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Reduction of Flywheel Housing Failures in Field by Process & Design Optimization

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Abstract

Through this research paper a case study conducted at Swaraj Tractors, Mohali, is presented. This study was on subject of failures of flywheel housing in field. Flywheel housing is a structural component which is used as coupling between Engine & Gear box housing of tractor. The problem was severe because it is fatal to customer & brings bad repute to organization. An analysis was done using Six Sigma technique. Pareto analysis was used to prioritize the problem. The cause and effect diagram was used to explore possible causes of flywheel housing failure through a brainstorming session and to determine the causes which had major effect. Each root cause was validated by DOE. The CAD model of component was made & subjected to FEA. Through FEA results it was concluded that flywheel housing design was not appropriate & factor of safety came out to be 3.8 which was very less. The design of flywheel housing was modified & new CAD model was subjected to FEA. The factor of safety was increased by 40%.The modified design of housing was implemented.

Keywords: Flywheel housing, Six Sigma, Root Cause Analysis, FEA, CAD model, Factor of safety.

Introduction

Flywheel housing is a structural component which encloses the flywheel & act as coupling between engine & gear box. The breakages of flywheel housings of tractor model S-735 were reported from the field. The preliminary study of broken flywheel housings showed that the crack started from lower left mtg. hole & propagated through flywheel housing wall to the right mtg. hole leading to failure of flywheel housing resulting in tractor breakage into two parts. This is very severe problem as it is fatal to customer, warranty loss to company as well as brings bad repute to organization.

Fig. 1 - Crack in Flywheel housing

Methodology

In Case Study, the Six sigma tools were used to investigate the problem. The Six sigma tools are also called seven basic QC tools. These are called the basic quality tools because they are suitable for the people with little formal training in statistics & the can be used for vast variety of quality related issues. The Six Sigma tools include:

- Check sheet
- Pareto chart

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- Flow diagram
- Cause & effect diagram
- Scatter Diagram
- Control chart
- Histogram

Check sheet

Check sheets are tally charts or data collecting sheet. It is a simple data recording device which helps to make decisions based on facts rather than anecdotal evidence [2, 5].The flywheel housing failure data collected from warranty department of last 12 months & placed in tabulated form as check sheet to get the clarity of failures. The data is presented vendor wise, zone wise & month wise.

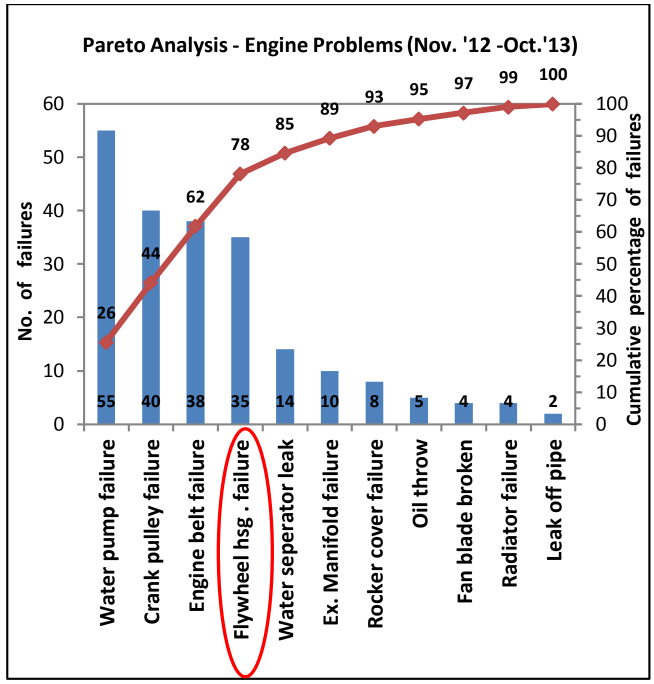
Month	Vendor		Zone				No. of failures
	Kumar	Jadhav	South	North	East	West	
Nov'12	2	1	1	1	0	1	3
Dec'12	1	1	1	1	0	0	2
Jan'13	1	2	1	1	0	1	3
Feb'13	3	0	1	0	1	1	3
Mar'13	2	2	1	2	1	0	4
Apr'13	1	2	0	1	1	1	3
May'13	1	1	1	1	0	0	2
Jun'13	3	0	1	1	0	1	3
July'13	2	2	0	1	1	2	4
Aug'13	1	2	1	0	1	1	3
Sep'13	0	2	0	1	1	0	2
Oct'13	2	1	0	1	1	1	3
Total	19	16	8	11	7	9	35

Table 1 – Check sheet for flywheel housing failures

The data was uniformly distributed & did not give any specific information regarding failures for particular area, vendor, or month.

Pareto diagram

The Pareto diagram is based on 80/20 principle which states that 80% of problems are caused by 20% of factors. It helps in identification of those 20% factors which contribute to 80% of problem & thereby prioritizing them to be solved. Pareto chart helps in separating "vital few" from "trivial many"[2,3]. This basically helps to understand where focus is required in order to have greatest impact. Following is the Pareto analysis made to identify the major defects in organization.



Graph 1 - Pareto Analysis of Engine Problems

Flywheel housing failure was identified as the one of the major four failures in organization. It was imperative to find actual reasons behind the failure. For this purpose cause & effect diagram was used which is also called as Root Cause Analysis (RCA)[3,4].

Cause & effect diagram

Cause & Effect diagram also known as Fishbone or Ishikawa diagram developed by Kaoru Ishikawa. It helps in root cause analysis of a problem by listing all the possible causes using brainstorming. It helps in discovering all the possible causes for a particular problem [8, 9].

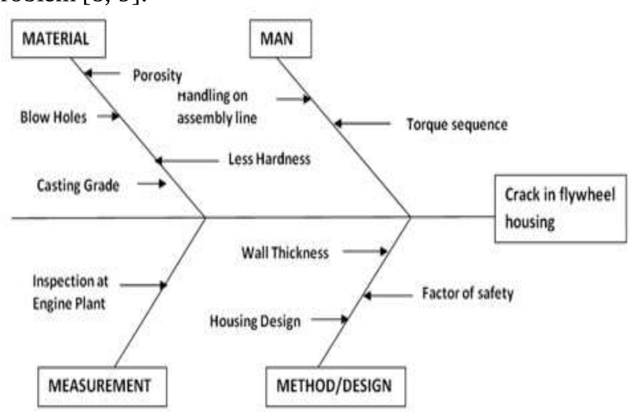


Fig. 2 - Cause & Effect Diagram

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Brainstorming

Identification of final root causes

All the probable root causes were listed down. But all these root causes were not responsible for failure of flywheel housing. So to find final root causes the every probable cause should be validated by taking one by one.[6]

Validation of Probable root causes

Probable cause 01– Grade of casting material

The poor grade casting has low tensile strength which can lead to failure, so the grade of casting was checked.

Method of Testing -5 nos of failed component received in warranty checked for grade of material at material testing lab.

Observation - Material grade was found to be F.G. 260 (same as specified in drawing).

Inference – The cause is invalid.

Probable cause 02– Hardness of casting

Method of Testing - 5 nos of failed component received in warranty checked for hardness at Material Testing Lab.

Observation –Brinell Hardness checked at Material Testing Lab and found within range as specified in drawing (180-230 BHN).

Inference – The cause is invalid.

Probable cause 03– Microstructure of casting

Method of Testing - 5 nos of failed component received in warranty checked for Microstructure analysis at Material Testing Lab.

Observation - Microstructure found ok.

Inference –The cause is invalid

Probable cause 04– Wall thickness

Method of Testing –The inspection of wall thickness of 6 nos. failed castings from warranty was taken & measured their thickness done with pistol calliper.

Observation - It was observed that the wall thickness in the failed components is less than specified in drawing.

	Wall thickness of Housing	
S.No.	Specified (in mm)	Measured (in mm)
1	6 +1	5.5
2	6 +1	6.1
3	6+1	5.7
4	6+1	6.2
5	6+1	5.4
6	6+1	5.7

Table 2 - Wall thickness of casting (ref Q.E. – Swaraj)

Inference –The cause is valid.

Probable cause 05– Factor of safety

Method of Testing - FEA of 3D CAD model of flywheel housing

Observation –To determine factor of safety, the 3D CAD model of existing flywheel housing was made by using NX 11 Software. Then CAD model was subjected to Finite element analysis (FEA) by using NASTRAN software.FEA of CAD model of flywheel housing was done by putting the predetermined load conditions at mounting points .The factor of safety at 2 nos lower mounting holes came out to be 3.9 whereas at 4 nos. upper mounting holes the factor of safety was 4.2 which was inadequate.

S/N	Loadcase	Max. Principle Stress (in Kg/mm^2)	Max. Deflection (in mm)	FOS @ Mounting Points
1	Front Axle Reaction - 790 Kgf	16 @ Four Holes	0.165	4.2
2	Rear Axle Reaction - 1510 Kgf	62.6 @ Two Holes	0.956	3.9
3	Total Vehicle Weight on C.G.	NO RESULTS AS C.G. LOCATION OF TRACTOR IS NOT KNOWN		

Table 3 - Results - FEA of CAD model of existing flywheel housing (ref CAE – Swaraj)

Inference – The cause is valid

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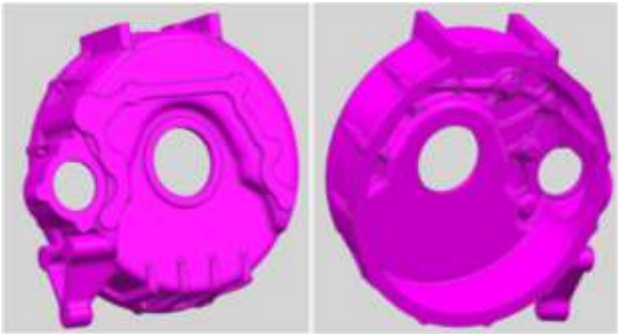

Fig. 3- CAD model of flywheel housing **(ref CAE – Swaraj)**

Probable cause 06– Design of housing
Method of Testing – FEA analysis of 3D CAD model of flywheel housing
Observation – The CAD model of existing flywheel housing was made by using NX Software. Then CAD model was subjected to by using NASTRAN software. The stress comes out to be more at lower mtg. holes. On through inspection it is found that boss thickness at lower mounting holes was less. Also width of ribs at lower portion of flywheel housing for strengthening was less..
Inference – The cause is valid

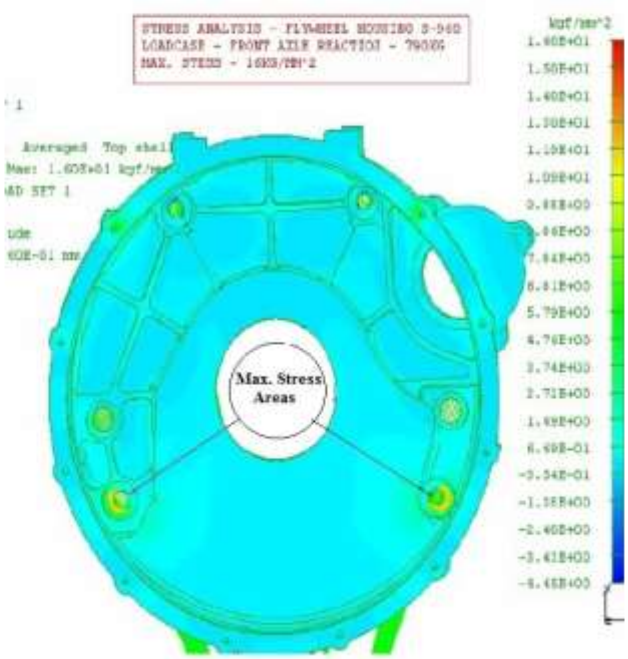

Fig.4 – FEA of existing flywheel housing **((ref CAE – Swaraj)**

The final root causes were identified:

S.No.	Final Root Causes
1	Wall thickness
2	Factor of safety
3	Design of housing

Table 4 – Final Root Causes

Corrective measures
To eliminate each Root Cause
Root Cause 1- Wall thickness
Action - Wall thickness was increased by 02 mm. A new CAD model was developed with increased wall thickness & model was subjected to FEA. The Factor of safety was improved as per result attached.

S/N	Loadcase	Max. Principle Stress (in Kg/mm^2)	Max. Deflection (in mm)	FOS @ Mounting Points
1	Front Axle Reaction - 790 Kgf	12.9 @ Four Holes	0.143	6.2
2	Rear Axle Reaction - 1510 Kgf	32.5 @ Four Holes	0.728	5.2
3	Total Vehicle Weight on C.G.	NO RESULTS AS C.G. LOCATION OF TRACTOR IS NOT KNOWN		

Table 5 -Results - FEA of CAD model of modified flywheel housing with increased wall thickness (ref CAE – Swaraj)

Root Cause 2 & 3 - Factor of safety & design of housing
Action – The design of ribs for strengthening in lower portion of housing was improved by increasing the width of ribs from 5 mm to 10 mm. The design of bosses of lower mounting holes was modified to provide strength by increasing thickness. The fillet radius of step was modified. The CAD model with modifications was again developed & subjected to FEA. Factor of safety improved as per result attached.

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S/N	Loadcase	Max. Principle Stress (in Kg/mm^2)	Max. Deflection (in mm)	FOS @ Mounting Points
1	Front Axle Reaction - 790 Kgf	11.5 @ Four Holes	0.125	6.7
2	Rear Axle Reaction - 1510 Kgf	28.5 @ Four Holes	0.654	5.5
3	Total Vehicle Weight on C.G.	NO RESULTS AS C.G. LOCATION OF TRACTOR IS NOT KNOWN		

Table 6 -Results - FEA of CAD model of modified flywheel housing with increased wall thickness & modified design (ref CAE – Swaraj)

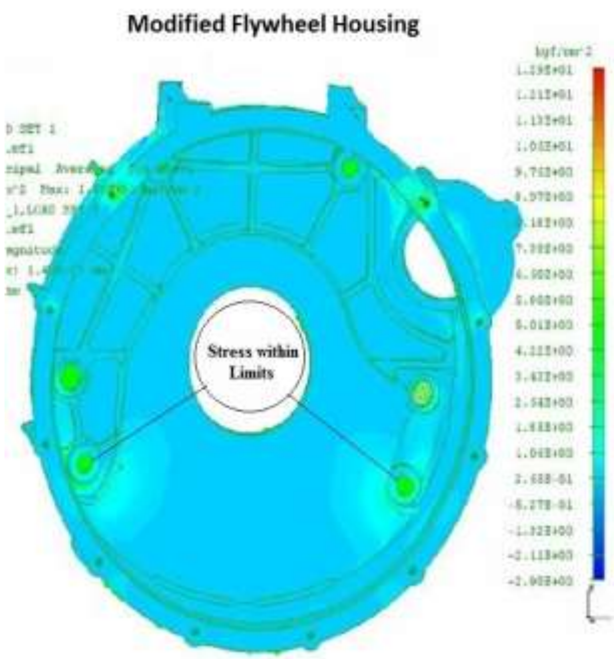


Fig.5 – FEA of modified flywheel housing with increased wall thickness & modified design (ref CAE – Swaraj)

Comparison of Existing & Modified flywheel housings

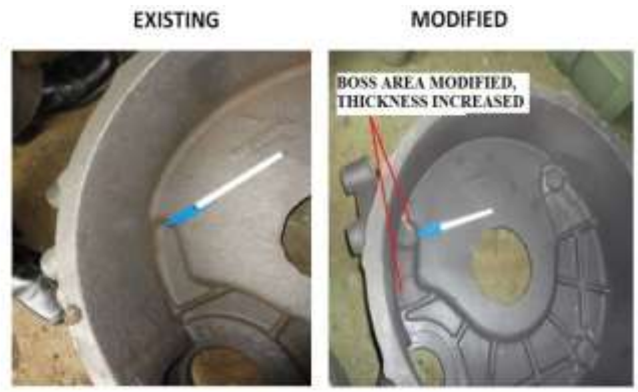


Fig.6 – Modification of Boss Area

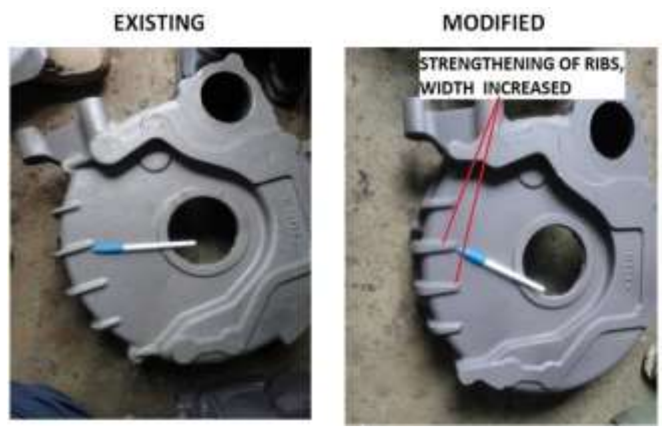


Fig.7 – Width of Ribs increased

Fig.8 – Fillet radius modified

Results and discussions

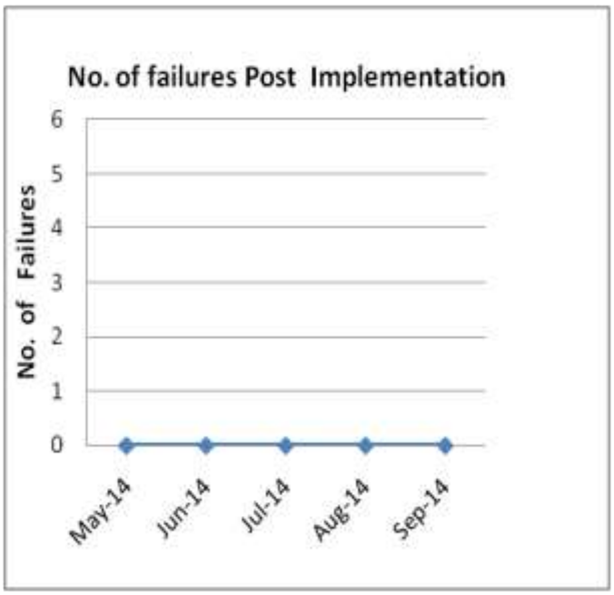
The factor of safety was increased by 50% for four holes at upper position & 42% for two holes at lower position of flywheel housing.

The design of ribs & boss were improved. The fillet radius is modified.

The design with modifications was released & implemented.

Summary

Pre Implementation:
Total Failures (Nov '12- Oct'13) = 35
Implementation date: 30.04.2014
Post Implementation: Zero failures till 30 Sept, 14



Graph 2 – No. of failures Post Implemenation

Conclusions & future scope

In the case study it was diagnosed that the problem was in design of flywheel housing. The component was designed on basis of old empirical relations. By FEA it was diagnosed that factor of safety was less than required. So it becomes necessary to do FEA of every structural component before design release.

Standardization of Designing procedure – The designing procedure should be standardized. The development of CAD model of every new component should be imperative before design release.

Horizontal deployment - FEA of flywheel housings of other tractor models should be done & modify the design if required.

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