REDUCING THE REJECTION RATE OF ENGINES MANUFACTURING DUE TO INJECTION TIMING VARIATION

Mrs. P.SIVASHANKARI
(Faculty, Department Of Automobile Engineering, Sathyabama University, Chennai, India)
1jsrshank1981@gmail.com

ABSTRACT

The white paper is on HINO 6 cylinder engine and the aim is to reduce the rejection rate of engines during testing due to the problems occur in valve timing and injection timing. The concept of Six Sigma is mainly practiced as a design to eliminate the production defects by improving the process of manufacturing. In the observation, the injection timing mark (spill mark) is not perfectly done and also the imperfection in flywheel marking machine locator pin increases engine rejection. The aim is to eliminate the engines getting rejected during engine test due to problems arising in the injection timing and valve timing. As there are a lot of problems arising in the test bed where the engine is tested, few of which are related to injection timing and valve timing. These problems mainly arise due to changes in the valve and injection timing variation.

KEY WORDS: HINO 6 CYLINDER diesel engine, six sigma methods, valve timing, injection timing

I. INTRODUCTION:

A. CI ENGINE

A diesel or CI (Compression Ignition) engine is an IC (Internal Combustion) engine which operates in the principle as the air is progressively compressed in the cylinder, its temperature increases, until when near the end of the compression stroke, it becomes sufficiently high (650-80O ^{0}C) to instantly ignite any fuel that is injected into the cylinder. When the piston is near the top of its compression stroke, a liquid hydrocarbon fuel, such as diesel oil, is sprayed into the combustion chamber under high pressure (140-160 kg/cm ^{2}), higher than that existing in the cylinder itself. This fuel then ignites, being burnt with the oxygen of the highly compressed air which is different from SI (Spark Ignition) engine where spark plug is used to ignite an air-fuel mixture. When the compression is increased, the combustion is attained without any separate system for ignition, higher the compression ratio increases the efficiency of engine in CI engine because the heterogeneous mixture is compressed and the fuel is not introduced till it reaches TDC (Top Dead Center) ie injection timing in the cylinder. In case of CI engine premature detonation does not affects the performance of engine hence compression ratio can be much higher whereas in SI engine, increasing the compression ratio is limited to prevent pre-ignition.

B. VALVE TIMING

The valve timing is the actual timing of valve lifting events mainly for opening and closing of inlet and exhaust valves. Whether it is a four stroke and two stroke IC engine, the cam shaft controls the valve timing. The valve timing is varied by introducing the new technology namely variable valve timing or by remodelling the cam shaft. Introducing the new technology and modification always conforms the mechanism of valve particularly the tappet clearance. In the actual valve timing, the engine has a period of overlap of valve at the end of exhaust stroke, the period, where both the valves are opened, leads to significant velocity assist in taking the fresh charge. Hence the designer of engine seeks an alternate solution to remain the exhaust valve closed during the intake of fresh charge and prevent the loss. or scavenged exhaust. The Fig.1 shows the valve timing for 4 stroke CI engine by illustrating the Suction stroke, Compression stroke, Power stroke, Exhaust stroke, and at various angle at which the valves of inlet and exhaust open and close.

C. INJECTION TIMING

The performance of CI engines is influenced highly by the design of injection system. In fact the advancement in diesel engine is achieved greatly due to the design in fuel injection system. The main purpose of fuel injection system is to supply fuel under high pressure to the cylinder during the power stroke. The Fig.2 shows the injection timing of four stoke CI engine .Hence the material and design of components should be suggested to withstand higher stresses and perform for duration to be extended that coincides with the durability targets. Great precision for manufacturing and tolerance are required for the system to function efficiently. Fuel must be injected at the respective timing that is the injection timing must be controlled and metered to meet the requirement of power

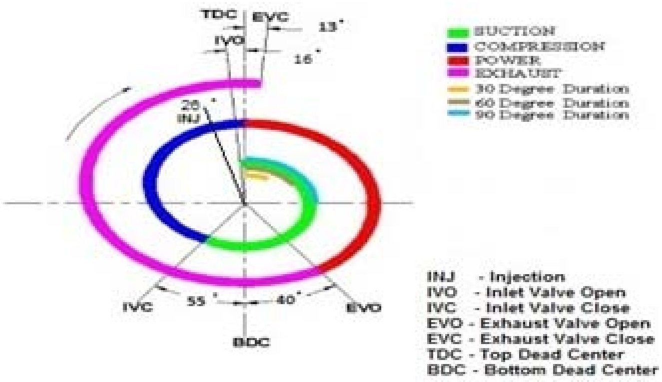


Fig 1 - Valve timing for 4 stroke CI engine

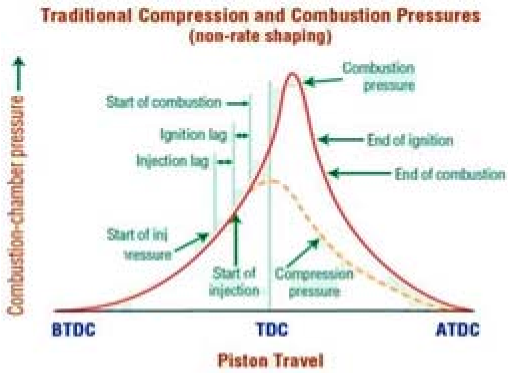


Fig 2 - Injection timing

D. LEAN SIX SIGMA – AN OVERVIEW

Six Sigma (6σ) is a strategy of management of business. Six Sigma is a process for the improvement strategies originally developed by Motorola in 1985. Six Sigma are obtained to recognize and eliminate the reasons for the imperfection and errors in the process of manufacturing, servicing, delivering the products and business. It follows a set of methods for management which includes analysis of numerical data's, generate a sound knowledge of people in this infrastructure within the organisation. The main aim of Six Sigma is to reach **"Breakthrough Performance Improvement"** in business, operation related to customer and performance measures. The operational measures are as follows.

- Customer Satisfaction Rating Score
- Time taken to respond to customer queries or Complaints
- Defect rate in Manufacturing
- Cost of executing a business process
- Yield (Productivity) of service operations or production
- Inventory turns (or) Days of Inventory carried
- Billing and Cash Collection lead time
- The efficiency of equipment (time taken to fix , Downtime, etc.,)
- The rate at which accidents take place
- Time taken to recruit personnel and so on...

Like its predecessors, Six Sigma asserts that:

- The efforts, which are followed continuously to have the process of results in predictable and stable state (i.e. reduce process variation), plays the important role in the success of business.
- The processes of Business and Manufacturing have characteristics that can be measured, analysed, improved and controlled.
- Achieving sustained performance and improvement in quality requires full involvement from the whole organization particularly from the higher level management.

In recent years, Six Sigma is combined with manufacturing (Management) of lean to achieve a new methodology named Lean Six Sigma.

LEAN

Lean is a philosophy and techniques of management fully aimed on continuous “eliminating waste” such that all time process, task or work action is made "Adding the values" as viewed from customer perspective and Lean “waste elimination” targets

EIGHT WASTES

The "Eight Wastes" namely:

- **Over-production**: Making more than what is needed by customer / market demand
- **Over-processing**: Doing more to a product/service (but not perceived as value by customer)
- **Waiting:** For material, information, people, equipment, procedures, approvals and more
- **Transportation:** Movement of products / items during or after production
- **Defects:** Errors, mistakes, non-complying products, services, documents, transactions
- **Rework and waste:** The output of transactions, products does not satisfy the specification. The product should be rectified, fixed, marked done, redone.
- **Movements:** It mainly involved about people, document movement, searching etc.
- **Inventory :** Buffer stocks or resources (Raw, Work in process, FG, Bench staff etc.,)
- **Unused Creativity:** The creativity knowledge of people and skill are ignored by the management.

The unused materials make the organisation to be inefficient, uncompetitive. The lean methods help to dispose waste and contribute the “business agility" through smooth work which flow across the organization resulting in constant fulfilment in needs of customer in an optimum manner.

E. SIX SIGMA METHODOLOGIES:

Six Sigma methodologies have two keys:

DMADV and DMAIC both are inspired by Deming's Plan-Do-Check-Act Cycle

- DMAIC is improved an existing business process
- DMADV is used for creating new product or design of process.

DMAIC

The basic DMAIC consists of the following five methodologies:

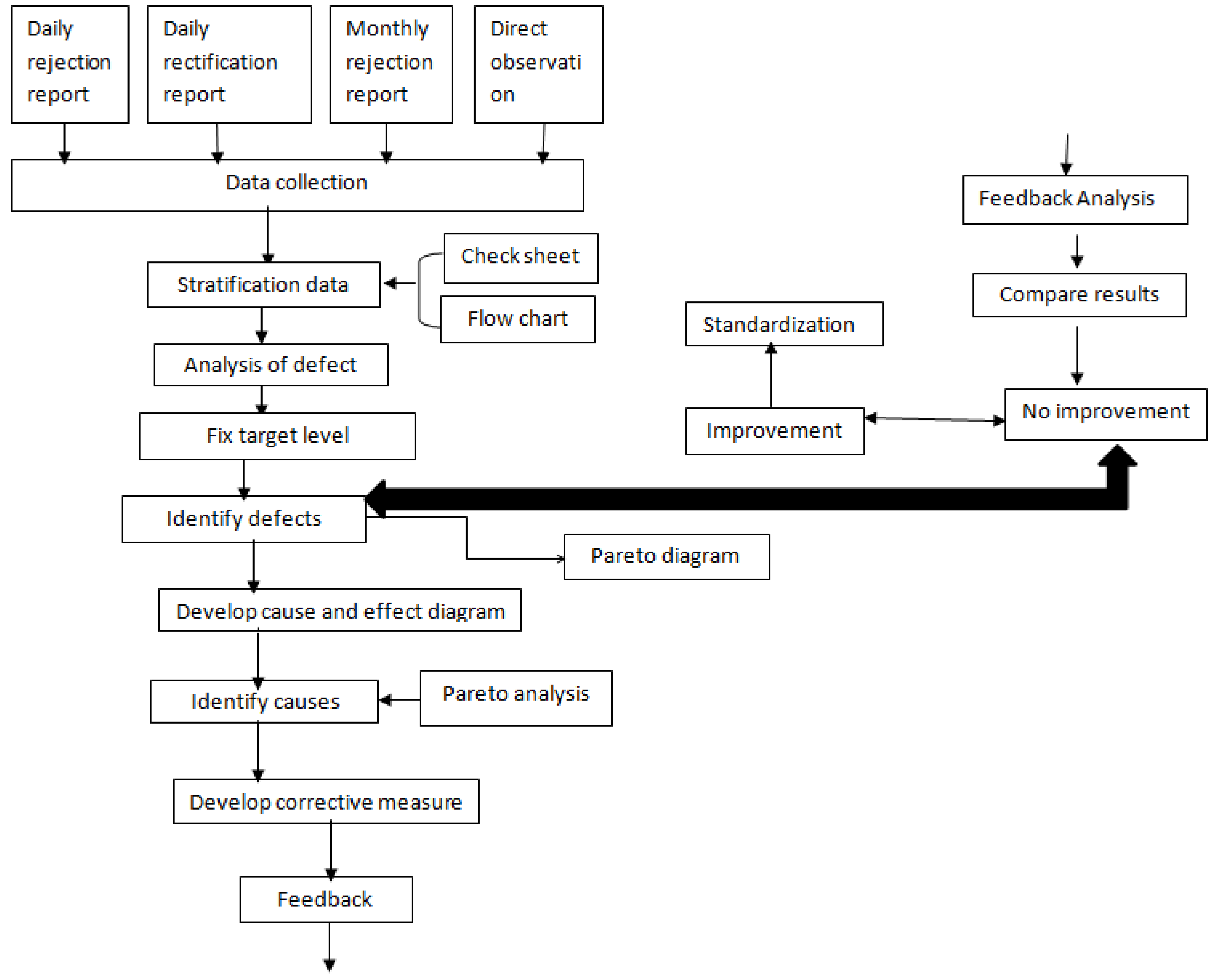
- **Definition** process goals improvement which are consistently related to the demands of customer and the enterprise strategy.
- **Measuring** key on aspects of the current process and collect relevant data.
- **Analyse and Determine** the data for the cause and effect relationships in which it is related and ensure in all factors.
- **Optimize** the process based upon data analysis using techniques like Design of Experiments
- **Control** is ensured that target deviations are rectified before it results in defects. Set up pilot runs to establish the capability of process, production to ensure that any deviations from target are corrected before they result in Defects. Set up pilot runs to establish process capability, move on to production, set up control mechanisms and continuously monitor the process.

DMADV (also known as DFSS - Design for Six Sigma)

The basic methodology consists of the following five Steps:

- **Define** design goats that are consistent with Customer demands and the enterprise strategy.
- **Measure** and identify CTQs (characteristics that are Critical to Quality), product capabilities, production process capability and risks.
- **Analyse** to develop and design alternatives, create a high-level design and evaluate design capability to select the best design.
- **Design** details, optimize the design, and plan for design verification. This phase may require simulations.
- **Verify** the design, set up prior runs, implement the production process and hand it over to the process owners. **Six Sigma Implementation roles**

MODEL FOR CONTINUOUS IMPROVEMENT



II. EXPERIMENTAL DETAILS

A. VALVE TIMING GEARS:

Valve Timing is the important setting in an engine. It is the **"PULSE"** of an engine. Valve timing should be perfect for good performance; better working of an engine. Setting of valve timing is quite typical job because one has to arrange 3 gears in certain order as shown in the fig. 3.

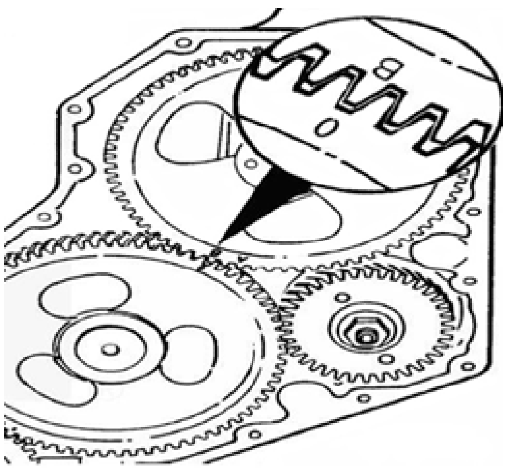


Fig 3 – Valve Timing Gears

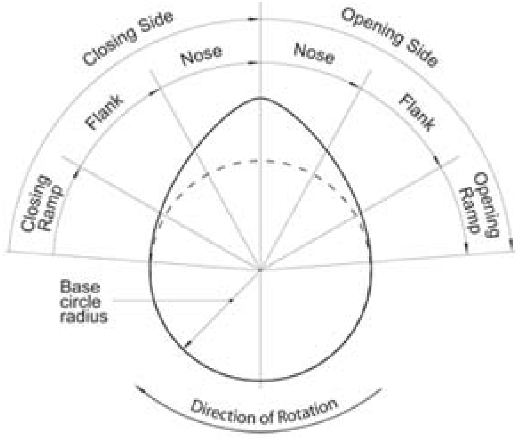


Fig.4 THE CAM LOBE

The three gears are Cam gear, Crank gear, and Idler gear. Each gear has a mark in correct order as shown in the diagram. One has to fix the gears with the mark coincide each other. The marks will be punched while facing of the gears. The cam gear marking should be “7½” gears from the key way. The crank gear keyway should be coinciding to the valley of the gear; it should not coincide to the teeth of the gear. After all this arrangement are correct it should be arrange properly in an order where the markings are coincide with each other. If one tooth changed also it will lead to severe problem in timing of an engine. The valley of the gear is shown in the fig.4 below.

B. CAMSHAFT AND TIMING GEARS:

The table: 1 refers the material used, type of cam shaft, bearing type, no: of camshaft journals, Hardness of camshaft lobes

TABLE: 1 DETAILS OF THE CAMSHAFT

Camshaft type	Forged with integral cams
Hardness of camshaft lobes	Rockwell C60 to C62
Camshaft journals	4
Bearing type	Renewable, bush type
Material	Alloy steel ,Leaded gun Metal/Carbon Bronze

C. CAM GEAR AND CRANK GEAR

The arrow mark in the above Fig.4 is the alignment mark that should coincide with the back plate. The keyway should be straight to the point. From that point the next mark should be 7 and 1/2 tooth distance. This mark is the coincidence mark with the idler gear. The keyway is in the shape (i.e., “|¯|”) which is used to fix the gear accurately in the shaft.

The crank gear, as shown as Fig. 5 is different from cam gear, not in the gear teeth but in crank gear the valley is straight to the keyway as shown in fig.5.The 1st cylinder should be at compression stroke while fixing the gear with the crank shaft. Finally all the 3 gears should be fixed in an order with all the marks coincide with each other gears.

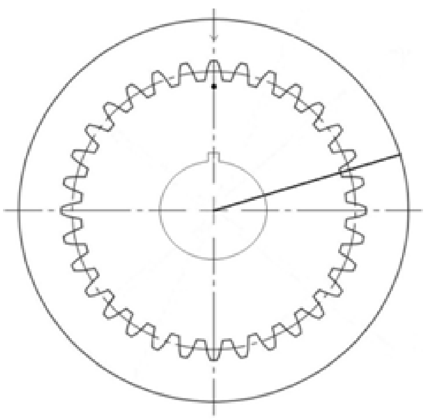


Fig. 5 -Cam gear

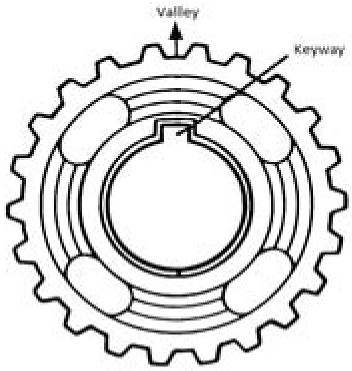


FIG. 6 CRANK GEAR

D. SETTING OF VALVE TIMING:

In flywheel there will be markings 1/6 at 0˚, 2/4 at 120˚ and 3/5 at 240˚.These are the injection timing mark. The firing order is 1-6-2-4-3-5.Rotate the flywheel to 1/6 (1 and 6th cylinder in TDC).Make sure that the 1st cylinder piston is at the compression stroke. To find out whether the piston is at compression stroke, check for the free rotation of the push rod. If it is tight then the piston is not at the compression stroke and then rotates 180 degree in clockwise direction and check once again. The piston is set at the correct angle and stroke fix the cam gear and crank gear with the idler gear with the markings coincide each other, thus obtaining the correct valve timing as shown in fig.7. Cam gear is fixed stable with the markings coincide with the back plate. While fixing crank gear and the idler gear make sure that the cam gear markings didn't change or moved. For the human beings pulse is the important one to make our metabolic activities fast and proper. It should not be fast and as well as it should not be slow, likewise in an engine the timing of the fuel injection in to the cylinder should be proper or else it will lead to bad performance and also wrong valve timing as in fig.8. In Ashok Leyland the injection should start 26˚ before TDC and the table: 2 shows the details of the opening of the valve as followed in Ashok Leyland

TABLE: 2 DETAILS OF THE OPENING OF THE VALVE

Inlet valve opens	At 16˚ before TDCs
Inlet valve closes	At 40˚ after BDC
Exhaust valve opens	At 55˚ before BDC
Exhaust valve closes	At 13˚ after TDC
Injection timing	At 26˚ before TDC

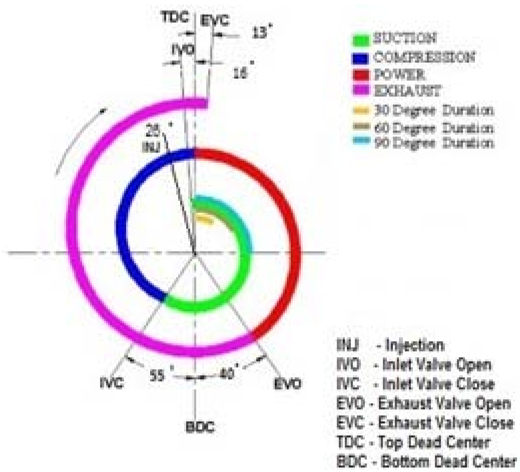


Fig.7 – Correct Valve Timing for 4 Stroke CI engine

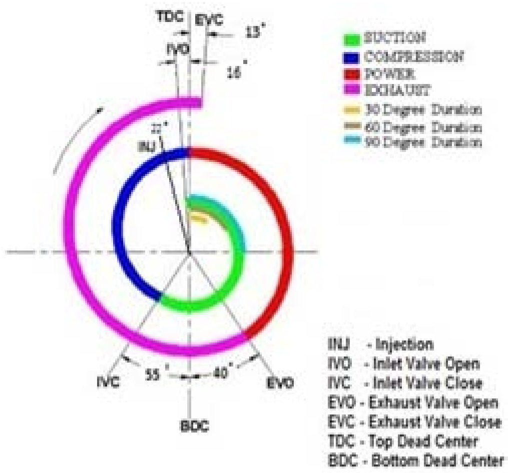


Fig.8 – Wrong Valve Timing for 4 Stroke CI engine

E. SETTING OF INJECTION TIMING:

The timing at which the injection of the fuel takes place inside the cylinder is called injection timing. The fuel is injected in each cylinder at different timings. This is called as firing order, normally there are 2 kinds among 6 cylinder engine 1-6-2-4-3-5 and 1-5-3-6-2-4. In four cylinder engine the fuel will be injected when 2 pistons are at TDC (i.e., end of compression stroke) and another 2 pistons will be at the BDC (i.e., end of suction stroke). In Ashok Leyland engine the injection starts at 18˚before TDC. Always the fuel takes some time to mix up with air and burn efficiently. This is called as ignition delay or ignition lag. The timing should be proper or else loss of power or fuel knock will occur in engine.

F. SPECIFICATION OF HINO ENGINE

The following are some required specification and details of HINO 6 Cylinder engine.

TABLE: 3 SPECIFICATION OF THE ENGINE

Power Output (max)	135 HP at 3000 RPM (without load)
	117 HP at 3000 RPM (with load)
Torque (max)	265 lbs at 1800 RPM
Fuel Consumption	0.358 lbs/ hp/ hr
	218 gms/ kw/ hr
	165 gms/ hp/ hr
Valve Timing	
IVO	16˚Before TDC
IVC	40˚After BDC
EVO	55˚Before BDC
EVC	13˚After TDC
Tappet Clearance Inlet	0.012”
Exhaust	0.016”
Bore Length	104 x 113 mm
PIS – DIS	5.759 LIT
Compression Ratio	17.9 : 1
Weight	420 KG

III. EXPERIMENTAL METHODS

A. PROBLEM SELECTION

Innumerable problems of small and large magnitude occur in any industry. Each problem has its uniqueness. Problem identification and selection is a very important step. The interest was to work on an engine, In engine, which is the most important component in every Automobile, manufacturing, the bottleneck was the test bed rejections. Thus we aimed at rectifying this bottleneck in engine test bed rejection i.e to increase the first pass off percentage of ALH 4 cylinder engines

1. *Various Studies:*

Before plunging into the solution a lot of pre work had to be done, like firstly engine manufacturing was thoroughly studied, this included

- Study on engine parts
- Study on engine assembly
- Study on engine dressing
- Study on engine testing

All this pre work was done so that we had a clear knowledge on engine manufacturing and also to find the key areas which caused major defects in engine test bed.

2. *Data collection:*

The causes for engine rejection were obtained from various departments in Ashok Leyland. These data was being maintained as daily and weekly reports in company. These data was collected and was consolidated as monthly reports. Data for analysis was collected from August 2011- September 2012. After collecting data for engine rejection different causes were grouped under 13 major causes. To find the severity of each cause, frequency of this occurrence of each cause was collected for a Time span of 3 months. i.e. November 2012 - January 2013

3. *Data Analysis*

Various quality tools were used to analyse the collected data. Bar charts were drawn to find the critical reason in each and every major defect. Pareto graph was used to find the critical major cause which on solving will have a drastic effect in increasing the first pass of percentage. Then by using all, these quality charts, the critical causes and reasons to work upon were found. The causes were zeroed in such a way that the solution found could be implemented i.e. the implementation is within the scope of Ashok Leyland.

4. *Solution:*

After finalizing the critical causes and reasons work was carded to solve those problems. A lot of interaction was done with the workers and engineers to achieve a solution for those causes.

5. *Implementation:*

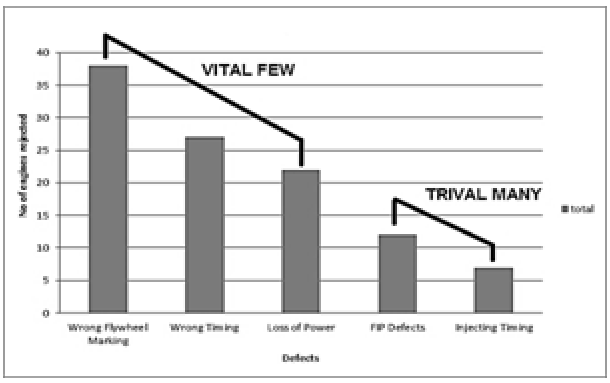
The solution given by us during our project tenure will be implemented by the quality department on a test run basis and implementation of solutions permanently will be based on the results of trial runs in the test beds.

B. MAJOR DEFECTS:

During engine testing, there are various causes due to which an engine gets rejected. Amongst these causes, there can be noticed a clear trend of certain causes occurring frequently. These causes have been segregated and termed as the major causes for engine rejection. The causes have been listed in decreasing trend quality. This trend of defects was noticed during our project study of rejection analysis i.e. from August 2012-November 2012.

C. PARETO GRAPH AND TREND CHART

The graph: 1 shows the relative importance of each rejection and is specified using Pareto Graph. The bar diagram in the chart depict the numerical value of the defects occurred during the period of analysis and the line represents the percentage of each defect in a cumulative way.The graph:2 shows the "Trend Graph" which was drawn in depict to the occurrence of defects in individual months during the analysis.



Graph.1 Pareto Graph

Graph.2 Trend Charts

1. *LOSS OF POWER:*

   Causes:

   - Injector failure
   - FIP delivery failure
   - Wrong timing

2. *FIP DEFECTS:*

   Causes:

   - Fuel delivery less/more
   - Load adjusting screw damage
   - Governor adjusting spring tension less
   - Delivery nozzle loose

3. *KNOCK:*

   Causes:

   - Valve timing wrong
   - Wrong tappet clearance
   - Crankshaft excess projection
   - Connecting rod length excess
   - Cam shaft lobe excess diameter
   - Wrong gear mounting

4. *UNABLE TO START:*

   Causes:

   - Valve timing wrong
   - Fuel injector pump timing reversely set
   - FIP spill timing wrong

5. *VALVE BLOWING:*

Valve blowing is due to escape of compressed charge from the combustion chamber during compression stroke. Due to the air leaks during compression stroke, the required compression pressure is not obtained. It is identified by peculiar noise by engine testers. Valve blowing occurs due to wrong fitment of crankshaft, improper tappet clearance, wrong valve timing and exhaust port block in cylinder head.

Causes:

- Valve stem bend
- Valve seating dimension variation
- Improper tappet clearance setting
- Camshaft dimension wrong

D. *PREDICTING THE ERRORS*

On the analysis of test bed rejection, we found that the engines are mainly \rejected due to the following things

- Valve timing wrong
- Wrong Injection timing
- Wrong flywheel marking
- Parallax error while setting injection timing mark

- Spill cutting mark punching
- Loss of power

1. Valve timing wrong:

Valve timing is a setting which is done by fixing the gear in an order as explained before. Each gear has a marking on it. Those markings should coincide with each other gears. These gears are being fixed in the engine manually. During this process the marking coincide with other gear is changed by 1 to 2 teeth's. Due to this error the engine gets knocking, valve blowing and further such kind of problems.

2. Wrong flywheel marking:

The wrong flywheel marking is due to the play arising between the rotary table and the fixture in it. Since there is no clamping device for holding the flywheel, the play is more between the surfaces. Since only a single Dowell pin is used to locate the flywheel hole from the centre. Next thing is there is only one flywheel marking machine which marks more than 100 flywheels a week, so that the dowel pin gets worn out. Due to all of this the marking is varied as shown in fig.9

3. Wrong Injection timing:

Injection timing is the time at which the fuel is injected to the particular cylinder at its compression stroke. The time of injection should be accurate when the piston reaching the TDC. Normally the injection starts 26˚ before TDC. But in some engine the injection timing varies due to the wrong timing setting in the FIP as shown in fig.10. The wrong timing mark in the FIP is due to the improper punching of the mark with the chisel. Even if the mark is perfect one has to set the timing by matching the timing mark in the flywheel. Sometimes in both of this case the error occurs.

4. Parallax error:

Parallax error is a difference in the position of apparent of an object when it is viewed along two different lines of sight as shown in fig.12. Parallax arises due to change in viewpoint but that can occur due to motion of the observer, or of that which is being observed, or of both. A simple example of parallax that can be practised in everyday life is the motor vehicles dashboard especially the speedometer needle-style. The needle is viewed from directly in front, the speed shows exactly 60 but viewed from the passenger's seat; experience a slight variation about 55 or 65 which is due to the viewing angle.

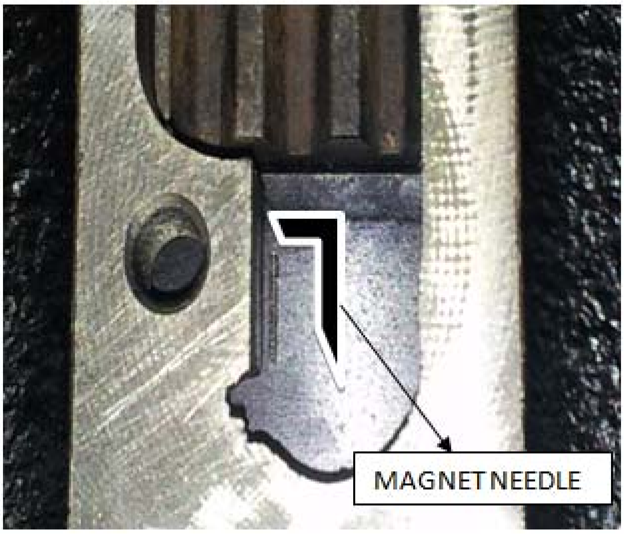


FIG: 9 Timing Mark in flywheel.

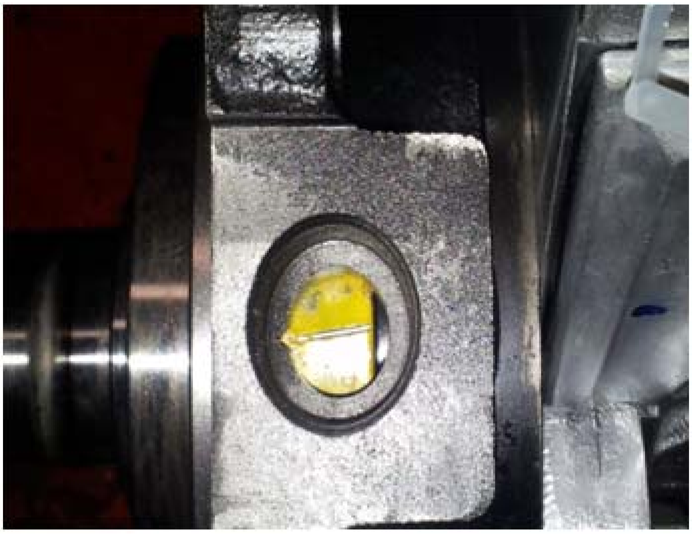


Fig. 10 Wrong Injection Timing

5.Spill cutting mark punching

This spill cutting is the main mark for injection timing in FIP. This mark is punched using a special tool as shown in fig.14 below, while punching there it makes improper marking as shown in fig 3.2 (cross marking). Before punching this mark one has to fix the timing in the FIP, the timing of fuel to be injected in to the cylinder (as per the firing order). The FIP is fitted in the spill marking machine and the timing is set in it and the mark is punched with the chisel.

Fig. 11 Before Punching Timing Mark In FIP

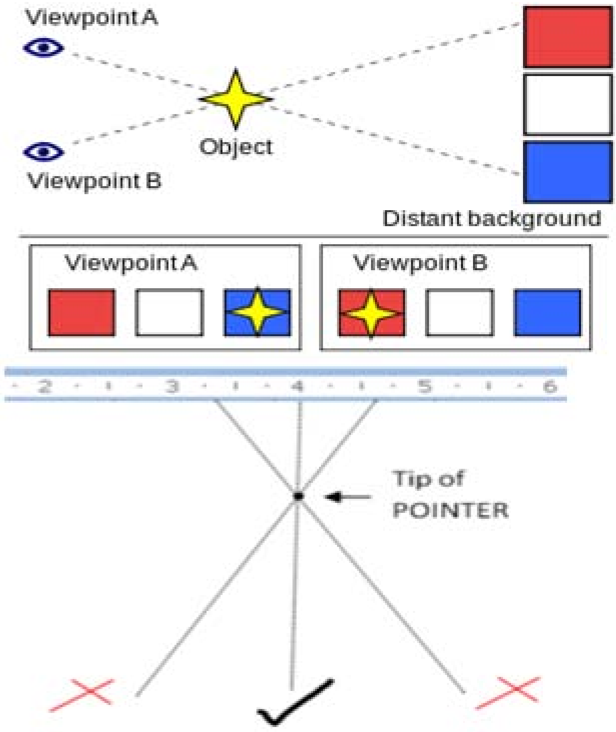


Fig: 12 Parallax Errors

6. Loss of power:

The loss of power will occur when the fuel is not injected fully in to the cylinder. There are several more things that can cause power loss in a diesel engine a clogged injector nozzle is the most likely culprit, since the amount of power they make is directly tied to how much fuel is injected in to the cylinder at high pressure. Restricted fuel flow will cause a lean combustion mixture reducing power output. The loss of power is due to the faulty tappet clearance, because the air will leak out through valves during compression stroke so that diesel will be injected at the end of stoke and no power will get inside the cylinder. This problem is called as valve blowing. The setting of injection timing in FIP and flywheel is shown in the figure below. The above fig 15 has shown the setting of injection timing in flywheel and in FIP. The setting is done by the mark punched in both the flywheel and in the FIP. One has to coincide the mark with each other perfectly or else the injection timing will vary and it will lead to loss of power in engine or fuel knock will occur in the engine. The parallax error is the main cause for the miscoincedance. The problem cause is explained already in the above chapter.

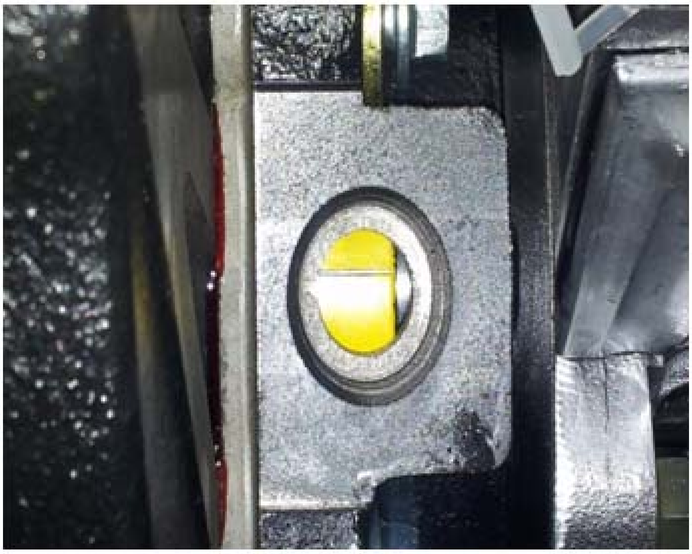


Fig: 13 Parallax Errors in FIP

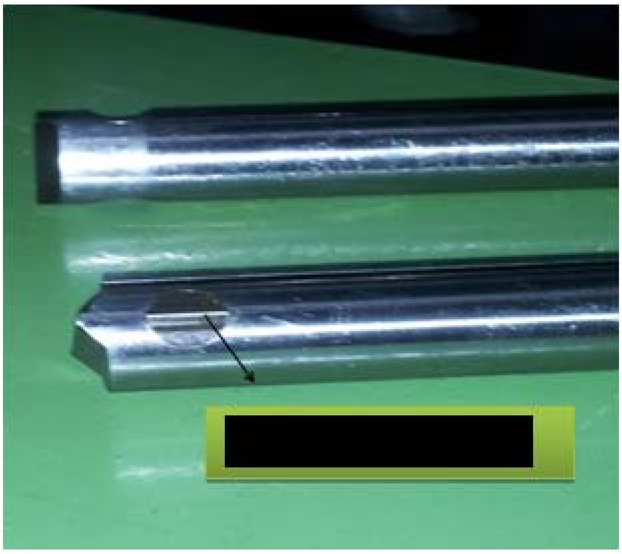


Fig: 14 (a) Chisel INJECTING TIME MARK TOOL

Fig: 14 (b) Chisel INJECTING TIME MARK TOOL

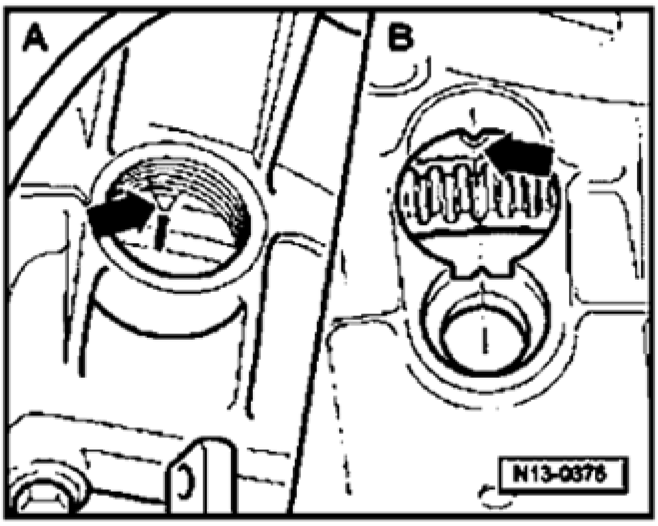
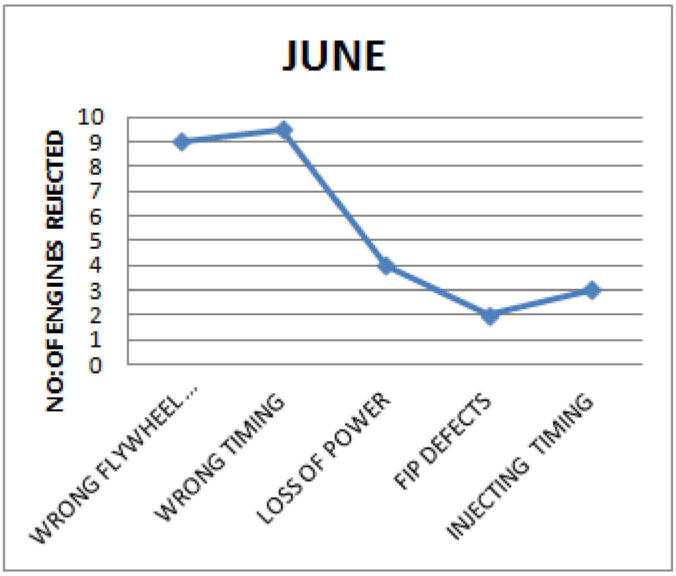


Fig: 15 Injection Timing Setting in FIP & Flywheel (a) - FIP, (b) - Flywheel

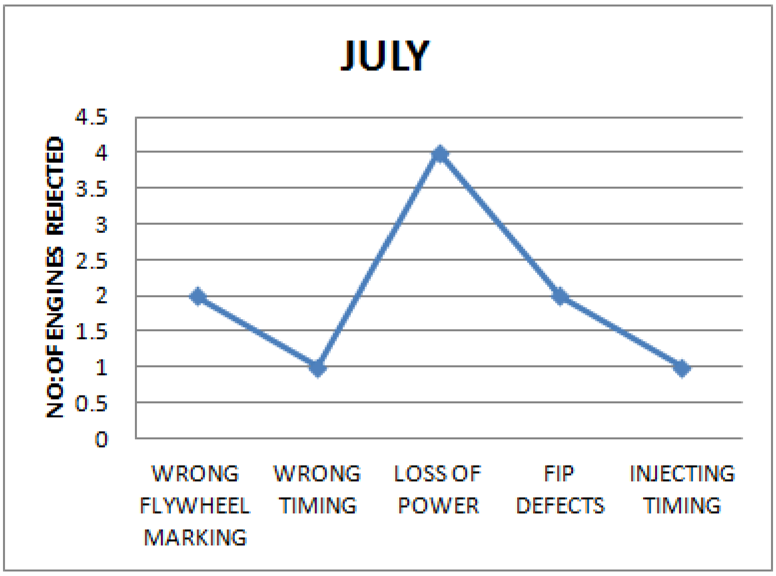
IV. RESULT AND DISCUSSION

A. GRAPHICAL ANALYSIS

In CI engine it is different from the spark ignition engine because the atmospheric air is sucked inside the combustion chamber and is being compressed by the movement of the piston and the diesel fuel is injected at the end of the compression stroke. The timing of injection of fuel is very much important for better running of engine. As we explained above the injection timing and valve timing is the pulse of an engine. The valve timing changes only because of wrong fitment of the cam gear with the back plate. First of all the keyway should be fixed accurately and mark in the gear should coincide with the mark in back plate. Most of time the gear will move while fixing the next gears (crank and idler gear) this will lead to wrong injection timing. Wrong markings in flywheel were also the cause for the engine rejection. In Ashok Leyland each engines have its own set of flywheels. Injection timing in every kind of flywheels are marked in a single CNC machine. As so many flywheels were marked per week, the jig (locator pin) worn easily and because of this the timing marks go wrong. Finally it will lead to injection timing wrong during testing. The parallax error is the major cause for the rejection of engines. This is a human error which happens during the injection timing mark coincidence in the FIP and Flywheel as shown in the fig.15 before.

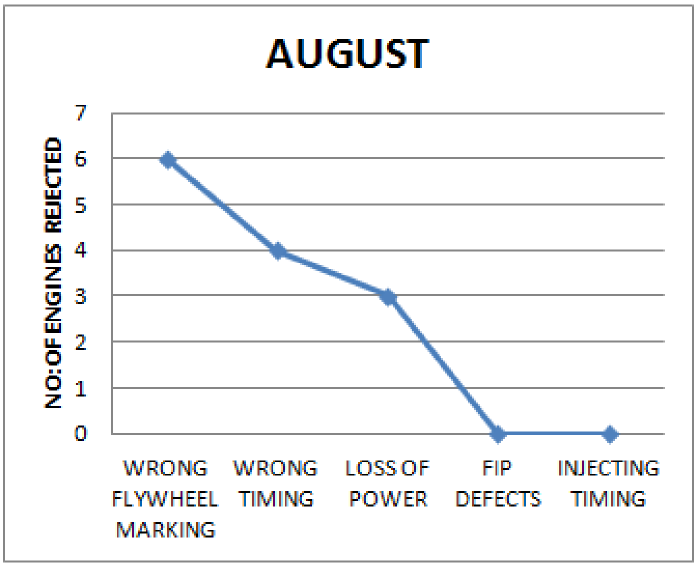


Graph.3 – Engine Rejection Rate in June

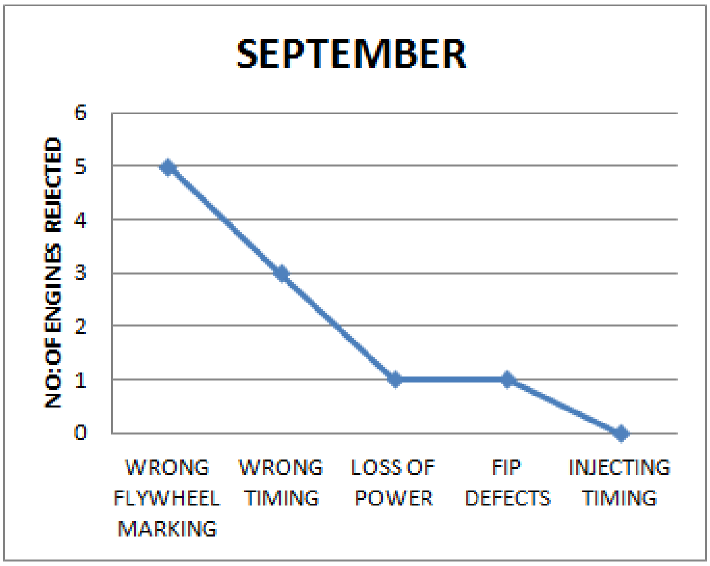


Graph. 4 - Engine Rejection Rate in July

The above graph.3 shows the defects occurred in the month of June and number of engines rejected due to different problems as represented.The above graph.4 shows the defects occurred in the month of July and number of engines rejected due to different problems as represented.

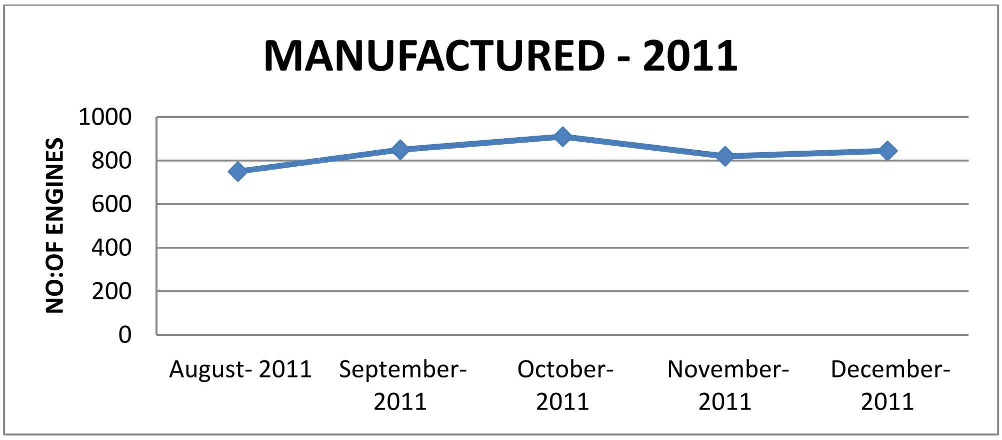


Graph. 5 - Engine Rejection Rate in August



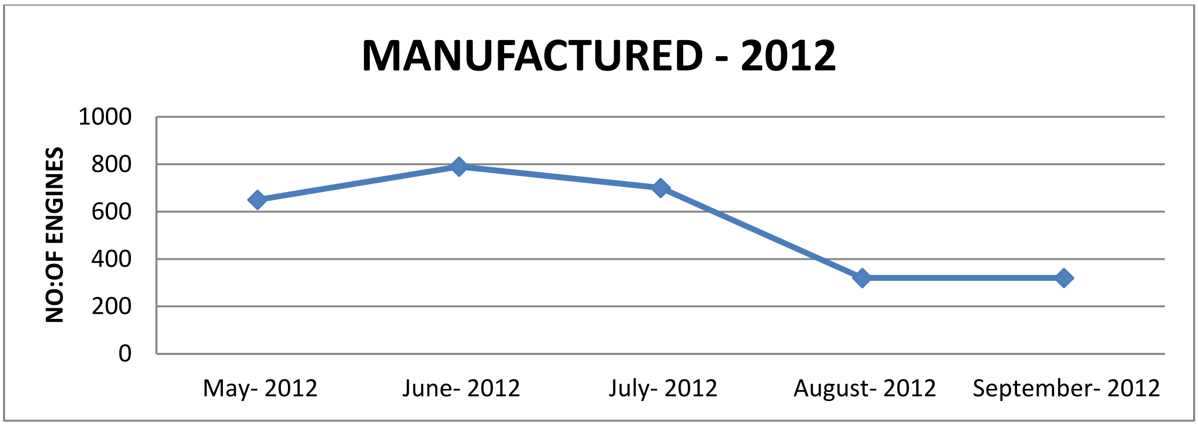
Graph.6 - Engine Rejection Rate in September

The above graph.5 shows the defects occurred in the month of August and number of engines rejected due to different problems as represented. The above graph.6 shows the defects occurred in the month of September and number of engines rejected due to different problems as represented.



Graph. 7 Engine Manufacturing Statuses – 2011

The above graph.7 shows the status of No of engines manufactured in the year 2011 as represented above. The above graph.8 shows the status of No of engines manufactured in the year 2011 as represented above.



Graph.8 Engine Manufacturing Statuses – 2012

V. SUMMARY AND CONCLUSION

A. SUMMARY

Finally we helped in rectifying and giving a solution to the problem to which the rate of rejection of engine has been decreased. As two of our concepts have been implemented and other is in review for implementation

B. SUGGESTIONS

1. Valve timing wrong rectification:

The valve timing changes only because of wrong fitment of the cam gear with the back plate. First of all the keyway should be fixed accurately and mark in the gear should coincide with the mark in back plate. Most of time the gear will move while fixing the next gears (crank and idler gear). So one has to tighten the locknut and check the rotation of the gear. Once the cam gear is fixed tightly and stationary, the idler gear should be fixed without shaking anything. While fixing the idler gear check whether the keyway in the crank gear is fixed properly in crankshaft when the 1st piston is at TDC. Once all the above procedure is done fix the idler gear with the markings coincide with each other gears (cam and crank gear). The markings are explained in the fig 3 and 5,6.

2. Flywheel Marking:

To reduce the play between the surfaces a proper clamping device has to be placed. A second locating pin has to be fixed to fixture. So the flywheel will be fixed tightly in the mounting table without any shake. A sleeve can be attached to the Dowell pin locator so it can be replaced for every 300 numbers of flywheels after it marked.

1. Injection timing & spill mark

1. Wrong injection timing will result in the major problems
   a. Fuel knock
   b. Loss of power
2. The fuel knock will happen when the injection is advanced. i.e., when the fuel is injected just 10 ˚ to 15 ˚ before TDC.
3. The fuels will get busted inside the cylinder and it will damage the engine parts.
4. Even though the power output is high because of blasting of fuel instead of burning but it is bad for engine life.
5. This problem will occur rarely because this much variation in injection timing will never come.
6. Due to the wrong punching of mark in the FIP this problems will come.
7. The parallax error makes the worker to fix the timing wrongly, either advancing the injection timing to 28 ˚ or delaying it to 22 ˚.
8. Here actual injection should start 26 ˚ before TDC.
9. To avoid cross spill marking we can use “Two” tapered triangle grooves in the chisel. (Refer fig 14).
10. By using a magnifying lens with a mark in centre, we can avoid parallax error while setting injection timing.

2. Loss of power

1. The loss of power is the most common problem when the engine is not delivering proper power output at the particular load.
2. This will be rectified by applying **Moore's** test.
3. This is very simple step by step procedure to check the fault in particular cylinder.
4. First of all check the tappet clearance because the clearance will change once the heat is obtained in valves.
5. If tappet clearance is perfect then check the FIP whether the fuel supply is perfect, sometimes the clogging of fuel due to some blockage in the delivery pipe or in injector nozzle will stop the fuel supply to particular cylinder.
6. This can be done by checking cylinder one by one.
7. Run the engine in test bed and loosen the delivery pipe at injector end in the 1st cylinder. If the power loss further then fuel supply in 1st cylinder is perfect.
8. Likewise repeat the process for the other cylinders, once the loss power remains when that particular cylinder fuel is cut then the fault is in that cylinder only.
9. The problem may either in faulty injector or at the plunger in FIP.

3. Flywheel mark matching (Parallax Error rectification):

1. By using a magnetic needle, we can avoid parallax error by co-inciding the mark accurately from one angle. (Refer fig 9).
2. There is no need to change the design of the flywheel housing since this magnetic needle is easy to stick and remove once the timing is set perfectly.
3. This requires very less expense to make this magnetic needle and 1 needle is more than enough to coincide the injection timing for more than 100 engines.
4. Thus we can avoid the parallax error (refer fig. 12 for parallax error)

C. CONCLUSION

Thus it helped in improving the first pass off percentage of engine during testing and reduced the rejection percentage.

REFERENCE

[1] Adams, M., Kiemele, M., Pollack, L., and Quan, T. (2003) Lean Six Sigma: A Tools Guide, Air Academy Associates, Colorado Springs, Colorado.

[2] Albright, T. and Lam, M. (2006) "Managerial Accounting and Continuous Improvement Initiatives: A Retrospective and Framework," Journal of Managerial Issues, Summer, Vol. 18 Issue 2, pp. 157-174.

[3] Box, T. (2006) "Six Sigma Quality: Experiential Learning," SAM Advanced Management Journal, Winter, Vol. 71 Issue pp. 20-23.

[4] Brue, G. (2002) Six Sigma for Managers, McGraw Hill, New York, New York.

[5] Chowdhury, S. (2002) Design For Six Sigma, Dearborn Trade Publishing Co., Chicago, Illinois.

[6] Creveling, C., Slutsky, J., Antis, Jr., D. (2003) Design for Six Sigma in Technology and Product Development, Prentiss Hall, Upper Saddle River, New Jersey.

[7] de Mast, J. (2006) "Six Sigma and competitive advantage," Total Quality Management & Business Excellence, May, Vol. 17 Issue 4, pp. 455-464.

[8] Dedhia, N. (2005) "Six sigma basics," Total Quality Management & Business Excellence, July, Vol. 16 Issue 5, pp. 567-574.

[9] Donnelly, S. (2006) "Lean and Mean", Time, July 10, 2006, pp. A1-A4.

[10] Eckes, G. (2001) The Six Sigma Revolution, John Wiley and Sons, New York, NY.

[11] Harry, M. and Schroeder, R. (2000) Six Sigma: The Breakthrough Management Strategy Revolutionizing the World's Top Corporations, Doubleday, New York, NY.

[12] Holtz, R. and Campbell, P. (2004) "Six Sigma: Its implementation in Ford's facility management and maintenance functions," Journal of Facilities Management, March, Vol. 2 Issue 4, pp. 320-329.

[13] Kiemele, M., Schmidt, S. and Berdine, R. (1997) Basic Statistics: Tools for Continuous Improvement, 4th Edition, Air Academy Press, LLC, Colorado Springs, Colorado.

[14] Knowles, G., Whicker, L., Femat, J., Canales, F. (2005) "A conceptual model for the application of Six Sigma methodologies to supply chain improvement," International Journal of Logistics: Research & Applications, March, Vol. 8 Issue 1, pp. 51-65.

[15] Lawton, L. (2004) "The Power of Ultimate Six Sigma: Keki Bhote's Proven System for Moving Beyond Quality Excellence to Total Business Excellence," Journal of Organizational Excellence, Summer, Vol. 23 Issue 3, p108.

[16] Linderman, K., Schroeder, R., Zaheer, S., Choo, A. (2003) "Six Sigma: a goal-theoretic perspective," Journal of Operations Management, March, Vol. 21 Issue 2, pp. 193- 203.