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DESIGN FOR MANUFACTURING AND ASSEMBLY OF A CONNECTING ROD

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Abstract

The recent developments in design for manufacture and assembly, the need for improving quality and reducing the manufacturing we need a more structured and flexible design approach. This is achieved by using software called DFMA. DFMA software enables us to analyze a product and reduce the number of parts, improve their manufacturability and ease of assembly, reduce product cost and anufacturing time. A Connecting Rod was modeled using the software SOLIDWORKS and then it is imported to DFMA. DFMA analysis was performed and computes all the essential requirements and the most optimal design was chosen.

Introduction

The connecting rod is one of the most important parts in engine that connects the piston to the crank or crankshaft in reciprocating engines. It converts the reciprocating motion of piston to rotary motion. They are most usually made of steel for production engines, but can be made of aluminium or titanium for high performance engines, or of cast iron in regular engines. As both ends are not rigidly fixed (one at piston end and other at crank end), the angle between the connecting rod and the piston can change as the rod reciprocates.

The load produced by the piston induces tremendous stress on the connecting rod, and increases with increasing engine speeds. One of the most common causes of catastrophic engine failure in automobiles is the failure of connecting rod.

The forged steel rod is fabricated by starting with a wrought steel billet. The billet is heated and forged in the material‟s plastic temperature range. Connecting rod cap end and main body can be forged separately and machined or the cap end is fractured, and then it is machined to final tolerance. We are here using the former technique.

Since the final shape of connecting rod cannot be formed in one blow, the forging dies of several impressions are used, each followed by other and moving progressively toward the final shape. The metal billet is transferred from one impression to another between successive blows. The cap part and lower rod part are forged separately, or forged together and sawed in two pieces.

After forging the desired properties of the part is obtained by heat treatment and then straightened. Balancing pads are used on both ends of the rods as additional weight, while forging, to ensure proper weight and balance of the finished rod. These balancing pads are then machined well as it controls the stability of the connecting rod. A certain quantity of metal is removed to get the final dimensions and finish (around 25-30% of the drop forged rough stock cap and rod).

Literature review

The engineer‟s main task is to apply scientific knowledge to the solution of technical problems and then to optimise that solution within the given material, technological and economic constraints. According to Lance N. Green & Elivio Bonollo, the development of new methods for design for manufacture and assembly, the need to incorporate quality during the design phase and the recent focus on transparent design work and communication have all created a need for a more structured approach to design. However the number of design methods and tools available to the designer in the process of design is numerous and for many practicing designers it has become unclear when and how to apply these.

The solutions to these problems are given by DFMA. DFM&A is a powerful tool in the design team‟s repertoire. To give engineers a structured way to evaluate ease assembly and the overall manufacturability of a product DFMA is designed. The DFMA process is composed of two major components: design for assembly (DFA) and design for manufacturing (DFM). Design for assembly requires the user to check whether each is necessary, and to consider the time and cost of assembling the product. Design for manufacture breaks the parts fabrication process down into its simplest steps, such as the type of equipment used to produce, the part and fabrication cycle times to produce the part, and calculates a cost for each functional step in the process. It integrates information about manufacturing processes allowing users to estimate manufacturing costs and make informed decisions about materials.

DFMA versus Traditional Design

In the past, design and manufacture tasks have been performed independently. In this scenario, the designer designs a product and „„„casts it over the wall‟‟‟ to the manufacturer to produce. Due to the lack interaction between the designer and manufacturer and often what results is a design that is difficult to produce using automation. Traditionally a productive process has some basic steps. First, the identification of customer needs and desires as an input, last an output represented by product or service to match as most as possible the needing expressed in the input and between them a productive transformation process fed by information, materials and machinery and a possible market demand as shown in fig.

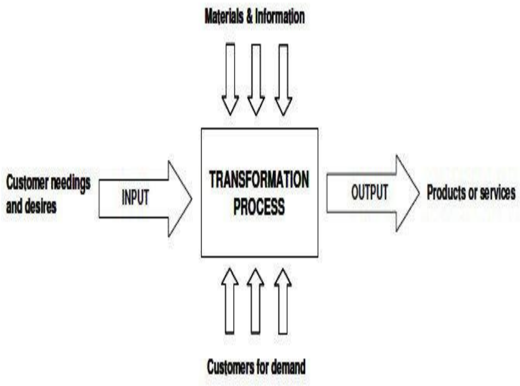

Fig: Model of a generic process or productive system

However, this kind of simple interpretation do not consider the information flows from the process to the input and output – information which can show some limitations or can express the necessity of change or improvement. Also, most of the known players do stepped investments and some products are just upgrades of their predecessors, not completely new developments. Finally, it is necessary to maintain an assembly line, method and machinery to ensure spare parts to the working population of products. Those apparent undesirable conditions may present a very good opportunity to rethink the development process along with the experience obtained from previous projects and the knowledge of where are the weakest points can reveal a path to start a DFMA.

Organizations learn in order to improve their adaptability and efficiency during times of change. This idea can effort the use of the experience of previously done mistakes to speed

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up the development process and also accomplish new technologies and philosophies to ensure that activities which now must be faster and give more precise results can really reach this target. In this way, DFMA offers a substantial advantage that they permit to run activities simultaneously in a parallel form, in opposition of the tasks sequencing.

DFMA Process

DFMA process requires the following steps:

1. Analyze the overall product or assembly for the number of parts, functionality of each part, ease or speed of part production, and ease or speed of assembly.

2. Redesign at the product or assembly levels i.e. simplify the overall design, minimize the number of parts and ensure overall ease of assembly (sequence, interference). The designer checks the assembly, part by part, and evaluates whether each can be eliminated, combined with another part, or the function can be performed in another way. To determine the theoretical minimum number of parts, the designer can consider whether the part moves relative to other parts, if it must be made of a different material, or if disassembly is necessary.

3. Redesign at the component level i.e. standardize components, simplify component designs, select materials and shapes which are straightforward to manufacture and ensure component ease of assembly (compliance, adjustments). Common parts result in lower inventories, reduced costs and higher quality. Operator learning is simplified and there is a greater opportunity for automation as the result of higher production volumes and operation standardization. Unnecessary part features should be avoided because they involve extra processing effort and/or more complex tooling.

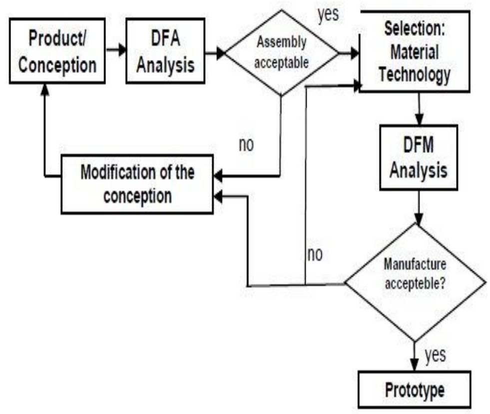

Fig: the DFMA Process Flowchart

Objective

Major changes in product design practices are occurring in all phases of the new product development process. These changes have a significant impact on how all products are designed and the development of the related manufacturing processes. The high rate of technology changes has created a dynamic situation that has lead to great competitiveness in reducing the number of parts and the manufacturing cost of the product. The objectives of this project are:

1. to model & design a connecting rod for manufacturing and assembly using the software‟s: SOLIDWORKS, SOLIDVIEW & DFMA.

2. To calculate the cost of manufacturing and assembly and

3. To give the suggestions for redesign.

DFM Concurrent Costing

DFM Concurrent Costing contains process and material information and calculations for quickly estimating the cost of manufacturing and finishing a part. It is designed to isolate the principal cost components, to allow us to verify design changes to reduce costs and to compare alternative processes and materials for the part.

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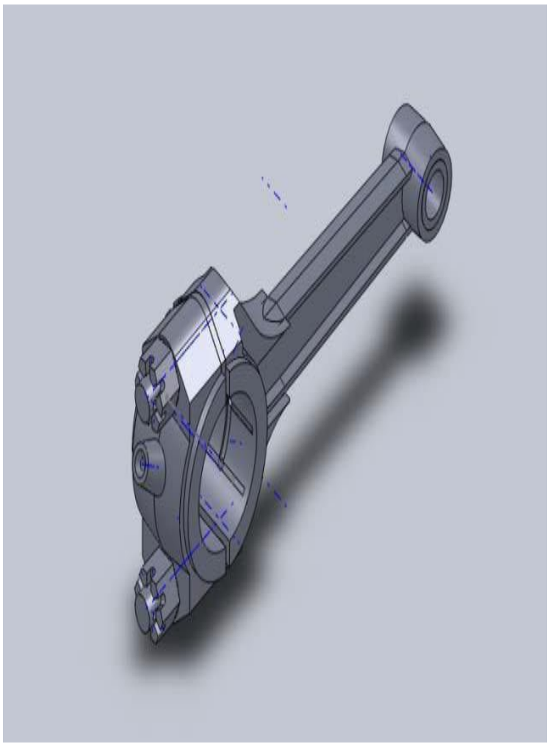
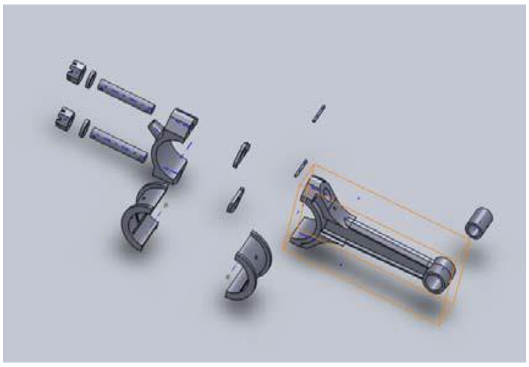
DFA

In DFA we can develop product assembly times from reliable, proprietary time standards. Along with detailed cost information based on assembly time, we can include item cost data. Redesign features in the software encourage systematic design review, leading to reductions in overall product cost.

DFMA Analysis of connecting rod



The assembly of the connecting rod:



Exploded view

DFM of parts

After the CAD models of all the parts were made, they were imported into the Concurrent Costing module by use of SolidView software. The DFM analysis* was performed on the parts by taking into consideration their most optimal & economic processes. The following results have been obtained:-

Results for main body:

Part Name: bodyconnect — Process: Forging, hot
Part Number: — Material: Generic high carbon steel

Life volume	Batch size	Cost per part, RS							Initial tooling investment
		Material	Setup	Process	Rejects	Piece part	Tooling	Total	
100000	1000	18.18	29.41	104.72	1.21	153.53	53.99	207.52	3,338,761

Results for small end bearing

Part Name: part2 — Process: Machined/cut from stock
Part Number: — Material: Generic high carbon steel

Life volume	Batch size	Cost per part, RS							Initial tooling investment
		Material	Setup	Process	Rejects	Piece part	Tooling	Total	
100000	12500	5.22	0.02	1.52	0.00	6.75	0.00	6.75	0

Results for big pin

Part Name: pin3 — Process: Machined/cut from stock
Part Number: — Material: Generic medium carbon steel

Life volume	Batch size	Cost per part, RS							Initial tooling investment
		Material	Setup	Process	Rejects	Piece part	Tooling	Total	
100000	12500	6.63	0.09	2.97	0.00	9.69	0.00	9.69	0

Results for small pin

Part Name: part4pin
Part Number:

Process: Machined/cut from stock
Material: Generic medium carbon steel

Life volume	Batch size	Cost per part, RS							Initial tooling investment
		Material	Setup	Process	Rejects	Piece part	Tooling	Total	
100000	12500	0.21	0.09	1.84	0.00	2.14	0.00	2.14	0

Results for big end bearing

Part Name: part5
Part Number:

Process: Machined/cut from stock
Material: Generic medium carbon steel

Life volume	Batch size	Cost per part, RS							Initial tooling investment
		Material	Setup	Process	Rejects	Piece part	Tooling	Total	
100000	12500	37.45	0.02	2.39	0.00	39.86	0.00	39.86	0

Results for washer

Part Name: washer6
Part Number:

Process: Machined/cut from stock
Material: Generic medium carbon steel

Life volume	Batch size	Cost per part, RS							Initial tooling investment
		Material	Setup	Process	Rejects	Piece part	Tooling	Total	
100000	12500	2.21	0.02	1.93	0.00	4.15	0.00	4.15	0

Results for cap

Part Name: cap
Part Number:

Process: Forging, hot
Material: Generic medium carbon steel

Life volume	Batch size	Cost per part, RS							Initial tooling investment
		Material	Setup	Process	Rejects	Piece part	Tooling	Total	
100000	1000	11.30	28.67	79.19	0.89	120.06	16.53	136.58	803,755

Results for washer

Part Name: part8washer
Part Number:

Process: Machined/cut from stock
Material: Generic medium carbon steel

Life volume	Batch size	Cost per part, RS							Initial tooling investment
		Material	Setup	Process	Rejects	Piece part	Tooling	Total	
100000	12500	0.56	0.09	1.92	0.00	2.57	0.00	2.57	0

Results for nut

Part Name: part9nut
Part Number:

Process: Forging, hot
Material: Generic medium carbon steel

Life volume	Batch size	Cost per part, RS							Initial tooling investment
		Material	Setup	Process	Rejects	Piece part	Tooling	Total	
100000	12500	1.57	0.94	10.45	0.11	13.07	22.54	35.61	1,376,826

Results for pin

Part Name: part10pin
Part Number:

Process: Machined/cut from stock
Material: Generic medium carbon steel

Life volume	Batch size	Cost per part, RS							Initial tooling investment
		Material	Setup	Process	Rejects	Piece part	Tooling	Total	
100000	12500	0.21	0.09	1.84	0.00	2.14	0.00	2.14	0

DFA of parts

After the DFM has been performed, the results are imported in the DFA module* and assembly is done. The directions for fixing the parts are given and the time taken for assembly is noted. The assembly cost is also calculated and any other standard procedures like painting, greasing, visual inspection are mentioned. As the assembly unit structure changes from company to company, all the parts have been assumed to be within reach. Once the assembly unit structure is known, the time & cost for moving the parts can be added correspondingly. The results obtained from the DFA of the parts are given in table below.

Per product data

	Entries (including repeats)	Number of different parts	Total time, s	Labor cost, RS	Item costs (including tooling), RS	Weight, kg
Parts	10	10	114.30	56.03	447.01	0.76
Subassemblies:						
Partially or fully analyzed	0	0	0.00	0.00	0.00	0.00
Named only	0	0	0.00	0.00	0.00	0.00
Excluded	0	0	0.00	0.00	0.00	0.00
Operations:						
Standard	0	0	0.00	0.00	-	-
Library	0	0	0.00	0.00	-	0.00
Column Totals	**10**	**10**	**114.30**	**56.03**	**447.01**	**0.76**

Cost totals based on a product life volume of **10,000**

	Labor cost, RS	Other operation cost, RS	Manuf. piece part cost, RS	Total cost without tooling, RS	Assy. tool or fixture cost, RS	Manuf. tooling cost, RS	Total cost, RS
Cost per product	56.03	0.00	353.95	409.98	0.00	93.06	**503.04**
Production life cost	560,294	0	3,539,485	4,099,779	0	930,577	**5,030,357**

Final Assembly Cost Analysis

All parts were assembled together to get the final product. The cost of the connecting rod has been calculated by adding the cost of the individual parts.

The cost analysis table is given below:-

No.		Name	Total other operation cost, RS	Total cost, RS	Weight per item, kg	Total weight, kg	Material
1	⊟	Untitled					
2		bodyconnect		209.78	0.38	0.38	Generic high carbon steel
3		part2		15.38	0.02	0.02	Generic high carbon steel
4		pin3		13.32	0.03	0.03	Generic medium carbon steel
5		part4pin		9.20	0.00	0.00	Generic medium carbon steel
6		part5		46.08	0.08	0.08	Generic medium carbon steel
7		washer6		10.38	0.01	0.01	Generic medium carbon steel
8		cap		140.90	0.20	0.20	Generic medium carbon steel
9		part8washer		8.80	0.00	0.00	Generic medium carbon steel
10		part9nut		42.08	0.01	0.01	Generic medium carbon steel
11		part10pin		7.14	0.00	0.00	Generic medium carbon steel
12	△	Totals for Untitled	**0.00**	**503.04**		**0.76**	

The final cost has been found out to be Rs. 503/-.

Redesign suggestions

Add assembly features such as chamfers, lips, leads, etc., to make the following items self-aligning.

Parent assembly	Name	Repeat count	Time savings, s	Percentage reduction
Untitled	pin3	1	1.50	1.31
	part5	1	1.50	1.31
	washer6	1	1.50	1.31
	cap	1	1.50	1.31
	part8washer	1	1.50	1.31
	part9nut	1	1.70	1.49
	part10pin	1	1.50	1.31
Totals			10.70	9.36

Conclusion

Connecting rod is an important part in engine assembly. So a more flexible design that improves quality and reduces the manufacturing is necessary. The DFMA of connecting rod has been done and we have found that the total cost of connecting rod and the total manufacturing time has been considerably reduced. Also the assembly has been done with ease by reducing the number of parts and make them self aligned.

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