in 3rd iteration. And the last stage is to do FE analysis on the finalized design.

5.2 FE Analysis on final design

When third iteration of topology optimization is looking feasible for manufacturing, a CAD model had prepared. Fig 3 shows the result of 3 iterations. The optimization result gives the load path information for component, so CAD model is prepared by the brainstorming and with the help of optimization result. This is 4th stage in which FE analysis had done with new CAD model.

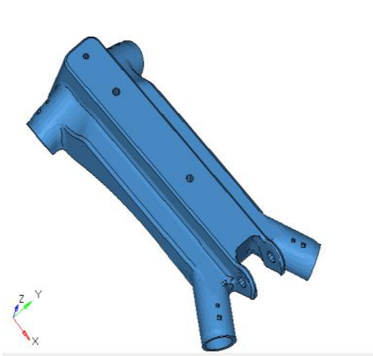


Figure 4: CAD model of New Design

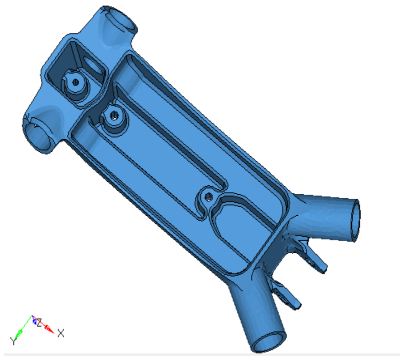


Figure 4: CAD model of New Design

V. Result and Discussion

6.1 Comparison of New and Baseline design

The ambition of our presentation is to represent the methodology for finding a correct design replacements by the help of CAE. In our case study the final CAD design has analyzed and compared with previous stamping bracket models. The new casting design is heavier than baseline design by 5 percent, and this is not big influencing value if we see the complete chassis. The three comparative result are giving information about the various stiffness.

1. Structural Stiffness
2. Torsion Stiffness
3. Bending Stiffness

6.1.1 Structural Stiffness

(See the Fig 5)

Stiffness = Applied Force / Max Displacement in Structure

$$\boldsymbol{k = f/d}$$

For Baseline Design

$$k = 10/\ 0.0049$$
$$k = 2040.86 \text{ N/mm}$$

For New Design

$$k = 10/\ 0.0036$$
$$k = 2777.77 \text{ N/mm}$$

Percentage gain in Structural stiffness $= \frac{2777.7-2040.86}{2777.7} * 100$

$= 26.53\ \%$

6.1.2 Torsinal Stiffness

Torsion stiffness is an important characteristic in chassis design with an impact on the ride and comfort as well as the performance of the vehicle. And According to Steven Tebby , Ebrahim Esmailzadeh and Ahmad Barari it is clear that simulation method is one of the best method for the calculation of torsion stiffness of chassis. (See the Fig 6)

Torsion Stiffness = Applied Torque / Angular Displacement

$$k = T/\emptyset$$

And $$\emptyset = \tan^{-1}\left(\frac{V}{B/2}\right)$$

Where
T= Applied Torque= Applied Force *Base width
∅= Angular displacement
V= Vertical Displacement at load application point
B = Base width

Calculation for Baseline Design

$$\emptyset = \tan^{-1}\left(\frac{0.054}{324/2}\right)$$

$$\emptyset = 0.01909 \quad \text{Degree}$$

$$k_{\text{Baseline}} = (10*324) / 0.01909$$

$$k_{\text{Baseline}} = 169722.367 \quad \text{N-mm/Degree}$$

$$k_{\text{Baseline}} = 169.722 \quad \text{N-m/Degree}$$

Calculation for New Design

$$\emptyset = \tan^{-1}\left(\frac{0.042}{324/2}\right)$$

$$\emptyset = 0.01485 \quad \text{Degree}$$

$$k_{\text{New}} = (10*324) / 0.01485$$

$$k_{\text{New}} = 218116.29 \quad \text{N-mm/Degree}$$

$$k_{\text{New}} = 218.116 \quad \text{N-m/Degree}$$

Percentage gain in Torsion stiffness $$= \frac{218.116 - 169.722}{218.166} * 100$$

$$= 22.18\ \%$$

6.1.3 Bending Stiffness

(See the Fig 7)

Bending stiffness = (Total Applied load) /(Deflection at point of application of load)

$$\boldsymbol{k = f/d}$$

Calculation for Baseline Design

$$k_{\text{Baseline}} = 10/0.001536$$

$$k_{\text{Baseline}} = 6510.5 \quad \text{N/mm}$$

Calculation for Baseline Design

$$k_{\text{New}} = 10/0.000779$$

$$k_{\text{New}} = 12825.5 \quad \text{N/mm}$$

Percentage gain in Bending stiffness $$= \frac{12825.5 - 6510.5}{12825.5} * 100$$

$$= 49.3\ \%$$

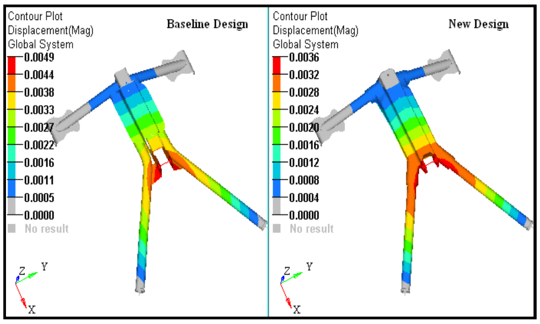


Figure 5: Displacement contour for comparison of Structural Stiffness. Comparison is based on unit loading.

Figure 6: Graphic comparison of difference for Structural Stiffness.

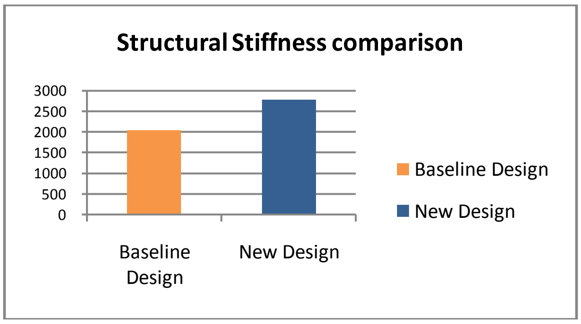


Figure 6: Graphic comparison of difference for Structural Stiffness.

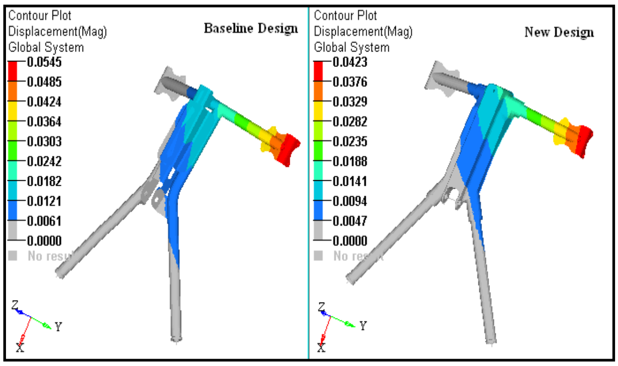


Figure 6: Displacement contour for comparison of Torsion Stiffness. Comparison is based on unit loading.

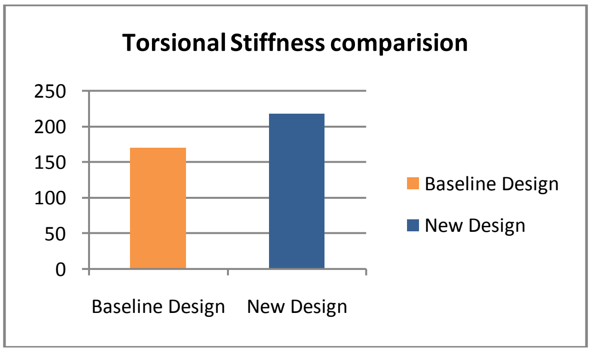


Figure 7: Graphic comparison of difference for Torsion Stiffness

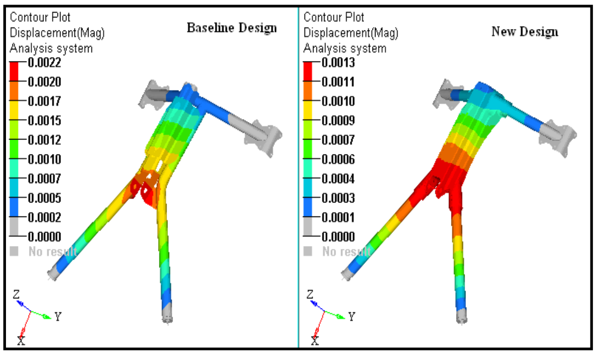


Figure 8: Displacement contour for comparison of Bending Stiffness. Comparison is based on unit loading.

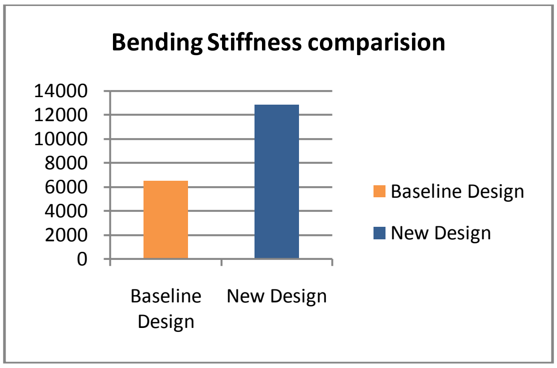


Figure 9: Graphic comparison of difference for Bending Stiffness.

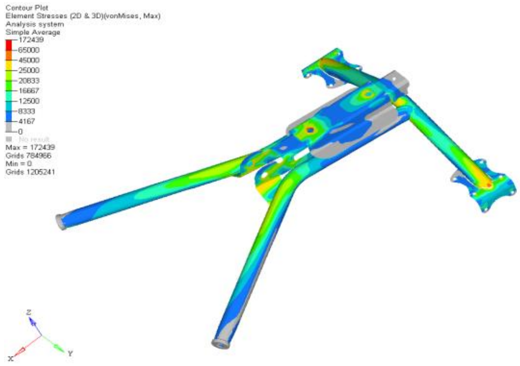


Figure 10: Baseline design Results for shock load (worst load case for bracket)

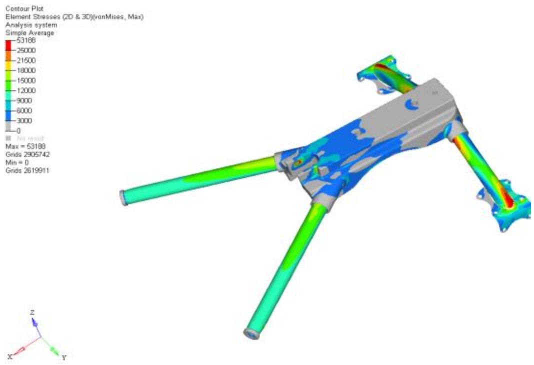


Figure 11: New design Results with AL 365 Material Bracket .

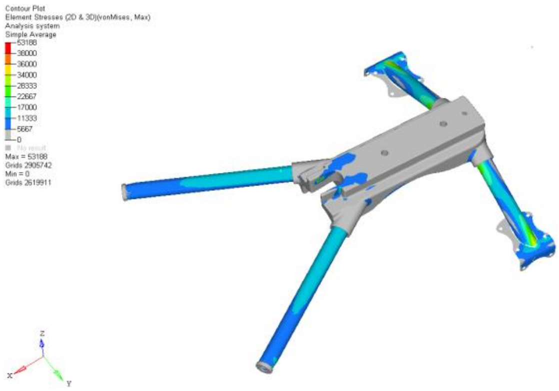


Figure 12: New design Results with AL- 6061 Material Bracket

	Baseline Design	**New Design**	**Percentage stiffness increase for new design**
	Stiffness	Stiffness	
Structural (N/mm)	2040.86	2777.77	26.53%
Torsinal (Nm/Degree)	169.722	218.116	22.18 %
Bending N/mm	6510.5	12825.5	49.3 %

Table 1: comparison of Stiffness

In above description it is clear that new design have better performance than baseline. Table 1 have the comparison details of various stiffness changes. We can see for every comparison the new Design is more stiff than baseline Design. And it is very easy to make by casting process only rather than stamping , bending and all previous processes. Finally new design checked for the shock load case because it is a worst load case for chassis. If component is safe for this load case it will be safe in all other load cases also.

Fig10, showing the result for the shock load on stamping brackets. As the contours representing no region is crossing the yield limit of 448 Mpa (65000 psi) . And Fig 5.8 is showing the result for shock load on Casting bracket and the contours represent that no any location is crossing the yield limit of 172 Mpa (25000 psi). for AL365 and 260 Mpa (38000psi) for AL 6061 .Thus this new design is safe for all load cases. As per the simulation results ,the new design is safe for both the material properties . And Al 6061 is more costlier than AL 365 . Thus it is better to choose AL 365 for final production.

V. Conclusion

1). As per results of Time Comparison it is clear that topology optimization based approach is more efficient than Traditional one. Where the time taken in the traditional approach is about 100 days , the new approach requires only 20 days with less efforts.

2) As stiffness comparison it is clear that our new design is better than baseline design. According to table 1 new design having more structural , torsinal , and bending stiffness than stiffnesses of old design. The total gain is 26.53 % , 22.18 % , 49.3 respectively.

3) This study also emphasizes on the reduction of the product design time. The total time saving of 80 days is big time saving for any design cycle approach.

4) With the final simulation done in context to the design and development of casting bracket, a development method has been stabilized for mechanical components. Such type of Design concept can be applicable for any of mechanical component , it may be from automobile sector , Medical equipment sector, Railway components, House hold product sector or many others.

5). This study forms the basis for company’s new design standards and practices, in terms of product planning and development.

6). The approach incorporated for the said study will gain significant momentum, in terms of product planning and development and can benefit the manufacturing set-up as a whole, making the company to move towards its ultimate goal leading to sustainability and profitability.

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