Improving Rockshaft’s Strength with Low Cost Using Reverse Engineering: A Case Study

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Abstract
Reverse engineering of mechanical parts requires extraction of information about an instance of a particular part sufficient to replicate the part using appropriate manufacturing techniques. This is important in a wide variety of situations, since functional CAD models are often unavailable or unusable for parts which must be duplicated or modified. Computer vision techniques applied to 3-D data acquired using non-contact, three-dimensional position digitizers have the potential for significantly aiding the process. Serious challenges must be overcome, however, if sufficient accuracy is to be obtained and if models produced from sensed data are truly useful for manufacturing operations. In the present paper the reverse engineering was used to modify the part of tractor in order to improve the strength of part with less cost. Strength of the part was improved by change in design and material, where as the cost was reduced by change in machining process and less cost of changed material.

Keywords
Reverse Engineering, RE, Rockshaft, CMM, Laser Scanners

I. Introduction
Reverse Engineering (RE) is the process of obtaining a geometric CAD model from measurements acquired by scanning an existing physical model. RE includes all the activities, to determine how a product works, or to learn the ideas and technology that were originally used to develop the product. Reverse engineering is a systematic approach for analyzing the design of existing devices or systems. To be more precise, reverse engineering is the process of discovering the technological principles of a device, object or system through analysis of its structure, function and operation [1].

As computer-aided design has become more popular, reverse engineering has become a viable method to create a 3D virtual model of an existing physical part for use in 3D CAD, CAM, CAE and other software. The reverse-engineering process involves measuring an object and then reconstructing it as a 3D model. The physical object can be measured using 3D scanning technologies like CMM, laser scanners, structured light digitizers [7]. The measurements are in the form of 3D point clouds that correspond to points on the surface of the object being re-engineered [5,6]. Using CAD models to represent the scanned object is very important in various industries because they help improve the quality and efficiency of design. In addition, they speed up the manufacturing and analysis process [4-3].

Reverse engineering is widely used for various reasons. First of all, by reverse engineering a part, the CAD model of a part that is no longer manufactured by its manufacturer or for which only traditional blueprints exist can be obtained. Also, there are cases where the original CAD model no longer corresponds to the physical part that was manufactured because of subsequent undocumented modifications that were made after the initial design stage [2]. Furthermore, stylists and artists very often create physical models of their concepts by using clay, plaster or wood. These real-scale models should then be used to create CAD models for manufacturing the objects on an industrial scale.

II. Case Study

The object we reversed in this case study is rockshaft of tractors, without any drawing prints. A rockshaft is by definition is a shaft that does not rotate completely around, but in a partial arc. The rockshaft is the lift shaft of the power-lift. It rocks about a half-turn and that moves an attached bell crank to lift the cultivators or an attached three-point hitch. Later models used a front mounted rockshaft actuated by a hydraulic cylinder to lift front mounted equipment. It was even available on some of the early new generation tractors as an option. Rock shaft arm is used to operate the cultivator and harrow. The rock shaft arm moves up and down which in term provides motion the agriculture equipments. By providing this motion to the cultivator, the soil is plucked for the agriculture purpose.

The material of the rockshaft was C43, which is a medium carbon steel with good strength and hardness. Using CMM and CAD software 3D model of existing part was generated.

Fig. 1: 3D Model of Original Rockshaft

The problems with the existing design were the failure of the spherical joint and also in case of jamming the ball forming the spherical joint cannot be pulled out of the arm. Even the material which is used for this component is costly and has less strength. In order to find out the effect of the applied load, different types of analysis were performed on rockshaft at a load of 22000 Kg for 0.49 sec.

A. Static Analysis
In this analysis the following observations were made
Mass: 1.58 kg
Volume: 2.017 x 10-4 m3
Density: 7850 kg/m3
Weight: 15.52 N

B. Stress Analysis

Fig. 2
C. Strain Analysis

Fig. 3:

D. Displacement Analysis

Fig. 4:

III. Material Selection for Modification

To reduce the cost of part, the material of the component was changed. For the current case study four materials from the carbon steels were chosen for comparison. They were C15, C35, C55, C60 along with C43 and the various properties of these materials were compared along with the cost as per the details given in Table 1.

Table 1. Comparison of the materials

<table>
<thead>
<tr>
<th>Properties</th>
<th>C43</th>
<th>C15</th>
<th>C35</th>
<th>C55</th>
<th>C60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Content (%age)</td>
<td>0.43</td>
<td>0.15</td>
<td>0.35</td>
<td>0.55</td>
<td>0.6</td>
</tr>
<tr>
<td>Tensile Strength (MN/m²)</td>
<td>600-800</td>
<td>500-600</td>
<td>550-650</td>
<td>700-850</td>
<td>750-900</td>
</tr>
<tr>
<td>Yield Strength (MN/m²)</td>
<td>340</td>
<td>300</td>
<td>430</td>
<td>450</td>
<td>490</td>
</tr>
<tr>
<td>Young’s Modulus (G/N/m²)</td>
<td>210</td>
<td>210</td>
<td>210</td>
<td>210</td>
<td>210</td>
</tr>
<tr>
<td>Density (Kg/m³)</td>
<td>7850</td>
<td>7850</td>
<td>7860</td>
<td>7830</td>
<td>7830</td>
</tr>
<tr>
<td>Thermal Expansion Coef. (K)</td>
<td>11.7</td>
<td>11.6</td>
<td>11.7</td>
<td>11.5</td>
<td>11.5</td>
</tr>
<tr>
<td>Thermal conductivity (W/MK)</td>
<td>46</td>
<td>58.6</td>
<td>52.6</td>
<td>46.6</td>
<td>46.6</td>
</tr>
<tr>
<td>Specific Heat (J)</td>
<td>500</td>
<td>460</td>
<td>460</td>
<td>500</td>
<td>460</td>
</tr>
<tr>
<td>Machinability</td>
<td>Good</td>
<td>Fairly Good</td>
<td>Good</td>
<td>Good</td>
<td>Poor</td>
</tr>
<tr>
<td>Cost per Kg (Rs.)</td>
<td>54</td>
<td>27</td>
<td>49</td>
<td>26</td>
<td>55</td>
</tr>
</tbody>
</table>

The tensile strength and yield strength of C60 material is maximum but the machinability is poor and is costly as compare to other material considered. Hence C60 not considered as material for change. Machinability and tensile strength of C15 are not good, so rejected for change. 

The machinability of C35 and C55 materials is good, but the strength of C35 is less than the original material, so not considered for the change. The material C55 have higher tensile and yield strengths, less density and less cost as compare to C43. Due to these properties of C55 material, it is considered as the new material for the use.

IV. Modified Part

As design modification we changed the ball end with a U-shaped end. This causes the division of loads in two sections of the U-shape of the arm which increases the strength and load bearing capacity of the arm. Due to this type of shape the reduction in stress concentration takes place in the part.

The basic disadvantage of the previous component is that the jamming of spherical joint takes place due to dust particle which restrict the motion of the joint is eliminated with the modified design. The machining cost of the spherical joint is much high as compared to this joint because more machining processes are used.

In this joint the spherical ball is replaced by the cross pin. Cross pin is used to give the dynamic movement to the joint. The same types of analysis were performed on modified part with same loading and time.

Fig. 5: 3D model of Modified Rockshaft

A. Static Analysis

In this analysis the following observations were made

- Mass: 1.61 kg
- Volume: 3.203 x 10^-4 m³
- Density: 7830 kg/m³
- Weight: 12.73 N

B. Stress Analysis

Fig. 6:

C. Strain Analysis

Fig. 7:
D. Displacement Analysis

Fig. 8:

This modified component has higher strength and has reduced weight due to the removal of the material from the central arm as compared to the original. The changes in the design lead to improvement in strength due to change of ball end with the U-Shaped end.

V. Conclusion

Form this study, the following conclusions were made:

- Change of ball end with a U-Shaped end cause the load to be divided in the two limbs of the U-Shaped end and reduces the occurrence of failure.
- The load-bearing capacity of the rockshaft arm is increased by providing U-Shaped joint.
- The weight of the component is less due to removal of central element and material.
- Strength increases due to change in material from C43 to C55.
- Elimination of spherical joint removes the jamming effect.
- The cost of the part is reduced by 51.85% due to change in machining process and reduced material cost.

References