IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684, p-ISSN: 2320-334X
PP 46-53
www.iosrjournals.org

Improvement on detection method and on product sealing Feature on sealed version gear reduction starters for Elimination of water ingress failure

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ABSTRACT : *An auto electrical parts manufacturing company located in Padi, Chennai, is manufacturing Gear reduction starters to various customers for their trucks and buses applications.*
Starter motors will be placed very close to the engine so that it can trigger the engine through it's ring gear upon switching on the ignition key. In India the road conditions are like a place where you cannot avoid water splashing on the engine compartment of trucks and buses. Hence without any doubt the water splashing from the road will get entered into the starter motor leading to shorting of motor. To avoid this firm has launched starters with water tight sealed version. Now the firm is facing water ingress issue on these sealed version starters as field failures (warranty issue) leading to loss in business.
An analysis has been made to find out the root cause for failure, methodologies adopted for the analysis were Cause and effect analysis and Process Failure Mode Effect Analysis. As a outcome of analysis to eliminate this failure a detection mechanism, Air Leak test rig was established at the end of production line to the certify that the parts were qualified as sealed version. Also product design changes were carried out to improve the sealing feature of the starter motor.

Keywords – *Air Leak testing, Cause and effect analysis, Process Failure Mode Effect Analysis*

I. INTRODUCTION

The Electric Starter Motor is a DC motor, converts electrical current into rotary motion. In doing so it converts electrical energy into mechanical energy. The interaction of two magnetic fields produces this rotational force. The field coils (either electromagnetic or permanent) located in the housing produce magnetic flux lines. Within the stationary field coils is the armature, a loop of wire (a conductor) with one end connected to B+, the other to B-. When current is applied to the armature flux lines circle the loop in one direction on one side and in the opposite direction on the other side. The interaction of the flux lines on the armature and the flux lines from the field coil cause the armature to rotate. The armature will only rotate to the point where the magnetic force is equal on both sides. (Armature 90º to magnetic flux lines of field) For the armature to continue to rotate, the polarity or direction of current flow must be reversed. Through the brushes and the commutator, the current flow is reversed as the magnetic forces become equal, causing the armature to continue to rotate. This constant reversal of current flow in the armature provides continual rotation. (Refer Figure 1.1). The customer line rejection trend shows the failure of gear reduction starter motor due to water ingress failure is the peak of all other failure, hence the same was selected for elimination. (Refer Figure 1.2).

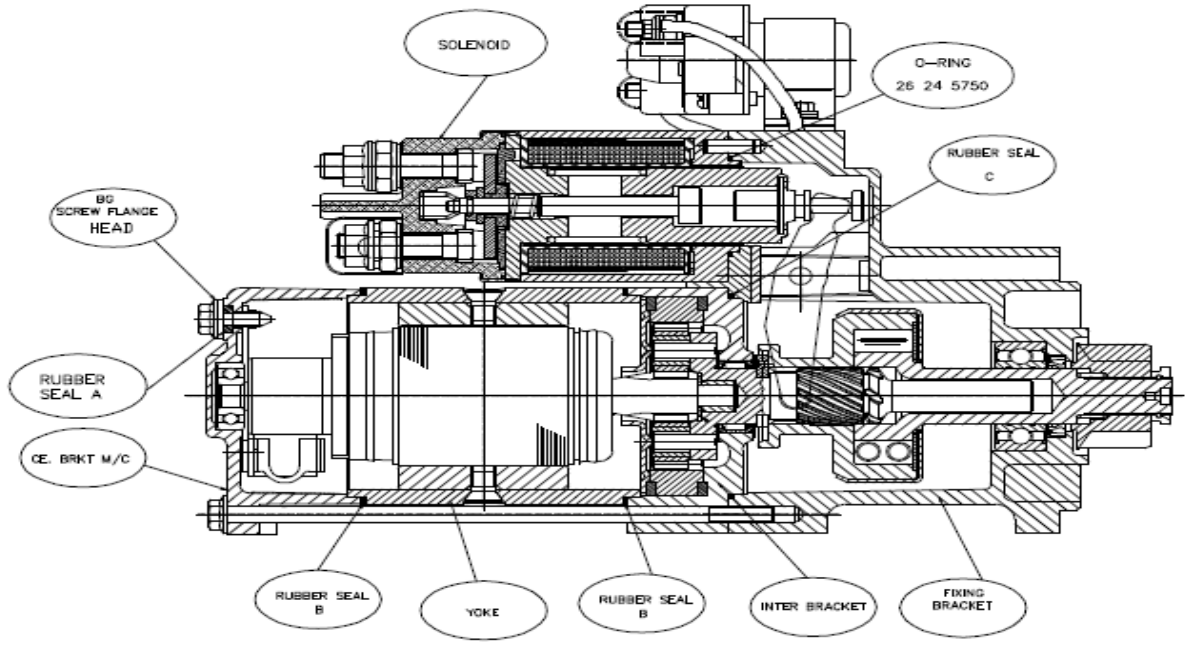

Fig. 1.1 Gear Reduction Starter Sectional view

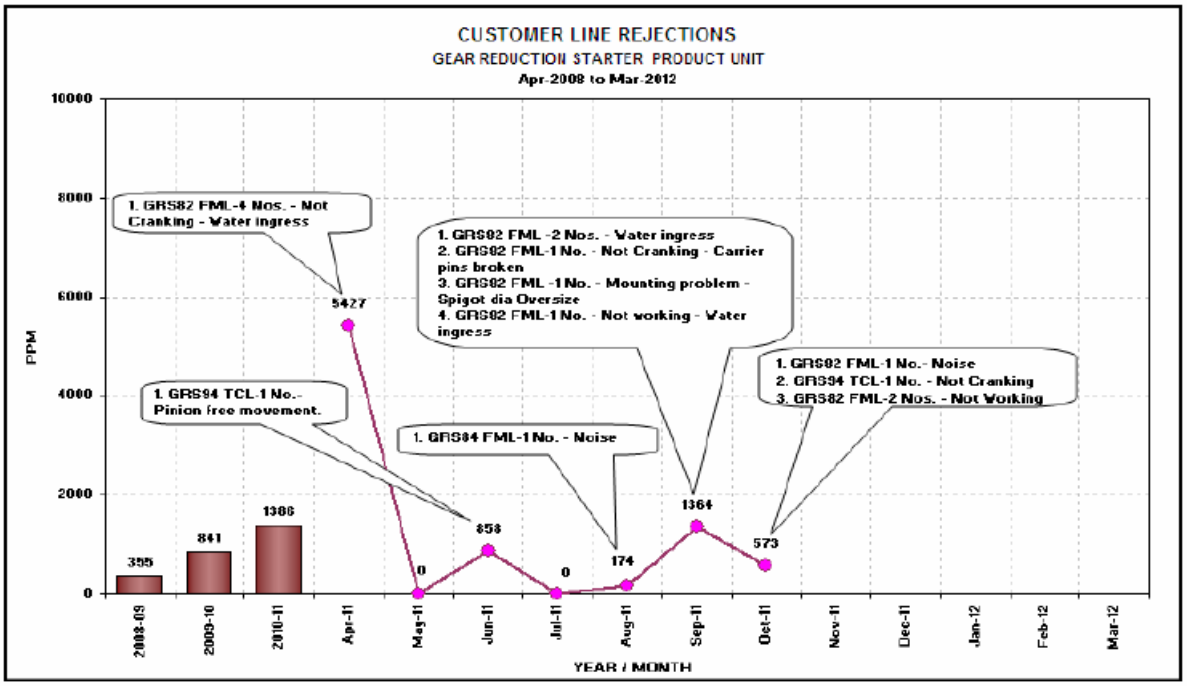

Fig. 1.2 Customer line rejection trend

II. PROBLEM ANALYSIS

The probable reasons for the water ingress in Gear reduction starters were listed and also grouped as into categories. It was decided to not to concern with the environment as there are no contributions identified. Cause and effect analysis was made. (Refer Fig. 2.1 Cause and effect analysis)

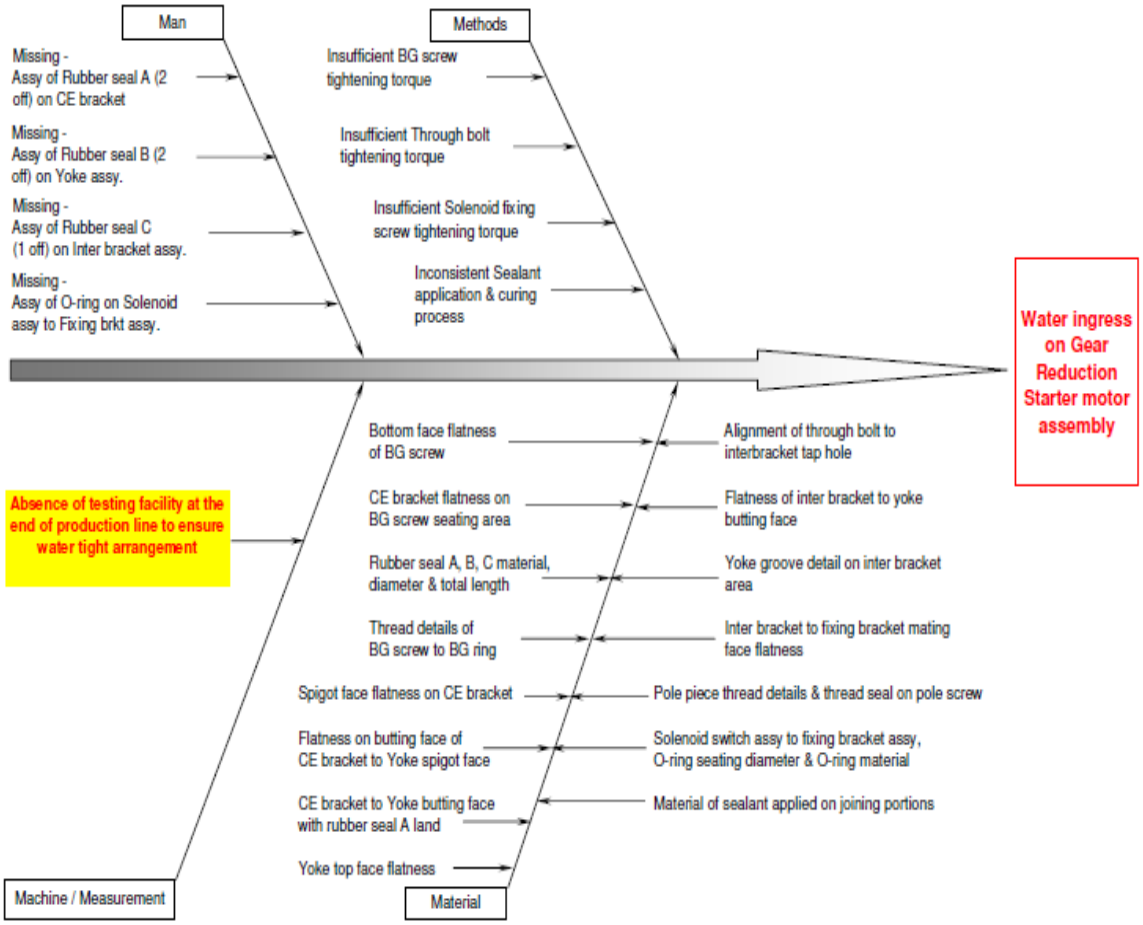

Fig. 2.1 Cause and effect analysis

2.1 Process Failure Mode and Effect Analysis:

A cross functional team was formed with experts from various functions and the PFMEA was performed to understand the potential effects of each failure. Since the potential effects of each failure mode are not the same. There are many kinds of effects for each failure mode and some are very severe and some are not that severe. It is important to know the potential effects of each failure mode to assess the risk involved.

III. COUNTER MEASURES

3.1 Air leak testing:

Based on the PFMEA reviewed by the CFT and as observed in the cause and effect analysis, it is made clearly that a 100 % (should be tested for all starters) testing facility is required to ensure the sealed version of starter configuration. It is impossible to conduct a water spray test for each and every starter assembled in line. Moreover by doing so the product it self will be degraded at the manufacturing site. Hence it is planned to have an Air Leak testing facility as the end of line testing for these starters. Air leak detectors are used to test the air-tightness of parts on production lines. They are specially adapted for automatic and semiautomatic workbenches. The method used is based on the measurement of a small variation or drop in differential pressure between the test and reference parts, when both are filled to an identical pressure.

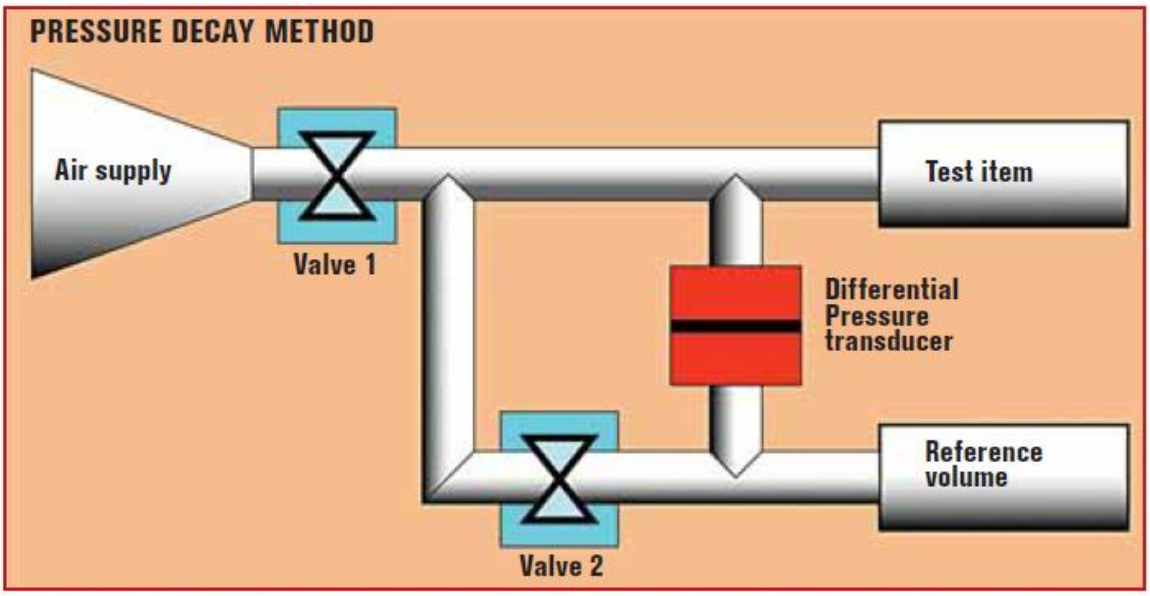

Fig 3.1 Concept of air leak testing

3.2 Sealed component measurement

This test is for hermetically sealed parts, which can not be filled. They are placed inside a bell which is pressurized. The first and the third measurements may be carried out in comparison with a reference. Methods available are test with reference, without reference or in central zero.

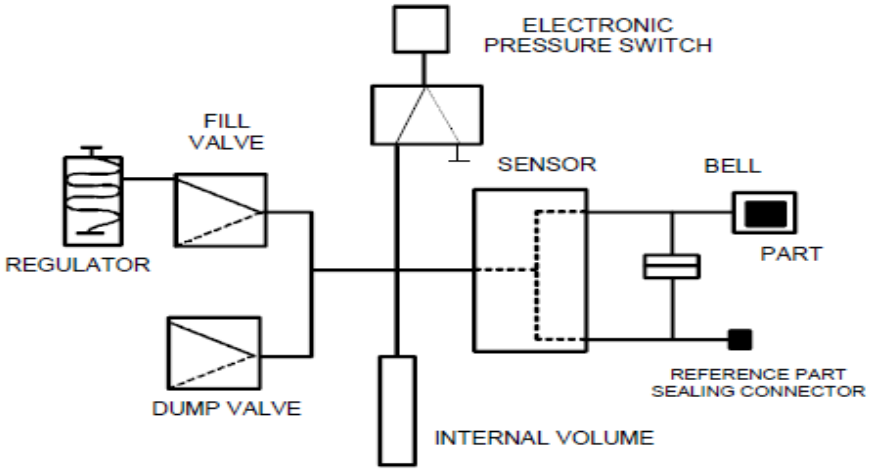

Fig 3.2 Sealed component measurement

3.3 Test bench manufacturing:

The test rig was designed with following major features,

1. Aluminium profile section table for machine base with table, wheels and anti vibration pads.
2. Air leak tester unit, Make: ATEQ F520, USA.
3. Reference chamber unit.
4. Pneumatic cylinder, valves and accessories for fixture activation.
5. Pressure sensor and FRL unit with digital air pressure switch.

6. Test Pass / Fail indication with buzzers.
7. Programmable logic controller based control panel.
8. Vertical photo electric sensors with interlock for safe machine operation.
9. Tap switch with safety mounting bracket for initiating auto cycle operation.
10. Emergency stop push button.
11. Operator panel with human machine interface.
12. Auto marking unit.
13. Rejection chute with interlock for machine operations.

Fig 3.3 Photograph of Air leak test rig

3.3.1 Pass part learning cycle

The Gear Reduction Starter motor assembled as per the specification was subjected to vigorous sealant application process where in all the joining and openings of the starter motor were closed and it was ensured that no water can enter on these parts. Such parts were built for the pass part learning cycle of the test rig. In pass part learning cycle the leak tester ATEQ F520 runs a cycle which automatically calculates and identifies the value of the good part together with the maximum and minimum limits (+/- 5 % modifiable)

3.3.2 Test specification

The testing specification was arrived based on testing the master part using the pass part learning cycle.

Input air pressure to tester: 1.5 bar
Test chamber air pressure: 0.5 – 0.7 bar
Permissible leak: 2000 Pascal Max
3.3.3 Run at rate establishment

This test rig was planned to introduce in the motor manufacturing assembly line. Hence it has become necessary to establish the run at rate for this test rig. (Refer table 3.1)

RUN AT RATE REPORT

Note : Component should be continuously produced for 1 hour. The actual output should meet the quantity calculated as per agreed cycle time (Target). No Stoppages & abnormalities. If there is component inadequacy, alteast run continuously for 30 minutes.

Equipment Name : Air Leak test rig **EN No :** R132156 **PPLG Engineer : DIK**

Supplier : Plant and Machine tool centre **Part Description :** GRS HD **Date : 16.03.2014**

Part Number	Trial No	Time		Cycle Time (secs)	Target	Actual	Run @ rate % (B/A x100)	M/c Stoppage (Mins.)	Reason for Stoppage / abnormalities	Counter measure taken
		Start	End		Qty (A)	Qty (B)				
26242292/W	1	9:00	10:00	33	106	109	103	Nil		
26242292/W	2	11:00	11:30	33	53	47	89	4	Auto marking cylinder not working.	Reed switch position adjusted and fixed.
26242292/W	3	15:00	15:30	33	53	51	96	2	Low air pressure from central compressor	Alert raised with Central Work Engineering Department

PPLG Enggr : R. DHARANI KUMAR **Supplier : E. SURESH - PMTC**

Table 3.1 Run at rate report

IV. SEALING FEATURE IMPROVEMENT ON PRODUCT

Efforts were also made to revise the sealing features of the product. In this context a comparison study was made by bench marking other related field applications (Refer Table 4.1). The below given details were passed on to the product design and development section for validation.

Part description	Existing design	Proposed improvement	Basis			Cost impact
			Other LTVS products	Other LTVS applications	Bench marking	
Fixing bracket assembly	Rubber grommet seating area is as cast	Machining operation to be called for grommet seating bore.	✔			✔
DE Grommet		Redesign of grommet to increase tightness	✔			✔
CE Grommet		Change for face sealing by adding the flap on Yoke seating area.	✔			✔
Inter bracket seal	Radial sealing	Seal design to be changed from square seal to O ring.	✔	✔	✔	✔
Yoke seals	Radial sealing	Face sealing instead of radial sealing. Seal design to be changed from square seal to O ring.	✔	✔	✔	✔
Yoke	No ID machining on yoke	Yoke ID to be machined to accommodate CE grommet				✔
Relay	0.5mm thick seal provided on rivet	Seal thickness to be increased from 0.5mm to 0.9mm	✔			

V. CONCLUSION

The failure modes and their causes that can lead to the water ingress in the Gear Reduction Starters were analyzed. To certify that all Starter motors being manufactured are in lieu of the sealed version configuration, Air leak test rig was manufactured and installed at the end of production line. Since the part needs to be tested in fully assembled condition it is decided to proceed with the air leak testing by sealed component measurement under test with reference.

Also by conducting a bench marking study on other application, the product design was revisited to improve the sealing feature of the product. Sealing feature was further enhanced by increasing the tightness of rubber grommets to aluminium brackets and in the Yoke assembly instead of face sealing, radial sealing concept was implemented.

ACKNOWLEDGEMENTS

The author would like to gratefully acknowledge the support of management of Lucas TVS and staffs of Madras Institute of Technology in helping to complete this project.

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