Finite Element Analysis Interrogation for the Design of Feedback Bracket of an Agricultural Tractor

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Introduction

The main objective of any manufacturing organization is to produce high quality products at the lowest possible cost. Many industries are adopting a concurrent engineering (CE) approach to develop and produce new products in the most efficient manner (Reiter, 2003; Rouibah et al., 2003). Computer Aided Process Planning (CAPP) systems can help to reduce planning time and increase consistency and efficiency (Nagaraj et al., 2002). However, the main problem of transferring CAD (Computer Aided Design) data to a downstream CAM (Computer Aided Manufacturing) system, in order to develop Computer Integrated Manufacturing (CIM) environment, is the lack of neutral formats as well as content to convey the CAD information (Ahmad et al., 2001; Natekar, et al., 2004). Here in this paper, feedback bracket is a newly design part of an indigenous tractor.

A feedback bracket is a typical part generally attached to a tractor three point linkage assembly. The three point linkage is used to attach ploughs and other implements to an agricultural tractor. The three points resemble a triangle at the rear of the tractor. It is an industry standard and all tractor manufacturer’s implements utilize it wherever required (TRACTORCO, 2013).

The three-point hitch (British English: three-point linkage) most often refers to the way ploughs and other implements are attached to an agricultural tractor. The three points resemble either a triangle, or the letter A. Three point attachments is the simplest and the only statically determinate way of joining two bodies in engineering. A three point hitch attaches the implement to the tractor so that the orientation of the implement is fixed with respect to the tractor and the arm position of the hitch. The tractor carries some or all of the weight of the implement. The other main mechanism for attaching a load is through a drawbar, a single point, pivoting attachment where the implement or trailer is not in a fixed position with respect to the tractor. Where an implement such as a plough exerts a drag force, the linkage may use this to increase the downward force on the rear wheels, and thus the traction available (WIKI, 2013). A typical tractor three point linkage has shown in Fig.1.
The 3-point linkage comprises these main parts:

- **Draft links** - the lower links to which the implement is attached. These are the links through which the tractor pulls the implement.
- **Lift links** - links that raise or lower the draft links.
- **Lift arms** - connect the lift links to the rock shaft.
- **Rockshaft** - raises or lowers the lift links.
- **Top link** - is the third connection point for the 3-point link and resists the roll-over force of the implement (FARMERS 2013).

As the part i.e. feedback bracket when comprised with the three point linkage it becomes an important assembly of any tractor. This bracket serves the dual purpose like taking all the jerks/force coming from implements and at the same time exerts pressure to the control valve assembly of the tractor. Thus it becomes one of the most critical parts. This paper presents the design of the bracket based on the analysis using Finite Analysis.

**CAD/CAM Integration**

The integration of Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) has received significant attention in the recent years according to the development of faster computing power tools. However, the actual integration between CAD and CAM, for the downstream applications such as process planning, can be achieved only when the manufacturing information can be obtained directly from 3D solid model and hence automate the process planning functions (Chang et al. 2002; Mansour, 2002; Miao et al., 2002). This automatic extraction of manufacturing information from CAD
systems play an important role to facilitate the concurrent engineering concept in order to achieve the link between the design and manufacturing activities. This successful link can be considered as fundamental step to automate the product development from the design stage all the way to manufacturing and shipping stages. Hence, the total life cycle of the product can be reduced dramatically (Bhandarkar et al., 2000; Marri et al., 2003; Meeran et al., 2003; Stage et al., 1999).

**Computer Integrated manufacturing**

One of the foundation tasks in a Computer Integrated Manufacturing (CIM) environment is to extract and identify the information in the CAD model file (Groover, 2001; Han et al., 1999; Roucoules et al., 2003). The conventional approach to feature extraction is accomplished by the human planner examining the part and recognizing the features designed into the part. Automated feature recognition can best be facilitated by CAD systems capable of generating the product geometry based on features, thereby making it possible to capture information about tolerance, surface finish, etc. (Fu et al., 2003). However, such CAD systems are not yet mature and their wide usage in different application domains remains to be seen. CAD files contain detailed geometric information of a part, which are not suitable for using in the downstream applications such as process planning. Different CAD or geometric modeling packages store the information related to the design in their own databases (Tseng et al., 1998). Structures of these databases are different from each other.

**Model Creation & Size Identification**

In the present study, 3D model of the feedback bracket was developed using Autodesk Inventor R11 software as shown in Fig.3. This 3D model was developed keeping in mind that the model should be used for analysis purpose so that it should withstand the static load as well as the dynamic load of the system. Initially the conceptual design was made using Auto CAD software. After the conceptual design, the detail design and manufacturing drawing was made. Using high capacity 3D software, 3D CAD model was generated for getting the proper visualization of the product. After making the model the same was checked virtually for fitment checking in the assembly.

Dimensional size identification for manufacturing the parts were done after completing the 3D CAD Model. The traditional method for calculating working dimensions was used where it was started from 3D Model whose design dimensions was known and calculates the working dimensions directly from these dimensions by adding and/or subtracting known dimensions from each other and then adding or subtracting the stock removal allowance as appropriate. The calculation was deterministic. It is much easier and more efficient to break the working dimension calculation into two parts:

First, calculate the position of each manufactured surface with reference to a fixed point, which is arbitrarily chosen as the position of the lefthand side of the finished part.

Then, calculate the working dimensions by taking the absolute differences between the positions of the surfaces defining the dimensions.

![Figure 3. Model (3D) of the Part](image-url)
Model Analysis

This model was analyzed using the finite element analysis software, ANSYS 14 Workbench to find out the maximum and minimum stresses, deformation etc. The model used for mesh has shown in Fig. 4. The following are the details associated with the analysis of the model:

Material Properties: Material properties are as follows:
Material : Structural Steel
Mass: 1.35kg
Density: 7850 kg/m$^3$
Volume: 1.7257e-004 m$^3$
Young’s Modulus: 2e+011 Pa
Poissons ratio: 0.3
Yield strength: 2.5e+008 Pa
Bulk Modulus Pa 1.6667e+011
Shear Modulus Pa 7.6923e+010

Meshing of Shackle

For Meshing of model SOLID 185 element is used. The characteristics of meshing is as follows:

Element type :Solid 185
Method of Mesh control: Hex Dominant
Size:13 mm

Statistics
No. of Nodes:10036
No. of Elements:2788

Boundary Condition

Feedback bracket is used mainly with the three point linkage assembly of an agricultural tractor. This assembly is again directly linked with the hydraulic sensor which actuates through with the hydraulic system and thereby lifting/lowering the implement attached at the rear of the tractor. But most of the time the part is subjected to compressive force only. Here the nature of loading is compressive which acts on the two faces and on the distance piece in between the two faces of the part. So the faces selected for the application of force during the model analysis.
Proof Load was taken 200 N in each face. Von mises stress and maximum deformation gets as shown in Table 1. Fixed support: Inner shaft i.e the distance piece

**Results and Discussion**

Analysis of was carried out of the bracket after application of load as stated in the previous paragraph. Due to contact of parts unavoidable stress concentration is formed hence probe values of stress as Max. Equivalent Stress (Von Mises Stress) is taken. Figure 5 & 6 shows the FEA analysis results for deformation and Von-Mises stress. Max. Eq. Stress from result: 2.9775e06 Pa or 297.75 MPa

<table>
<thead>
<tr>
<th>Proof load, N</th>
<th>Von mises Stress (MPa)</th>
<th>Max. Deformation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>297.75 MPa</td>
<td>5.4029e-06</td>
</tr>
</tbody>
</table>

The ultimate tensile strength is 4.6e08 Pa or 460 Mpa which is much higher than the von mises stress. Again Yield strength of shackle is 2.5e08Pa or 250 Mpa. Hence the design is safe.
Based on the analysis result, the design was finalized and the part was manufactured. This has shown in Fig. 7. The same was tested under actual field conditions as well as in the laboratory as shown in Fig 8. The applied load was approx. 200 N in each face of the bracket. Hence the proof load was selected as 200 N.

The effect of angle of proof load also important as far as the design is considered. In this case, the acting load usually works at an angle starting from 15deg to max of 45 degree. Hence load applied accordingly with the stated boundary condition. Values of Von mises stress and maximum deformation in each angle and load achieved has been presented in Table 2. The effect of load Vs. Von-Mises Stress and effect of load Vs. deformations has shown in Fig. 9 & 10 respectively.

<table>
<thead>
<tr>
<th>Angle, deg.</th>
<th>Load, kN</th>
<th>Von Mises Stress, Mpa</th>
<th>Max. Defor.mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>200</td>
<td>155.97</td>
<td>1.7157</td>
</tr>
<tr>
<td>20</td>
<td>250</td>
<td>190.36</td>
<td>1.6370</td>
</tr>
<tr>
<td>30</td>
<td>300</td>
<td>223.75</td>
<td>1.5091</td>
</tr>
<tr>
<td>40</td>
<td>350</td>
<td>260.45</td>
<td>1.3344</td>
</tr>
<tr>
<td>45</td>
<td>400</td>
<td>297.75</td>
<td>1.2310</td>
</tr>
</tbody>
</table>

Figure 7. Manufactured part

Figure 8. Developed Part in Assembled condition in a real system for testing

Figure 9. The effect of Angle Vs. Von-Mises Stress
Conclusions
The 3D model helps a lot to the operator for easy understanding of the geometry which reduces the product development time and thus this is suitable for the most creative levels of design work at the highest levels of product design. This analysis was important to check the breakage/damage of the part during static and as well as dynamic condition. The maximum and minimum values of the stresses are 297.759 MPa and 2025 Pa respectively. The ultimate tensile strength is 4.6e08 Pa or 460 Mpa which is much higher than the von mises stress. Again Yield strength of shackle is 2.5e08Pa or 250 Mpa. Hence the design is safe. The proof load also checked with the actual test of the part and from the results it reveals that the design was safe as far as the application of the part is concerned.

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References