International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-4, November 2019

Application of LED (Lean Embedded D3) Methodology to Improve Quality of Starter Motor EGT- Assembly

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Abstract**:** ***In the era of liberalization and open global market economy, Each and every organization wants to produce and deliver good quality products at a minimum price in order to remain competitive in the markets .To achieve this objective one must pay proper attention to their quality and lean manufacturing practices and aim for zero defects in their organizations. In the present work a new methodology namely LED3 (Lean embedded D3) methodology is applied to address the quality issue in starter motor manufacturing company. The root cause for failure of starter motor was successfully traced out using Ishikawa and five why analysis and a new technique was implemented to overcome the quality issue. After successfully implementing the new method the rejection rate has come down drastically from 7% to less than1% and Cycle time reduced from 1min to 30 sec. Total 3 hours saved per day.***

Keywords: Lean six sigma, Process mapping, Pareto analysis, Ishikawa diagram

I. INTRODUCTION

An internal combustion engine is not usually self-starting, so auxiliary machine is required to start it. Many different systems have been used in the past but modern engines are usually started by an electric motor in the small and medium sizes or by compressed air in the large sizes [1]. The purpose of the starting system is to convert chemical energy stored in the battery into electrical Energy then into mechanical energy is then transferred through gears and drives from the starter motor. After the transfer and conversion of all this energy the engine flywheel begins to rotate. The rotation must be of sufficient speed to allow the engine to form the combustible air-fuel mixture required for starting [2].

Components of starting motor system

The starter motor system has Battery, Ignition switch, Starter motor assembly, Starter safety switch and cable wires etc.

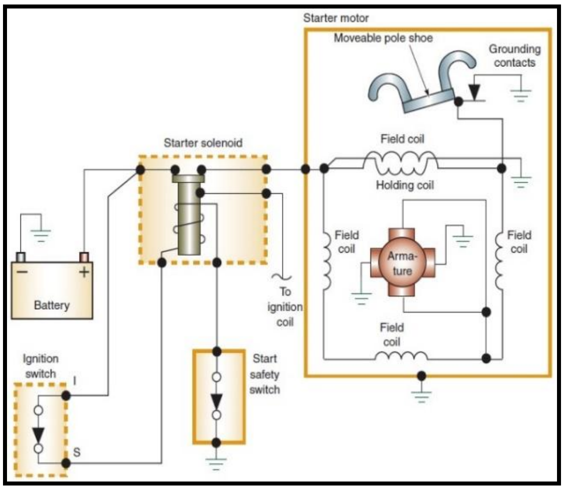

Fig .1.Components of starter motor

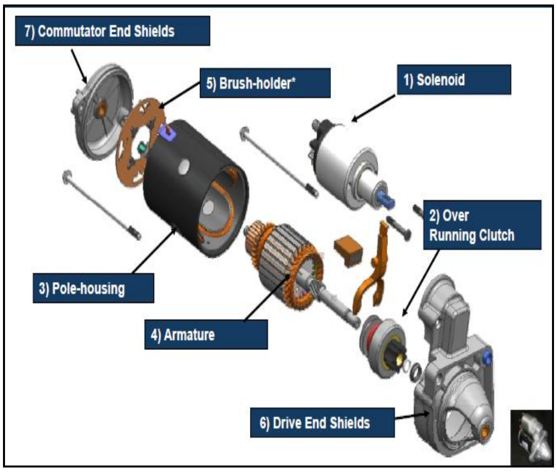

Fig.2. Blow-Up model of starter motor

A. Epicyclic Gear Train (EGT)

An Epicyclical gear train (EGT) shown in figure.3 is used in starter motor to have a great gear ratio in a given compact space. It consists of sun gear and planetary gear and planetary carrier and a ring gear. The EGT also includes components like drive shaft, straight pin Sun gear etc. (Gear Ratio = Speed of ring / Speed of sun gear + 1).

Manuscript published on November 30, 2019.
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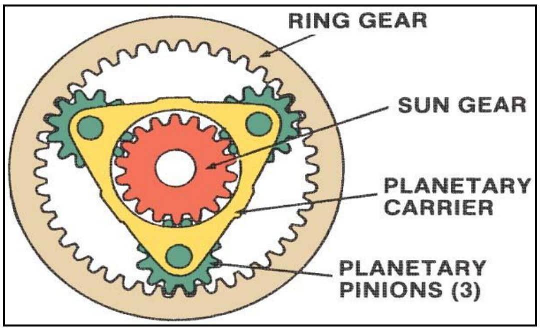

Fig.3. Epicyclical Gear Train

II. REVIEW

Starting internal combustion (IC) engine without starter motor is very difficult. Prior to the invention of starter motor, several techniques were used to start the IC engine. They include wind-up of ropes and springs, gunpowder cylinder etc., hand driven removable crank, pulling cord which was wound on pulley etc but these techniques are really risky and inconvenient [3-5]. These methods are not effective and efficient because sometimes they make engine to rotate in the reverse direction also. Once the engine starts, the starter should disengage from main engine, but sometimes starter will fail to disengage from main engine results in more noise and power loss .Mr. H.J.Dowsing, an electrical engineer of England developed electrical starter motor and installed in Arnold of Benz engine in 1911.subsequently Charles.F ,M.Leland with Henry DELCO Dayton Engineering Laboratories Company (DELCO) invented and filed patent in US [6-8]. In the Reduction and Reduction Flange (R&RF) Starter motor sub assembly station there will be a pin pressing operation into the drive shaft which will be carried out before assembling it with rest of the parts.

A. Straight Pins

Straight pins are used in EGT assembly .These pins must be hard enough to withstand the compressive forces during the assembly operation. The straight pins are shown in the figure5 and figure 6

Fig.4. Straight Pin

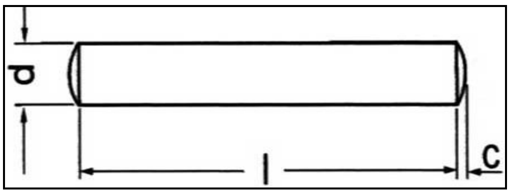

Fig.5. Straight Pins-2D.

III. PROBLEM STATEMENT

The straight pin pressing operation is carried out at the Epi cyclic gear train (EGT) assembly line of the R&RF starter motor. There was a customer complaint that the starter motor was noisy and failed to take load. Due to this the vehicle was producing more noise while cranking the vehicle engine and lead to break down of starter motor. This lead to a rejection of a batch of starter motors. In the straight pin pressing station, in the existing method Drive shaft pin pressing without load monitoring system. And all the three pins are pressed by single flat fixture more over there are.no Pokayoke for drive shaft hole (ID) oversize and pin (OD) oversize. Due to Improper pressing and no proper alignment results in errors as shown in figure.6 and figure.7

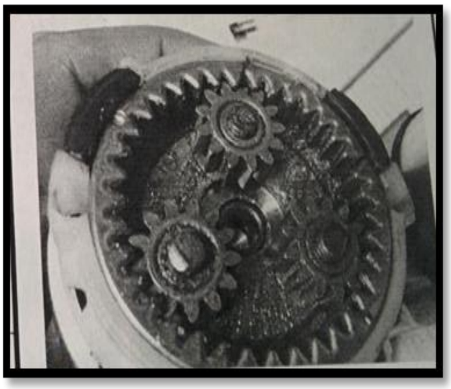

Fig.6.Broken EGT

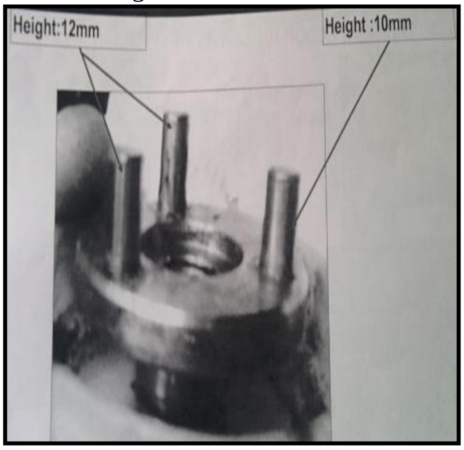

Fig.7. Variation in pin height

VI. METHODOLOGY

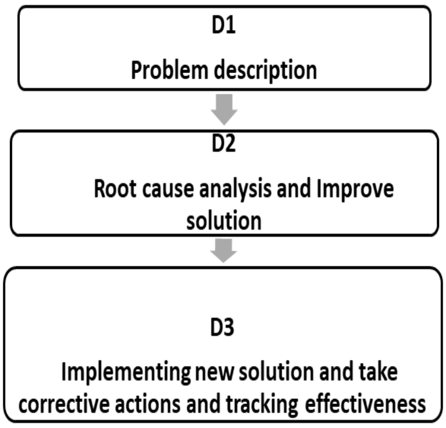

Fig.8.Flow Chart of Methodology

The methodology of Lean embedded D3 (LED3) is shown in the figure.8and it consists of three phases namely Phase-1 Describe (D1) Phase-2 Develop (D2) Phase-3 Deploy (D3). Phase-1 defines the quality issue and is converted into critical to quality (CTQ) so as to express the current quality in measurable terms. Tools used in this phase are to define the problem, identify CTQs, understand the process flow and measure base line performance. Phase-2 is to analyses the problem, to establish cause and effect relation and root cause of the problem. Phase-3 is used to improve processes and Implement the optimal solution and establish a monitoring mechanism .The quality issue in the EGT assembly line is thoroughly analyzed using these new methodology as explained below.

A. Ishikawa diagram (Fish bone diagram)

The Cause & Effect (C&E) diagram also called as fishbone diagram or Ishikawa diagram. It is a quality tool for identifying root cause for a given problems .The root cause for noise problem in EGT assembly line due to broken gear is analyzed using Ishikawa diagram as shown in the following figure.9

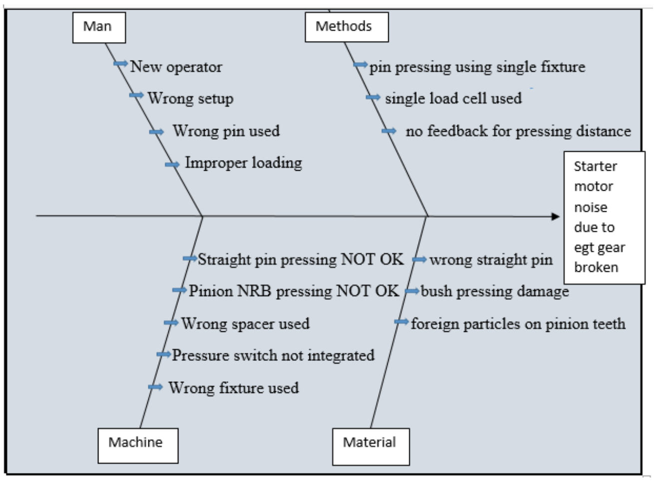

Fig.9. Ishikawa diagram

B. Five Why Analysis

Problem description	Why did it happen	1st why	2nd why	3rd why	4th why	5th why	Counter measure
Straight pin pressing not ok		Straight pin pressing improper	Pin height variation	While pressing Pillar rod broken	Single flat fixture used for pressing High pressure on pressing cylinder	Pressing pin fixture design	Pressing fixture design to be modified Air pressure interlock in the process.
Line name: EGT assembly line	**Why wasn't it detected**	No load monitoring system	No Pokayoke implemented	pressure interlock system not activated	Program not done with process.	LVDT not introduced	

Figure .10.Five why analysis

The critical analysis was done using five why analysis to understand the actual root cause for straight pin pressing quality issue and not detecting error immediately. After five why analysis a counter measure was proposed to change in the design of fixture and employ LVDT to monitor the progress of pin to the EGT assembly. The tolerance limits for various type of drive shaft and load range are shown in table 1 and tab 2 respectively as follows

Suggested Tolerance Limit & Load limits

Table 1. Suggested Tolerance Limit

Part No Drive Shaft	Nominal Value (mm)	Upper Limit Tolerance (mm)	Lower Limit Tolerance (mm)	Pitch Circle Diameter (mm)
TYPE A	5	4.969	4.957	29.60 (+/-0.03)
Type B	6	5.969	5.957	31.7
TYPE C	6	5.969	5.957	33.74

Table 2. Load Limits

Type	Minimum (Kg)	Maximum (Kg)	Depth (mm)
TYPE A	250	1200	5
TYPE B	250	1500	5
TYPE C	250	1800	5

IV. RESULT AND DISCUSSION

In sub assembly line of R&RF starter motor, in the Epi cyclic gear train (EGT) line the straight pin pressing operation is carried out before assembling it with the other components such as cover ring, intermediate bearing and pinion gears etc. After pin pressing operation process, there was no proper practice of checking whether there exists proper mechanical interference between the individual pins (OD) and holes (ID) of drive shaft after the pressing operation and also we could not know the force acting on the individual pins for pressing, which was leading to rejection of starter motor in assembly line. In order to reduce the rejection of starter motor and the total lead time of assembly line. There was only a flat fixture and a load type load cell as shown in the figure10.

Fig.10. before Modification **Fig.11.After Modification**

After installing the modified fixture shown in figure.11 above in the assembly line for the pin pressing operation with three individual button type load cells three individual load readings system is proposed. With this it is easy to identify whether the three pins pressed are within the load limit which is set for different types of EGT.and LVDT measures the maximum depth of the pin inserted which is digitally displaced. Pokayoke has been implemented to the machine and linked with the PLC in order to prevent the defect and also giving a caution to the operator to reduce the defects. If any defect is found the piston does not retract to its initial position indicating the defect. After implementing new methods, the Starter motor failure has come down to less than 1% due to proper pin pressing correct in the span of 2 months reading

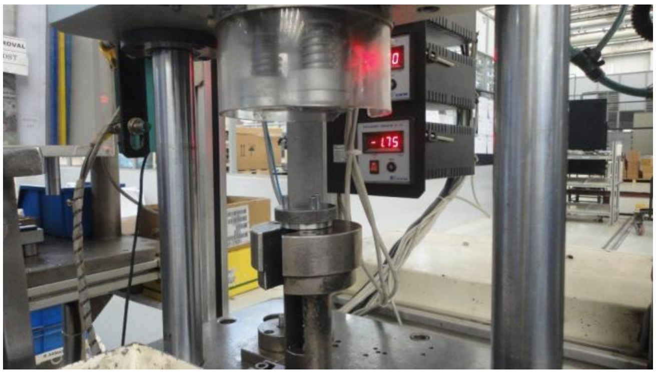

Fig.12. Load monitoring and LVDT display

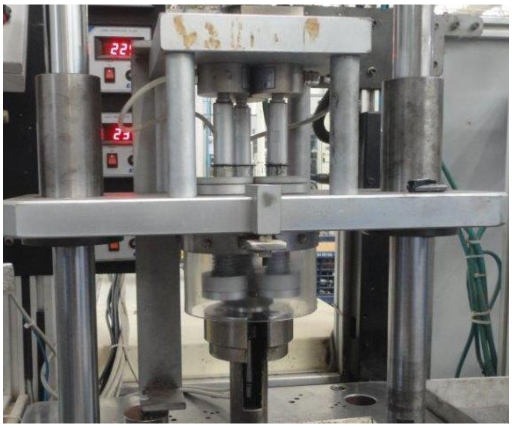

Fig.13: Pokayoke for error detection

A. Monitoring of the process after Modification

The fig.14 shows the control charts for load 1, for the type A Similarly other two loads are also with in the control limits hence no defects from the EGT assembly line

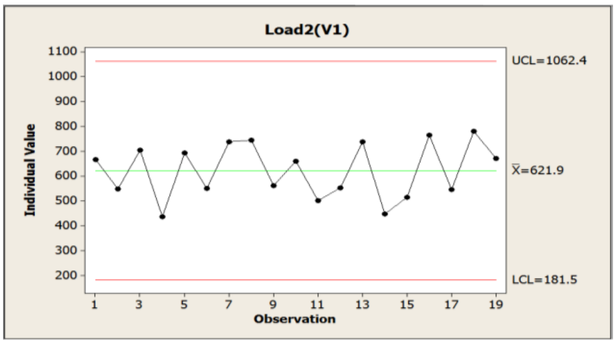

Fig .14. Control chart for load 1

V. CONCLUSIO N

It is very important for any organization to produce high quality products and maintain that quality to promote customer satisfaction and degree of standards this is achieved by effective utilization of man, methods, machine, and material. This means the quality of the product mainly depends on the skill of the operator, efficiency of machine and quality of material used. After implementation of proposed fixed system and LVDT and monitoring system, a) the Cycle time reduced from 1min to 30 sec. b) Increase in the number of EGTS produced 65/Shift/Operator. And also there is a Total time of 3 hours is saved in a day. By modification of the machine and introducing the load cells through which the force is calculated on each pin by this we can easily detect the where exactly the defect is due to hole ID oversize or the pin OD oversize, by using LVDT we are able to measure the depth of the pin pressed in to the hole of the Drive Shaft, by implementing POKAYOKE in to the machine the possible Defects can be identified easily and rejections are reduced. By implementing all these methods we can decrease the time and 100% accurate result will be obtained and also it reduces the total lead time of the R&RF starter motor and probability of failure of starter motor with respect to pin pressing operation in the EGT assembly line

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