Cost Reduction of Arm Cross Bar of Wheel Loader through Value Engineering

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Abstract: This paper presents a methodology that can be used for cost reduction of any product using the fundamental principles of Value Engineering. The paper specifically focuses on assembly called Arm Cross Bar (ACB) which is a sub-assembly of earth moving equipment called Wheel Loader. Wheel loader is a heavy equipment often used in construction and mining application, primarily used to transfer material from stockpiles to trucks, or transport material around job sites. Using value analysis tools, ACB was analysed and design alternatives were identified, that can reduce the weight as well as cost of the assembly without compromising the functional parameters. This will help the company to offer the product at a very competitive price [i, ii]. This will enhance customer delight, increase in sales of product and very importantly reduce the carbon foot print.

Keywords: Value Analysis (VA) / Value Engineering (VE), Wheel Loader (WL), Arm Cross Bar (ACB), Function Analysis System Technique (FAST)

I. INTRODUCTION

The wheel loader, also known as a front end loader or bucket loader, is one of the most widely used machines in mining and construction today and is noted for its extreme versatility and payload capacity to perform multiple tasks at a low cost. Wheel Loader is self-propelled heavy equipment used mainly for material handling, digging, load-and-carry, road building, and site preparation. The major structural components of the wheel loader are shown in the Fig.1(a). It consists of bucket, Z-bar linkage, front chassis, rear chassis and cabin.

A Z-bar linkage shown in Fig.1(b), which is used for manoeuvring an implement such as a bucket or pallet forks, consists of an ACB pivotally connected between front chassis of the machine and the implement, a link pivotally connected between the implement and a crank which is pivotally connected between the link and the ACB. Two lift cylinders rotate the ACB to raise and lower the implement, and a tilt cylinder drives the crank and link to rotate the implement between a dump position and a racked position.

In modern day market, cost effectiveness has become a major challenge for all organizations. Using a systematic approach to perform cost reduction not only yields cost improvement but also provides decision-makers with the trade-offs involved in achieving these reductions. Cost reduction on ACB would certainly achieve a high level of value and proportion, which will create a substantial decrease in the direct material cost of the product. With this cost reduction, the company can offer the product at a very competitive price than competitors. In this paper, VE based systematic approach is used to reduce the weight as well as cost of the ACB without compromising the functional parameters.

II. METHODOLOGY

VE is the systematic application of recognized techniques by multi-disciplined teams that identifies the function of a product or service, establishes a worth for that function, generates alternatives through the use of creative thinking, and provides the needed functions and reliably at the lowest overall cost [iii].The below Fig. 2 shows the flow of a standard VE job plan.
III. ORIENTATION PHASE

In this phase, the concurrence from the senior management was obtained. The scope and objectives for the value study were developed. The VE team was formed and the roles and responsibilities were defined. The appropriate information about the project were gathered and distributed to the team for their study and review.

IV. INFORMATION PHASE

In this phase, VE team obtained project data and key documents such as scope of work definition, drawings, specifications, reports, detailed project cost information, quality data, marketing information, process flow charts, etc. Also the information about the project was distributed for team member’s review. VE team visited fields to understand the machine functions and captured customer feedback. High-level project functions were also identified.

V. FUNCTIONAL ANALYSIS PHASE

A functional analysis was carried out to develop an intimate knowledge of the product and its systems [iv]. For this purpose, each function of the product was represented in the form of an active verb and a measurable/countable noun. Representation of functions in this form makes them more vivid and lays a path towards the creation of Function Analysis System Technique (FAST) diagram. FAST diagram provides important information about interrelationships and connections between the functions. The functions are classified into basic (B) and secondary (S). Fig.3 shows ACB assembly.

The main functions of the ACB parts are given in the Table1.

Table 1 Functional Feature Matrix for ACB

<table>
<thead>
<tr>
<th>Sub-Assembly</th>
<th>Parts</th>
<th>Number</th>
<th>Features</th>
<th>Existing Cost (%)</th>
<th>Value Gap</th>
<th>Value Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arm Assembly</td>
<td>Arm Plate - LH</td>
<td>1</td>
<td>Thickness</td>
<td>Provide Strength</td>
<td>62.41</td>
<td>1.37</td>
</tr>
<tr>
<td></td>
<td>Arm Plate - RH</td>
<td>1</td>
<td>Profile</td>
<td>Accommodate Structures</td>
<td>14.94</td>
<td>1.37</td>
</tr>
<tr>
<td></td>
<td>Boss</td>
<td>12</td>
<td>Section</td>
<td>Withstand Load</td>
<td>4.12</td>
<td>1.13</td>
</tr>
<tr>
<td></td>
<td>Tube</td>
<td>1</td>
<td>Section</td>
<td>Withstand Load</td>
<td>8.00</td>
<td>1.13</td>
</tr>
<tr>
<td></td>
<td>Plate</td>
<td>2</td>
<td>Thickness</td>
<td>Provide Strength</td>
<td>5.87</td>
<td>1.13</td>
</tr>
<tr>
<td>Cross Bar Assembly</td>
<td>Stopper Pad</td>
<td>1</td>
<td>Section</td>
<td>Withstand Load</td>
<td>1.05</td>
<td>1.13</td>
</tr>
<tr>
<td></td>
<td>Gasket</td>
<td>2</td>
<td>Thickness</td>
<td>Provide Strength</td>
<td>0.34</td>
<td>1.13</td>
</tr>
<tr>
<td></td>
<td>Rib</td>
<td>1</td>
<td>Thickness</td>
<td>Provide Strength</td>
<td>0.34</td>
<td>1.13</td>
</tr>
<tr>
<td></td>
<td>Boss</td>
<td>2</td>
<td>Section</td>
<td>Withstand Load</td>
<td>0.34</td>
<td>1.13</td>
</tr>
</tbody>
</table>

VI. CREATIVE PHASE

In this phase, a creative Brainstorming [iv] exercise was conducted and ideas were generated for the cost reduction of ACB. The non-feasible ideas among the list of ideas generated are eliminated by Feasibility Ranking Technique. The ideas were transformed into the CAD model for evaluation of the concept.

VII. EVALUATION PHASE

All the concepts were evaluated against a custom selected set of the following weighted parameters. These parameters were finalized based on the objectives of cost reduction and compactness.

A. Ease of manufacturing
B. Durability
C. Force flow
D. Weight of components
E. Variety of components
Next step was to allocate weightage to the parameters using a paired comparison technique. In this technique, each parameter is compared with every other parameter and a weightage is allocated with respect to their relative importance \[ v \]. The weightage matrix is given in Table 3.

The weighted parameters were then used to evaluate the generated concepts to arrive at the best concept. New concept is rated against each selected parameter, and score was allocated. A score of 1 is allocated for poor conformity with that parameter and score of 5 is allocated for the best conformity. The decision matrix thus created is given in the Table 4. The decision matrix indicates that the new concept is better than the existing one.

### Table 3 Parameter weightage matrix

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>Weightage</th>
<th>Modified</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A1</td>
<td>C1</td>
<td>D2</td>
<td>A2</td>
<td>A2</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>B</td>
<td>B1</td>
<td>B1</td>
<td>B2</td>
<td>B3</td>
<td>7</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>D1</td>
<td>C2</td>
<td>C3</td>
<td>6</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>D2</td>
<td>D3</td>
<td>8</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>E1</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>6</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

0 No difference in importance.
1 Minor difference in importance.
2 Medium difference in importance.
3 Major difference in importance.

### Table 4 Decision matrix

<table>
<thead>
<tr>
<th>Parameters</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>Total</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing</td>
<td>4</td>
<td>8</td>
<td>7</td>
<td>9</td>
<td>2</td>
<td>1</td>
<td>106</td>
<td>2</td>
</tr>
<tr>
<td>New Concept</td>
<td>3</td>
<td>18</td>
<td>4</td>
<td>32</td>
<td>3</td>
<td>21</td>
<td>115</td>
<td>1</td>
</tr>
</tbody>
</table>

The below Fig. 5 shows the existing and new concepts of ACB design.

Proposed modifications for ACB compared to the existing design are, Arm plate thickness reduced from 45 mm to 36 mm. Fabricated box structure is proposed instead of seamless tube. Arm plate profile has been modified for smooth stress flow. Reinforcement plates and ribs are used at high stress areas.

### VIII. DEVELOPMENT PHASE

In this phase, the strength of the new concept is verified using Finite Element Analysis (FEA) and software used is Ansys13.0.

The results of the FEA here are considered as more reliable since a strong correlation exists between the existing prototype machine testing results and FEA results. Hence FEA can be used as a reliable aid to measure the strength of the structures \[ v \]. The concept is verified against 15 load cases and FEA confirmed that the new concept is better than the existing. Fig. 6(a) & 6(b) shows sample loading and boundary conditions and von Mises stress plot.

Estimated weight reduction is 13% and cost saving is around 12% for a single machine of the proposed model with
respect to the existing one. Estimated annual market potential for wheel loaders in India is 2500 machines. Assuming 10 percentage market share during product induction, yearly savings expected is around 24 lakhs for 250 machines.

IX. CONCLUSION

VE is a powerful tool which can be used to analyse a product systematically, to bring out all possible avenues of value addition. Furthermore, systematic approach professed by VE in the areas of concept generation and concept finalization helped us to create, compare and finalize the concepts in shortest possible time without any argument. The cost estimation projected a significant saving for the new ACB design. The new design is yet to be implemented and institutionalized. Further value addition is possible by extending the study to other sub-assemblies also.

Reference