Systematic Fact Finding and Problem Solving for Leakage in High Pressure Line in Diesel Engine

Abstract: *In today's fast paced world an automobile is becoming one of the very important and necessary accessories of modern age human. With the advent of new technologies and safety equipments in automobiles, more and more customers are getting attracted. Thus pressure on the automobile manufacturing industry is immense to fulfill ever increasing market demand in stipulated time. Various production concepts like assembly lines etc are used for mass production of vehicles. But the time constraints come in the way when the industries faced with some serious complaints over its products which eventually cost to the company as replacements and do damage to the brand image. In such cases the addressing real problems behind the complaints becomes very important to avoid such future incidents. The problems discussed in this paper are about leakage in HP line of a diesel engine at TATA Motors Pune. Approximately 25 incidents per thousand vehicles in warranty cases were found to be suffering from this particular problem so it was decided to find and address real issue. The high pressure line in diesel engine was found to be leaking at the injector side of the cylinder head. During this study no. of factors like human errors, inadequate clamping, HP line design, manufacturing defects, Material, turbulence in the line, and vibration of structure are found to be culprit. In this paper process of fact finding and problem solving using various quality tools for leakage in hp line of diesel engine in an automobile industry is discussed and new design of reinforced hp line is introduced.*

Keywords— *HP line leakage, Diesel engine.*

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1. Introduction

Fuel injection has become the primary fuel delivery system used in automotive engines, having replaced carburetors during the 1980s and 1990s. A variety of injection systems have existed since the earliest usage of the internal combustion engine. The primary difference between carburetors and fuel injection is that fuel injection atomizes the fuel by forcibly pumping it through a small nozzle under high pressure, while a carburetor relies on suction created by intake air accelerated through a Venturi tube to draw the fuel into the airstream. So inevitably delivery of fuel at high pressure has to be done from high pressure fuel pump to fuel injectors. This is done by various types of pipes and tubes; jacketed fuel injection pipe is a popular type of fuel delivery type. The pipe incorporates an outer jacket that shrouds the inner high pressure pipe. This jacket is usually metallic in construction and can either be a thin walled tube or convoluted hose. It is also called as double walled or sheathed fuel injection pipe. In the event of a burst in the injection pipe the leaking fuel will be collected by the jacket and piped away safely.

1.1 Problem Definition:

Diesel engines manufactured at TATA motors are equipped with sheathed fuel lines. As the company has strict quality policy and good servicing reputation at customer level keeps track of problems encountered by the customers on the field and depending on the problem various warranty issues are addressed. At the same time if some problem occurs at significant numbers on IPTV log (Incident per thousand vehicles) is sent to the engineering team to make changes in the next lot of diesel engines. High pressure fuel lines on the diesel engines are experienced by fuel leakage on the field. This number is found to be 25 Incidents per thousand vehicles. So the problem is decided to be addressed by the engineering team. Various fact finding and problem solving methods are used on production floor such as FMEA, 8D etc.

2. Literature review

2.1 8D Methodology:

Eight disciplines problem solving (8D) is a method used to approach and to resolve problems, typically employed by quality engineers or other professionals[1]. Its purpose is to identify, correct and eliminate recurring problems, and it is useful in product and process improvement. It establishes a permanent corrective action based on statistical analysis of the problem (when appropriate) and focuses on the origin of the problem by determining its root causes[2]. Although it originally comprised eight stages, or 'disciplines', it was later augmented by an initial planning stage. The 8D follows the logic of the PDCA cycle. The disciplines are as shown in Fig. 1.

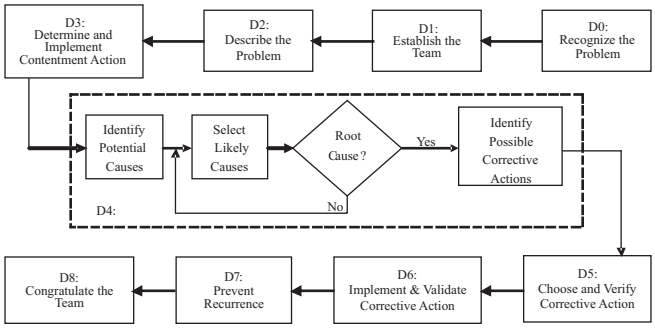

Fig. 1: Flow Diagram of 8D Technique

A. D0-Preparation of Problem Solving Process

The methodology contains Emergency Response Action (ERA): (Response against the complaint is registered). In order to establish the problem following steps are followed.

Step-I Category (SPARK):-
Safety (S)
Performance/output/ Functional related (P)
Aesthetics (A)
Reliability/Durability (R)
Key Dimensional - Assembly/ further installation (K)

Step-II

Consult with relevant experts in Safety, CFT, Other relevant department such as VQA/ 5C agency/ ERC/ Testing/ Metallurgy/ COP team/ Customer/ Service – Relevant Department for consultation :VQA, Assembly/ Testing, 5C agency, & Customer.

Step-III

Segregation/ Deviation – if defect not known (Rectification support provided).

Step-IV

Emergency Response stocks (for component having high lead time)

Flow Chart/ procedure/ guideline for problem solving.

B. D1 – Team Formation

Second stage of the methodology after fully establishing problem is forming team for same. In order to form various members of the team following steps are followed.

Step I - Team Charter preparation
- Champion (Decision making) –
- CFT, with group team leader – As per D0

Step-II
- Recorder/ Document controller – Register complaint in recorder

Problem is registered by arranging initials of Sr. Number, Year, Month, Category (SPARK), and Customer

E.g.: C P 04 12 001

Step II – setting up team goal statement

Step III – Meeting planning is done on immediate/ weekly/ monthly basis at customer end.

Step IV – Meeting agenda is prepared with the action plan

Step V - Master List of 8D is made.

Step VI – Kick-off meeting - Initial meeting with full fledged discussions, with fact & figures.

Step VII – Field visit is arranged if sample to be brought out or addition details related assembly if any, logistics/ material handling, misinterpretation/ misunderstanding, similarity in test conditions/ perception, insufficient information/ communication gap.

C. D2 – Description of Problem

Identify Problem -

i) **Symptom** (A characteristic sign or indication of the existence of something else) -

ii) **Defect** (any part of a product or service which doesn't meet customer satisfaction)

Use of 5W 2H tool is done to define the problem definition.which contains questionnaire of Who, What, Where, When, Why, How, How many.

D. D3 – Contain symptoms - Implement & verify interim containment actions

Temporary/ Interim - (Start with Problem reported,

Ends with Corrective action) implementation and Setting firewall till implementation of corrective action, will be removed after approval by customer Tools to verify interim action are check sheets, dot plots & Histograms, control charts, Paynter charts.

E. D4 – Find & verify Root Causes

Table 1
Methods to find root causes [3]

Supporting Tools	Screening Tools	RCA Tools	Verification Tools
1) Component Search	1) Multi-variable analysis	1) C & E analysis	1) Scatter Diagram
2) Paynter Chart	2) Process parameter search	2) DOE	2) Paired Comparison
3) Brain storming	3) Histogram	3) Why-Why Analysis	3) Field trial
4) 5W-2H	4) Is/Is-not analysis		
5) Check sheet	5) Pareto analysis		
6) Control Chart	6) Stratification		

F. D5 – Selecting Permanent corrective actions (Mistake Proofing)

Through pre-production test programs, quantitatively confirm that the selected corrective actions will resolve the problem for customer.

G. D6 - Implement Permanent corrective actions

- Stop D3 – Stopping Containment actions
- Time line - Corrective Action with responsibility & target date
- Implementation
- Performance of corrective action

H. D7 – System Impact

Check the system impact of corrective action on bigger scale

I. D8 – Congratulating the 8D Team

Team is congratulated for their effort.

Considering effectiveness of 8D method the problem is decided to solve by this method.

3. 8D Implementation

As described in literature review first step of 8D is the recognition of problem. As stated earlier High pressure fuel line was found to be leaking at the injector side. Various such repeated claims are done at field and suffered for warranty issues. 5W tool given out the information needed to establish the problemWho: Customer complaint, what: Fuel Leakage from HPP, Where: @ Field, When: @ warranty meeting, Why: Threading damage & vibration etc., How: by service centre, How many: 25/1000 HP lines

Concluding the problem during warranty meeting service has register customer complaint of HPP due to fuel leakage from several sides was considered as S-safety, P-performance, R-reliability related as per SPARK category described in literature review. So it was decided to form team and try to eliminate problem. As per the second step of the 8D's. Team members were Jagdish Bagre (Leader), Pravin Joshi, M. Dhande, P. Sharma (ERC Expert), Supriya Darekar (Trainee) Third step was to create interim solution for the problem till it gets corrected. So it was decided till the issue get addressed Buffer stock of HPP is made available for replacement at Customer end and torque is checked at every pipe. Next and very important of all steps of 8D is identifying root cause. Brainstorming which is one of the investigation tool stated in Table 1 was carried out on HP line leakage to find out potential cause. Following are the categories and points formed at the session.

A. HP Pipe

Crack, area of contact, tightening, ID under size, damage, wall thickness, torque Less / more, engine vibration, wrong fitting, damage / rusty, metallurgical property

B. Mounting bracket

Fitment not ok/ shifted, torque not applied, loose, over tightened, Material not ok, Thickness less

C. HP Clamp

Fitment not ok/ shifted, mounting pipe dia. undersize/ oversize, tightening

D. Assembly Process

Any additional fitment on mounting bolts, assembly process flow, any wrong method used, storage / handling

E. Manufacturing Process

As per drawing ok / not ok, bending Fixture used

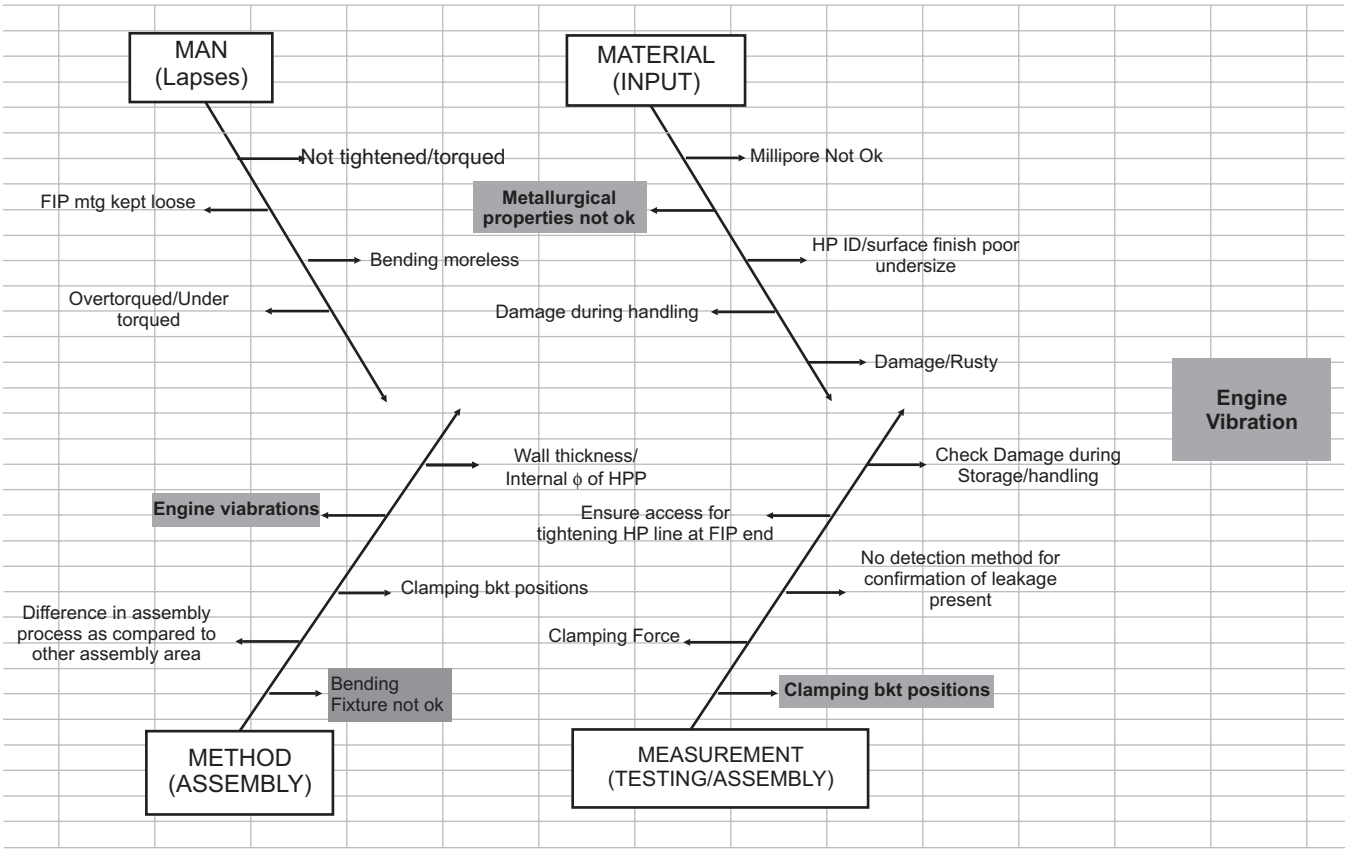

Fig. 2: Fishbone Diagram for HP line Leakage root causes

storage / handling to document the results of brainstorming fishbone diagram is done shown in Fig. 2.

3.1 Cause analysis:

As shown in figure 2 the main root causes are highlighted which were Metallurgical properties of brackets, engine vibration, and clamping bracket position. So studying causes one by one the assembly method on engine line is investigated first, i.e. procedure for assembly performed by workers during fitment of HPP from FIP to Injector, we found some lapses those are;

Measurements:

1. Gap between AC face to HP pipe bracket between 0.1-2.2 mm
2. Gap between head face to HPP bracket between 0.9 - 2 mm
3. Linier shift of HP bracket Hole with engine hole around 0.5
4. for proper fitment of upper bracket 4 washer used at bolt which has exactly 2mm length (8mm for 4 washers)
5. Measure the distance between the all bracket, and total length of HPP by thread.

Important points among above were the design issues. Due to gap between brackets often at workstation it was forcefully fitted with plastic hammer. So incurred stresses in the material may cause of concern. Measurement of distance between brackets revealed that the gap between the two brackets is less than ideal resulting in imbalanced structure.

Material:

As per suggested by engineering research center at TML, the existing material was found to be incompatible with high pressures during engine operations. EN32 was identified was good material for such type of application but the incurring cost of design change at vendors was as high as five times of the existing. So the material properties were decided to be supported by better vibration proof design. Vibration analysis of the structure showed that the support structure for hp line needed to be redesign.

Process: manufacturing

There are various bends in the design of hp line. So the manufacturing process of hp line was studied at

the vendors. And found that one of the bending fixtures may be causing cracks on the line.

Next step of 8D is taking corrective action for the problem. Through pre-production test programs, quantitatively confirm that the selected corrective actions will resolve the problem for customer.

From brain storming and fish bone diagram we check all facts 1 by 1 n take corrective action for that,

1. Figure 3: New HP line Design

   ID of the hp line was planned to be checked for corrosiveness and check sheet is implemented at workstation for the same.

2. Millipore are checked by
   a. Scheduling of cleaning of all material bins and recorded.
   b. HP line Millipore scheduled to be checked part wise & weekly to be send to TML

3. Metallurgical problem of the brackets were resolved by making structure vibration proof as per the findings during cause analysis study. And number of brackets are increased from 4 to 5 as shown in Fig. 3 C1, C2, C3 were newly added brackets.

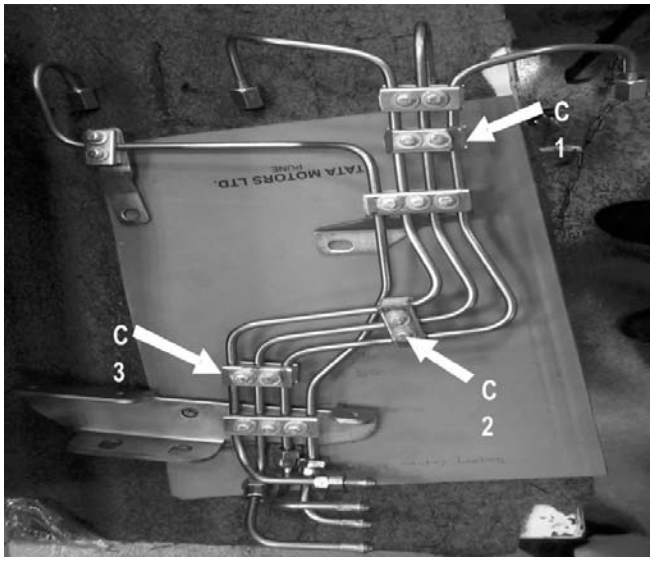

Fig. 3: New HP line Design

4. HPP line edges fouling with sharp edges of bending fixture

Bending more / less - 100 % Bending is checked at supplier end on master engine. (One person is dedicated on daily basis from vendor to TML). And as well the master bending fixture is redesigned for the issues found during cause analysis study as shown in Fig. 4. The change in the design is highlighted by blue circle.

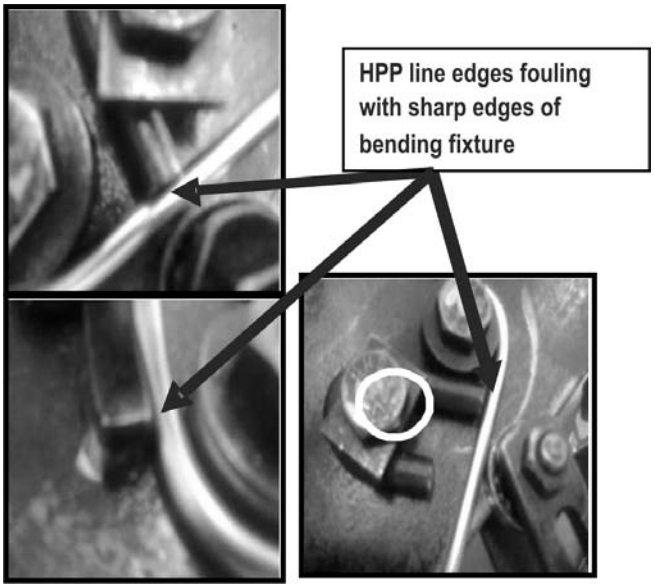

Fig. 4: Bending Fixture left: previous right: new [5]

5. Fig. 5: New Bracket Design

Upper Bracket of the hp line which had gap used to be minimized by 4 washers is redesigned and end plate is fabricated flat to close that gap. New design is as shown in Fig. 5.

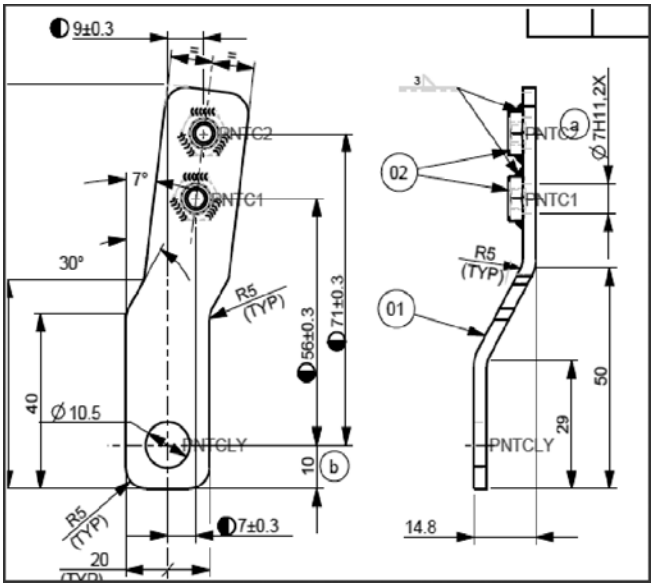

Fig. 5: New Bracket Design

Table 2: Performance of New HP line

Job No.	Fitment Km	Date	Till Date Km	Km	Remark
1	14444	26/10/2012	23298	8854	No fuel Leakage
2	20203	30/08/2012	42214	22011	No Fuel Leakage
3	23391	10/01/2012	41856	12465	No Fuel Leakage
4	9312	28/08/2012	22775	13463	No Fuel Leakage
5	14995	13/08/2012	27896	12941	No Fuel Leakage
6	39510	24/08/2012	47879	8369	No Fuel Leakage
7	50405	11/12/2012	55148	4743	No Fuel Leakage

3. Result and Analysis

All the proposed changes were employed on the field then interim actions are lifting off and team members are thanked. New improved hp line installed vehicles are tracked which showed results so far shown in Table 2.

4. Conclusion

So the study on leakage in hp line of diesel engine at Tata Motors is addressed by changing design of brackets, vibration proofing the design and change in the process which was potential cause of damage of hp line during bending of line. Changes were implemented successfully and so far shown great results. The study thus proves 8D to be an effective problem solving method for production process. The method is successfully employed to the problem and results were reported.

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