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Tappet Noise Reduction in Motorcycle Engine

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***Abstract* - The tappet noise is a major concern in Internal Combustion (I.C.) Engines. The tappet noise refers to the noise made by Lash or clearance between rocker arm and valve stem in an engine. It also occurs as a result of lash or clearance between valve lifter and valve stem at start up for at least 30 seconds. The tappet noise is characterized by its characteristitic "tak-tak" sound which is clearly audible on the engine dynamometer at 1400 r.p.m. Tappet noise predominates when engine is in hot condition, i.e. after 4-5 kms of running after it is assembled on the vehicle frame. Earlier there were cases of about 300-350 (average) engines suffering from tappet noise out of the average 1000 engines assembled at an average daily. This led to increase in engine rework after its assembly and considerably leading to annoying noise. Investigations suggested that the camshaft design was the major source of tappet noise. Following that the camshaft design was changed and a new camshaft was introduced by replacing it with the older design of camshaft. To further reduce the no of cases to minimum the further investigations was started. It was concluded that the change in design does not contribute to the tappet noise anymore. Now the investigations on engine assembly tappet setting station started (both at sub assembly and main assembly station) and it was concluded that the noise was coming due to the improper setting of the tappets (inlet and exhaust) at the sub assembly of tappet setting station and at the main assembly station.**

***Keywords* - Tappet Noise, Shim, Decibel, Valve Stem, Lash**

I. INTRODUCTION

Project Description

Aim of the project- To reduce the tappet noise in the motorcycle engine by giving and implementing ideas and suggestions during the tappet setting at the main assembly and sub assembly stations.

Target of Project - To Reduce The Number Of Cases Of Engines Having Tappet Noise From 40-45 (Average) Daily To Minimum And To Reduce Noise Level Of Engines From 78 Db To 70 Db.

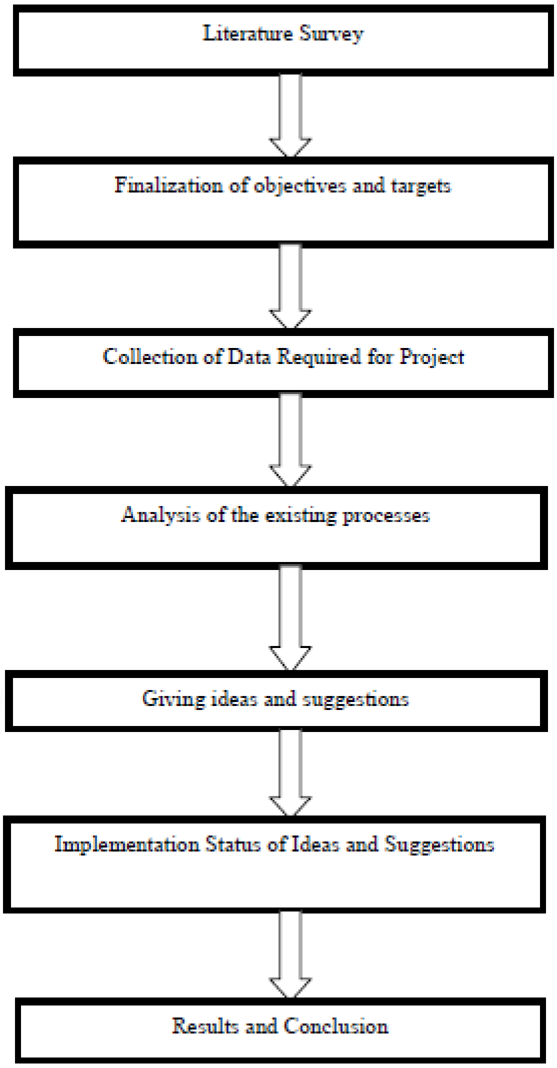
Need and Justification - Any Products Success Depends Upon Satisfaction Of Customer. Customer Mostly Concerned About Two Things I.E. Quality And Price. To Lead The Market And To Beat Competitors, One Should Make The Product Having Fine Quality With Minimal Cost. This Can Be Done By Eliminating The Defects Which Are Very Critical And Need To Be Eliminated For Better Engine Efficiency And Smoother Running.

Justification of Choice

Importance of Problem:

- Loss of efficiency
- Unwanted noise
- Engine rework after vehicle assembly
- Reduces engine life
- Customer dissatisfaction

1.1 Scope of the project



Flow Chart 1.1 Project Scope

II. LITERATURE SURVEY

SAE Papers

S.No.	Document	Title	Comment
1	SAE Paper No-1999-01-1711	An Investigation of Valve train noise for sound quality of I.C. engines	Information on valve train noise and sound quality of I.C. engine
2	SAE Paper No-970004	Amorphous Carbon coatings for low friction and wear in bucket tappet valve trains	Information on effect of carbon coatings to reduce wear and friction in valve trains
3	SAE Paper No-2001-01-1886	Applying hard thin coatings to tappet to reduce friction	Use of hard coatings such as DLC,Mos2,CrN or TiN to tappets to reduce coefficient of friction
4	SAE Paper No-962030	A valve train friction and lubrication analysis model and its application in a cam/tappet wear study	Information on analysis of friction and lubrication model and application to cam/tappet wear study
5	SAE Paper No-952472	A study of friction characteristitics of engine bearing and cam/tappet contacts from the measurement of temperature and oil film thickness	Impact of oil film thickness measurement to study friction characteristitics of cam/tappet contact

III. TERMS AND DEFINITIONS USED

What is Tappet

A tappet is a mechanical part that reciprocates to receive or transmit intermittent motion, especially the part of an internal-combustion engine that transmits motion from the camshaft to the push rods or valves. I.e. the **tappet** is that part, also termed a **cam follower** that runs on the camshaft and is made to move vertically by the action of the rotating cam. In an overhead valve engine, this tappet is fitted low down in the engine block. From there it drives a long thin pushrod, up to the top of the engine, above the cylinder head. Here the **rockers**, arranged on a **rocker shaft** beneath the **rocker cover**, reverse the direction of the valve movement to press the valves downwards to open them.

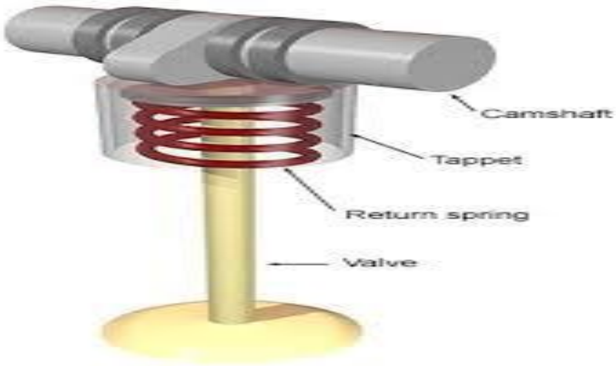


Figure 3.1. Tappet Assembly

What is Tappet Noise

A tappet noise refers to the noise made by the Lash or Clearance between the **Rocker arm** and **Valve stem** in a car. It also occurs as a result of the lash or clearance between the **valve lifter** and **valve stem** at start up for at least 30 seconds. It normally occurs if oil is not regularly changed.

Figure 3.2.Tappets in Motorcycle

IV. UNDERSTANDING THE PROBLEM

Introduction

In motorcycle engine, the problem of tappet noise is a big concern. The tappet noise is characterized by characteristitic "tak-tak" sound which is very annoying. The tappet noise is audible easily on Dynamometer (Engine and Chassis) at about 1400 rpm and predominates when engine is hot i.e. after 4-5 kms of running after it is assembled on the vehicle. The process of identification of tappet noise is to run the vehicle for 4 to 5 kms and by hearing the noise by placing the ear close to the engine. The tappet noise comes from the cylinder where the I.C. engine parts such as camshaft, inlet and exhaust valves, rocker arm and valve stem are present.

In M2W Ltd, earlier the situation was that about 350 engines out of the 1000 engines assembled daily at an average were recognized with the tappet noise. Following this the first major step was taken by the company to reduce the effect of tappet noise. In this step, the design of camshaft was changed as there were faults with the current design.

This change in the design of camshaft subsequently reduced the no of cases to around 40-45 but still 40-45 is a huge number. Also it leads to engine rework after the vehicle assembly and for that extra man is required to perform the tappet setting and also tappet setting process consumes time of about 10 to 15 min. The main cause for the tappet noise in I.C. engine is the play between rocker arm and valve stem.

When engine runs at high speed, due to the excess clearance between valve stem and rocker arm, the striking action of the two components take place, greater the speed of the engine, greater will be the striking action and greater will be the sound produced.

Effects of Tappet Noise

The effects of tappet noise are as follows:

- Loss of engine efficiency
- Unwanted noise from the engine

- Overheating of engines
- Engine rework after vehicle assembly
- Reduces engine life
- Increases fuel consumption
- Decreases fuel efficiency
- Customer Dissatisfaction

Analysis of the Problem

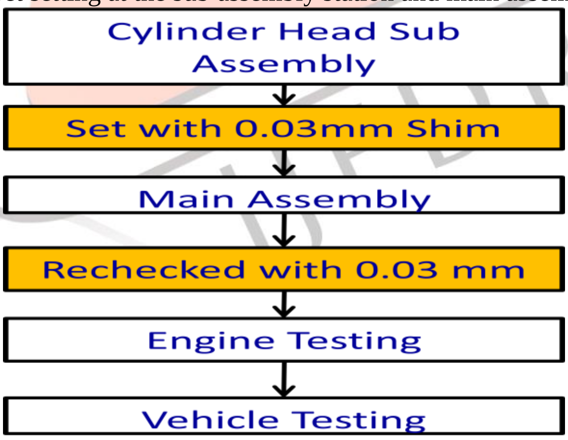
After the analysis of the problem, it was found out that the present design of the camshaft does not contribute to the problem anymore. In fact the problem was due to the improper tappet setting and improper measures taken while setting the tappets on sub-assembly and main assembly stations. There were various issues during the tappet setting on the sub-assembly and main assembly station which were contributing to the problem of tappet noise.

Now the theme of the project was to suggest and implement ideas during the tappet setting at the sub assembly and main assembly station so as to reduce the problem of tappet noise in motorcycle engine.

Figure 4.1. Mahindra Centuro Motorcycle engine

V. TAPPET SETTING PROCESS

Assembling and process of engine tappet setting at the sub assembly station and main assembly station is as follows:



Flow Chart 5.1 Tappet setting process

From the above flow-chart , out of the total process, the process of tappet setting at the main assembly and the sub assembly station is the most critical task and improper tappet setting at the two stations eventually led to the tappet noise.

Figure 5.1 Tappet setting at sub assembly station

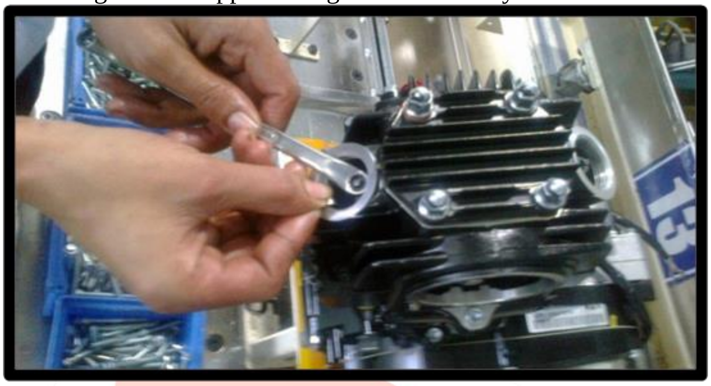


Figure 5.2 Tappet setting at main assembly station

VI. EXPERIMENTATION

The experimentation or data collection process involves the collection of the data of the no of faulty engines out of the total number of engines assembled and to plot the graph between number of defects and days.
The data was collected initially for 10 days and the no of defects were recorded and the graph was plotted.

Graphical Representation (current level)

S. NO.	DAY	NO. OF DEFECTS(OUT OF 1000)
1	1	42
2	2	45
3	3	43
4	4	36
5	5	39
6	6	34
7	7	52
8	8	45
9	9	28
10	10	35

Table 6.1 No of defects table

The above data can be represented in the graphical form as follows:

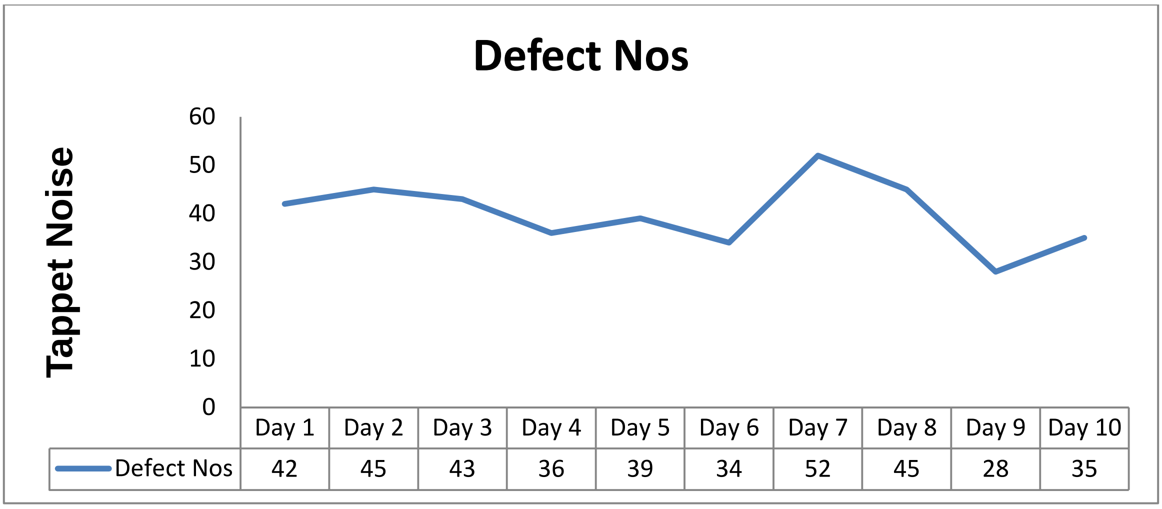


Figure 6.1 Graphical representation (Current Level)

Graphical Representation (present and target level)

From the table 8.1, it can be seen that the highest no of cases were recorded on day 7 and lowest no of cases were recorded on day 9, so the average can be taken as:

Present (average) = (maximum cases + minimum cases)/2 i.e.

(52+28)/2=40

The same can be represented on graphical level as follows:

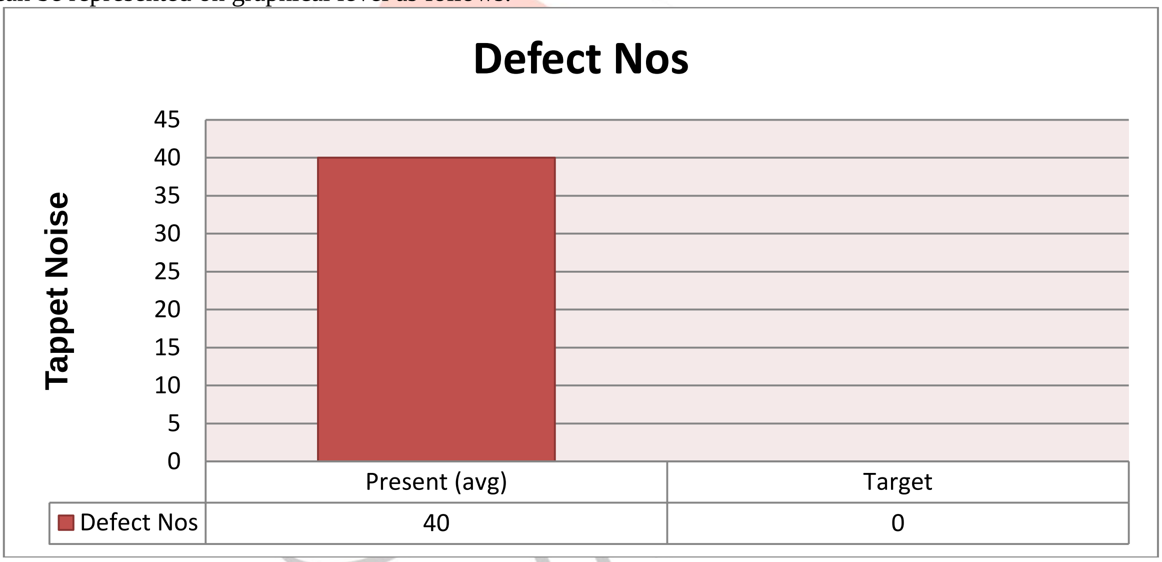


Figure 6.2 Data Collection (Target level)

Noise Level data of Engines

To calculate the noise level of engines, the noise level of 5 normal engines and 5 tappet noise engines was calculated by the help of noise level meter also known as decibel meter which gives the value of sound level in decibel (db) which is the unit to measure the noise level and the results were obtained as follows:

- Noise Level of Normal Engine=70 db
- Noise Level of Tappet Noise Engine=78 db

Here the decibel meter is kept at the distance of 1 foot from the noise source and the readings were taken.
The data obtained is as follows:

Noise Level Data of Normal Engines

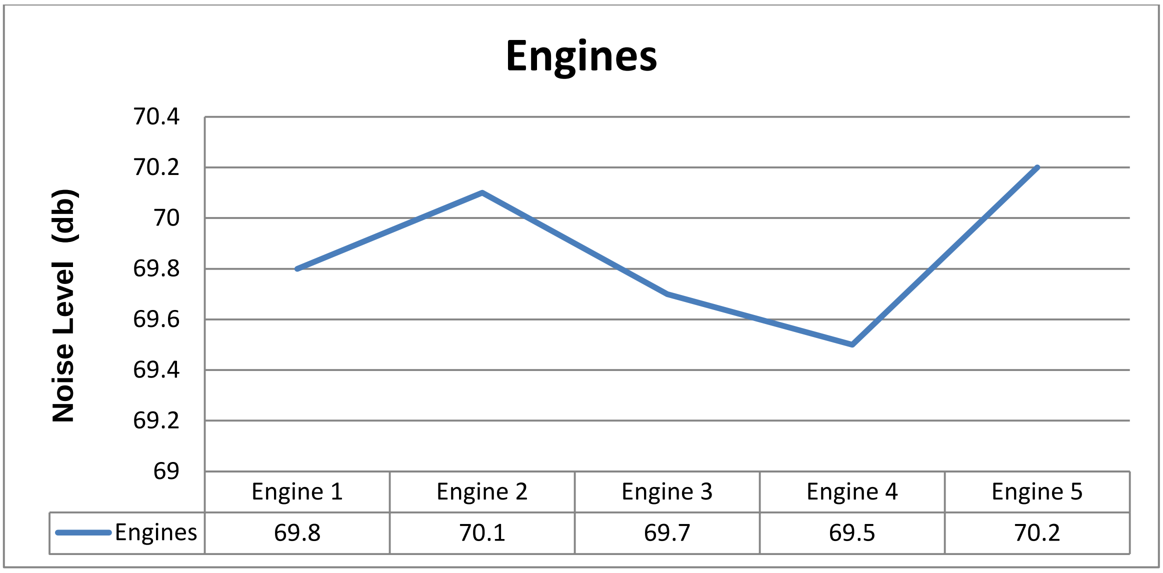


Figure 6.3 Noise level data of normal engines

Hence the average noise level of normal engines is 70 db

Noise Level data of Tappet Noise Engines

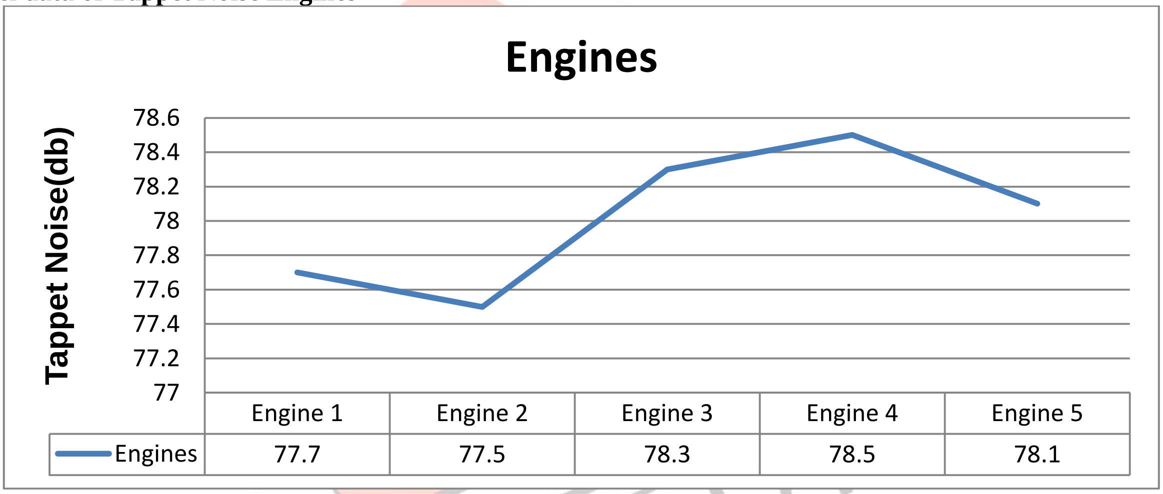


Figure 6.4 Noise level data of tappet noise engines

Hence the average noise level of tappet noise engines is 78 db

The difference in the noise level of different engines is due to the difference between the gap between the valve stem and inlet and exhaust valves. Usually the gap of 0.03 mm or 30µ is kept standard but as the gap increases beyond 0.03 mm i.e. 0.04 mm, 0.05 mm and more, the tappet noise starts to predominate.

To check the inlet and exhaust gap of tappet noise engines, an activity was performed. In this activity, the inlet and exhaust gapes of the tappet noise engines were checked by insertion of shim or feeler gauge of 0.03µ, 0.04µ and 0.05µ, the greater the shim will qualify, the greater will be the noise.

VII. Analysis

The analysis is performed in three stages, these three stages are:

1. Analysis (Level 1)
2. Analysis (Level 1 Stratification)
3. Analysis (Level 2)

The details of the analysis are as follows:

Analysis (level 1)

The level 1 analysis is represented by a fish bone diagram, the fishbone diagram looks like the skeleton of fish and hence the name is fishbone diagram. The fishbone diagram consists of 5 factors which contribute to the problem. These 5 factors are:

- **Man**
- **Machine**
- **Method**
- **Material**

- **Design**

The factors are together known as (4M 1D) factor. These factors indicate the contribution towards problem. This diagram indicates whether the factors namely, Man, Machine, Method, Material of Design is the source for the problem.

The fish bone diagram to identify the problem is as follows:

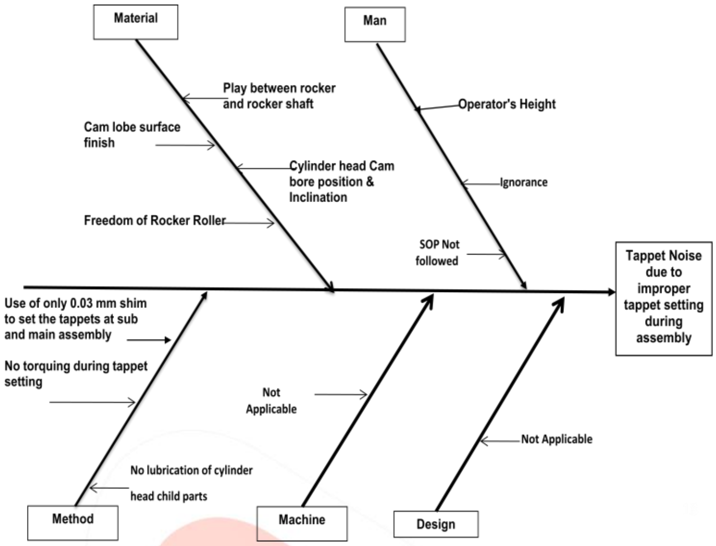


Figure 7.1 Fish bone diagram

From the above diagram, it can be concluded that the contributing factors to the tappet noise problem can be as follows:

1) **Man**
   - SOP not followed
   - Operator's height
   - Ignorance
2) **Material**
   - Play between rocker and rocker shaft
   - Cam lobe surface finish
   - Cylinder head cam bore position and inclination
   - Freedom of rocker roller
3) **Method**
   - Use of only 0.03 mm shim to set the tappets at sub assembly and main assembly
   - No lubrication of cylinder head child parts
   - No torquing during the tappet setting
4) **Machine**
   - Not Applicable
5) **Design**
   - Not applicable.

Analysis (level 1 stratification)

This is the second step after level 1 analysis, in this stage the root causes for the problem are listed according to the relationship with the problem. The relationship is listed according to the contribution to the problem. The three relationships are as follows:

1. **Weak relationship:-** It has little or no effect to the problem
2. **Medium Relationship:-** It has effect greater then weak relationship but lesser than strong relationship and is moderately important
3. **Strong Relationship:-** It has the highest effect to the problem and is very important

Out of the level 1 analysis, the key causes are selected and are listed according to the relationship related with the problem. The relationship table for level 1 stratification is as follows:

S.No	Causes	Relationship
1	SOP Not followed	△
2	Operator's height	○
3	No lubrication of cylinder head child pats	◎

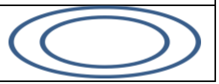
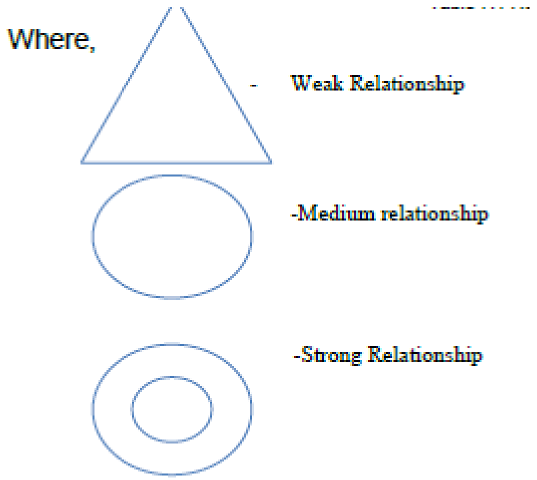
4	Use of only 30µ (30 mm) feeler gauge or shim to check inlet and exhaust tappet gap	
5	No torquing tool used during tappet setting	

Table 7.1 Relationship table



Analysis (level 2)

The level 2 analysis is the third step in analysis. This step consists of listings of various causes taken in fishbone diagram of step 1 under the category 4M (Man, Material, Method and Machine) and 1D (Design) followed analysis on them and action taken on each and every problem. The level 2 analysis table is the brief summary of the action taken over the problem and the type of analysis performed on it.

The table for the level 2 analysis is the causes/issues related to the 4M and 1D, analysis performed on each and every cause and action taken to eliminate the problem.

The table of analysis 2 is as follows:

Table 7.2: Level 2 Analysis Table

S. No	4M,1D	CAUSES	ANALYSIS	ACTION TAKEN
1	Material	Play between rocker and rocker shaft	Found as per design	
		Cylinder head Cam bore position & Inclination	Found as per design	
		Freedom of Rocker Roller	Found as per design (deflection 10 to 18 µ)	
		Cam lobe surface finish	Found in 1-2 cases but does not create much effect on tappets	
2	Man	SOP Not followed	SOP followed sincerely	
		Ignorance	Ignorance of setting gap properly	Educated and trained about the implication of loose tappet nut & more tappet
		Operator's Height	As per ergonomics, operator height should be like that he or she should comfortably be able to set the tappet gap	Operator of appropriate height is applied on tappet setting station
3	Method	Use of only 30µ(0.03mm) shim to check the inlet and exhaust gap	Tappet setting is performed only with shim of 0.03 mm. Difficult to set large gaps	Tappet setting with shim of 80µ (0.08mm) started and is rechecked by 30µ shim
		No lubrication of cylinder head child parts	Cylinder head child parts such as rocker arm, camshaft, Inlet & Exhaust Valves were assembled without lubrication	Cylinder head child parts lubrication started
		No torquing during tappet setting at main assembly	Due to absence of torquing on tappet nut, nut was not fully tightened causing tappet gap to increase	Torquing of 70 kgfcm started on main assembly station
4	Machine	N/A	N/A	N/A
5	Design	N/A	N/A	N/A

VIII. Implementation of Corrective Actions

This stage comes after the analysis stage, the key or the root causes were identified along with their relationship towards the problem. The causes with weak relationship are not taken into consideration. The target was to attack on the causes with medium and strong relationship. There were five causes which were taken into consideration as per relationship table. These possible causes are as follows:

- Height of the operator as per man-machine interaction (ergonomics)
- Lubrication of cylinder head child parts
- Use of multiple feeler gauges (shim) instead of only 30µ (0.03 mm) feeler gauge.
- Use of torquing tool used during the tappet setting.

All the corrective measures were taken one by one and sequentially. After the implementation of each corrective action, the data was recorded and compared with the original data and corresponding graph was plotted comparing the present value with the previous value.

The corrective measures taken are as follows in detail:

Operator's height

As per the Ergonomics, also known as man-machine interaction, the operator height should be like that he or she should be able to work on the machine properly. Since the platform is fixed and cannot be raised or lowered, so the target is to assign the operator of appropriate as per the height of platform such that tappet setting for the operator becomes easy and he or she may be able to set the tappets easily and the problem of tappet noise could be eliminated.

The salient features of this action taken are as follows:

- As per ergonomics, operator height should be like that he or she should comfortably be able to set the tappet gap
- The operator is applied according to the height of the fixture, the height of the operator is chosen such that both inlet and exhaust tappets are visible to him/her comfortably.

As per the study of tappet gap setting at the main assembly, it was found that the inlet and exhaust gap comes at different height at the fixture as shown in the image:

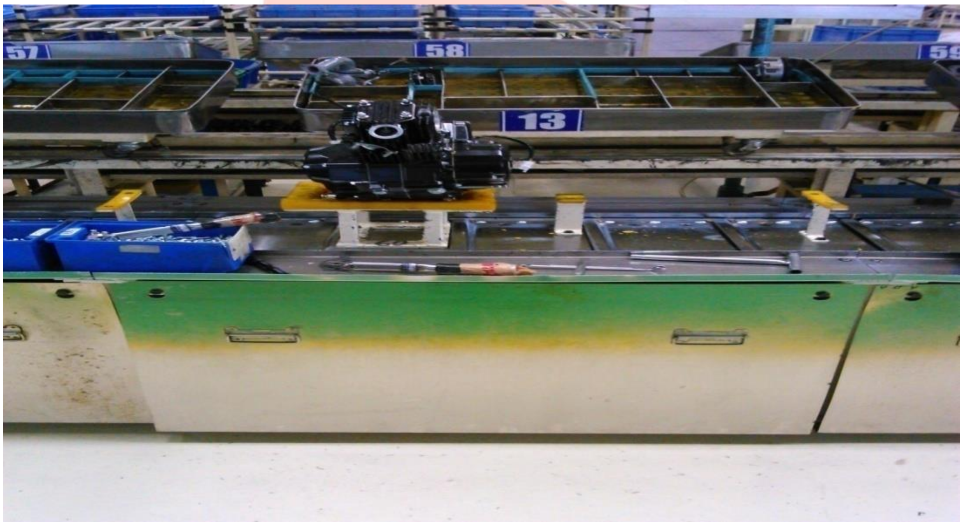


Figure 8.1 Engine on the fixture

It can be seen from the figure that the inlet and exhaust comes at a different height. The inlet tappet comes at more height than exhaust tappet and hence sometimes it becomes difficult for the small height operator to set the inlet tappet gap and for the large operator to set the exhaust tappet gap. Both these factors contribute to the tappet noise due to the improper gap setting. So an analysis was performed and following observations and calculations were taken of overall height of fixture, engine on fixture height and overall height from ground to the top cover of engine, the observations are as follows:

Observations and calculations

- Height of conveyor= 72 cm
- Fixture height= 17 cm
- Height of engine and fixture from top of conveyor= 50 cm
- Engine height= 50-17= 33 cm
- Inlet tappet height=32 cm
- Exhaust tappet height=27 cm
- Total height (from bottom of conveyor to the top of engine)= 122 cm
- Total height (from bottom of conveyor to inlet tappet)= 121 cm
- Total height (from bottom of conveyor to exhaust tappet)= 116 cm

Analysis

So in order to set the inlet and exhaust tappet gap properly, the operator of height should be like that he or she should be able to set the inlet and exhaust tappet gap easily. To overcome the problem, the operator of various heights is applied to the tappet setting station. The operator is applied according to the height of the fixture, the height of the operator is chosen such that both inlet and exhaust tappets are visible to him/her comfortably.

And as per study, it was concluded that the minimum height of the operator for comfortable tappet setting was found out to be **5 feet 5 inches**.

Result conformation

After the implementation of this counter measure, no number of cases reduced to 32 (average) from 40 initial (average). Thus the first countermeasure was successfully implemented. The results plotted in graphical form are as follows:

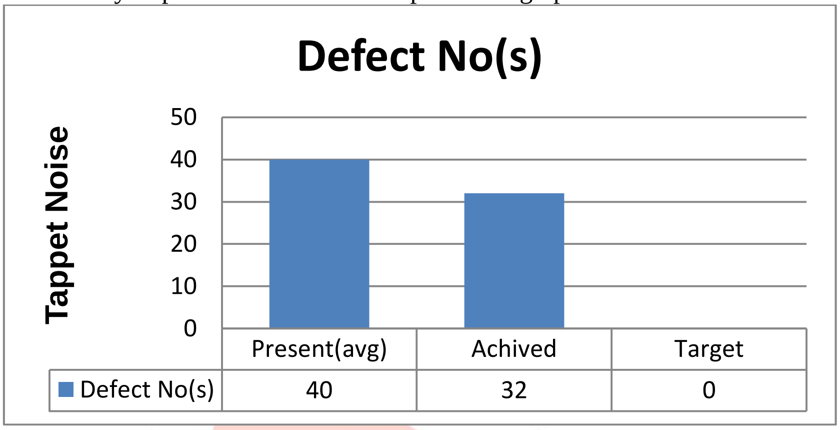


Figure 8.2 Result Conformation

Still the target of minimum was far away from achieved. So after one month of this countermeasure, the new countermeasure was started which is as follows.

Lubrication of cylinder head child parts

The cylinder head child parts include camshaft, rocker arm inlet and exhaust valves, and camshaft bearings are moving components and are very critical. The relative motion between these moving components can cause friction between the moving parts causing wear and tear between moving parts which contributes to the noise.

As per the analysis, it was observed that the cylinder head child parts were not being lubricated while assembling on the line. This was the key contributor to the tappet noise.

So after the analysis, the lubrication of the cylinder head child parts started at the sub assembly station. The idea was to see the effect of lubrication on the problem of noise and to verify whether this activity can reduce the noise to a considerable level.

The following steps were taken in this activity:

- To identify critical components like camshaft, rocker arm, valves, bearings etc, which are critical from noise point of view.
- After identification of the critical components, start the lubrication of these critical parts by the lubricating oil.
- Take the cases of lubrication of cylinder head child parts before the assembly of child parts, and after the assembly of child parts.
- Take 10 engines of both the cases and identify which among the two mentioned above are effective in reducing the noise.
- Then apply the most effective method to the engines
- Take the data
- Verify the results

Analysis

As per the activity, the analysis was performed with the cylinder head child parts lubrication before the assembly and after the assembly. An analysis was performed by taking 10 engines in which child parts were lubricated before their assembly and 10 engines were taken in which child parts were lubricated after the assembly and the noise was analyzed after the assembly of the engines on the bike and after 4-5 kms of running of the bike.

It was seen that the engines in which child parts were lubricated before the assembly were less in number than the engines in which the child parts were lubricated after the assembly. Out of the 10 engines taken in former case, tappet noise occurred in only 2 engines and in the latter case, tappet noise occurred in 5 engines.

So in the second month, the lubrication of cylinder head child parts started. And the data was recorded.

Result conformation

After the end of the month, the average data was taken and it was observed that the no of cases reduced to 25 from 32. It is clear that the no of cases reduced now as compared to the previous. But still the target to bring down the no of cases was still far away. The data in the graphical from are as follows:

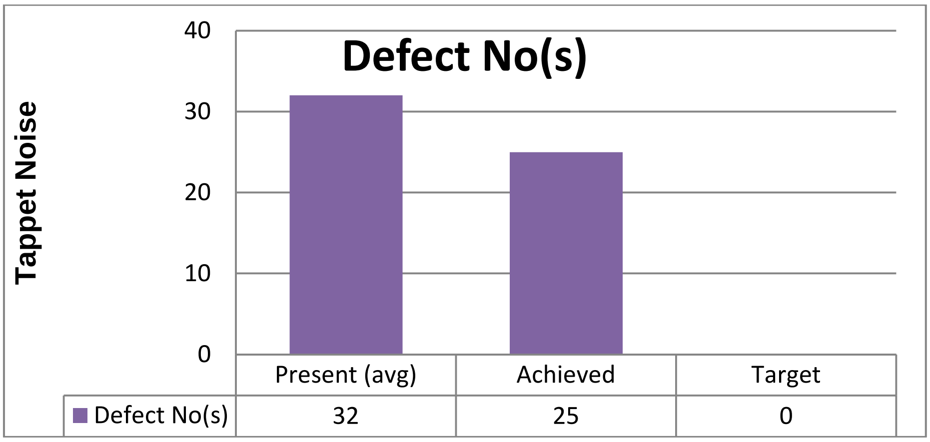


Figure 8.3 Result Conformation

To further bring down the no of cases, the third countermeasure started which is as follows:

Use of multiple shims for tappet setting

Earlier, the tappet setting was performed only by the 30µ (0.03mm) shim. It was difficult to set gaps more than that. If the tappet gap is huge (higher than 0.03mm), it becomes very difficult to set the gap with just 0.03mm shim. If the gap is not too much and the 0.03 mm shim qualifying, then the gap is perfect and no setting is required as little amount of gap is necessary because due to high temperatures, the thermal expansion of the components (rocker arm and valve stem) takes place and if appropriate gap is not provided, the expansion of the components may seize the engine.

In this countermeasure, multiple shims (ranging from 20µ to 80 µ) were used during the tappet setting and data was recorded by performing the tappet setting of the various engines with shims of range of 20µ to 80µ.

Figure 8.4 Shims used in tappet setting

Analysis

In the analysis part, the shims of 20µ to 80µ were taken and 10 engines were taken for each shim to perform the tappet setting. I.e. tappet setting was performed with each shim for 10 engines and the corresponding data were recorded.

It was seen that the number of cases reported was very less when tappet setting was performed with the shim of 80µ as compared to the other shims.

Result conformation

So the tappet setting started with the shim of 80µ and after setting the gap, it is rechecked with the shim of 30µ in case if the gap is more than 30µ. The rechecking is performed to ensure that there is no gap.

This action caused the number of cases reduced to 16 (average) from existing 25 (average). This is shown in graph as follows:

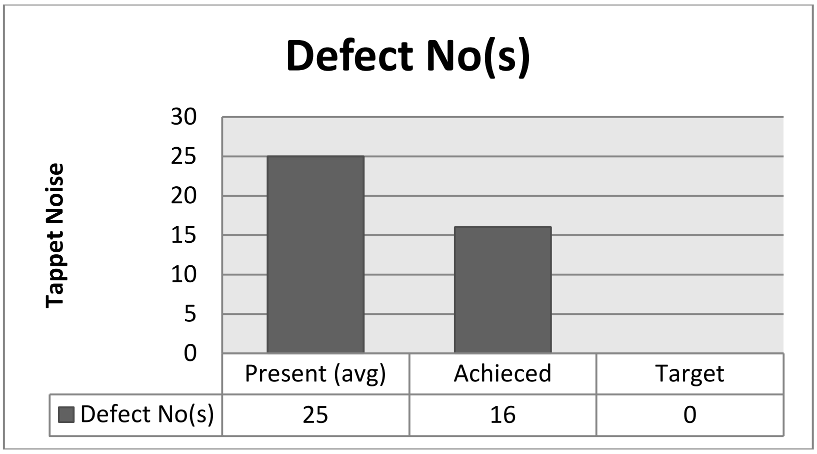


Figure 8.5 Result Conformation

Still the minimum target was far away. So, to further bring down the no of cases, the third countermeasure started which is as follows:

Use of torquing tool during tappet setting

The torquing is done to ensure that the revolving components such as bolts, nuts etc is properly fixed in its mounting place. Torquing is done by the help of torque wrench which when applied to the screws, bolts etc gives a "tak" like sound which indicates that component is tightened properly.

The torque is measured in **kgfcm**, where kg indicates kilogram, f stands for force and cm stands for centimetre.

During the tappet setting, torquing is necessary which signifies that the nut or bolt has tightened properly and cannot be tightened further. This prevents the moving of nut and bolts.

It was observed that the torquing was performed during the tappet setting at the sub assembly but not at the main assembly station. The torquing of 70 kgfcm was performed at the sub assembly station. The absence of torquing at main assembly station was a key factor for tappet noise since due to rocker arm loose nut; there was play between rocker arm and valve stem of inlet and exhaust valves which was contributing to the tappet noise.

Figure 8.6 Torque Wrench

Analysis

An analysis was performed and it was concluded that the absence of torquing at the main assembly station was a key contributor to the noise. In the analysis part, a comparison was made between 10 engines were taken in which torquing was performed at the main assembly station and 10 engines were taken in which tappet setting was not performed at the main assembly station. It was seen that 4 out of 10 cases were found in engines in which there was no torquing at the main assembly station as compared to 1 engine in the case where torquing was performed at the main assembly station.

So following the analysis, the torquing of 70 kgfcm started on main assembly station. The torque for the tappet nut was found to be 70 kgfcm when measured by the torque wrench.

Figure 8.7 Dial Torque wrench

So following this, the torquing started at the main assembly station.

Result conformation

After the torquing started at the main assembly station, the no of cases reduced to 2 (average) from 16 (average). This is shown in the graph below:

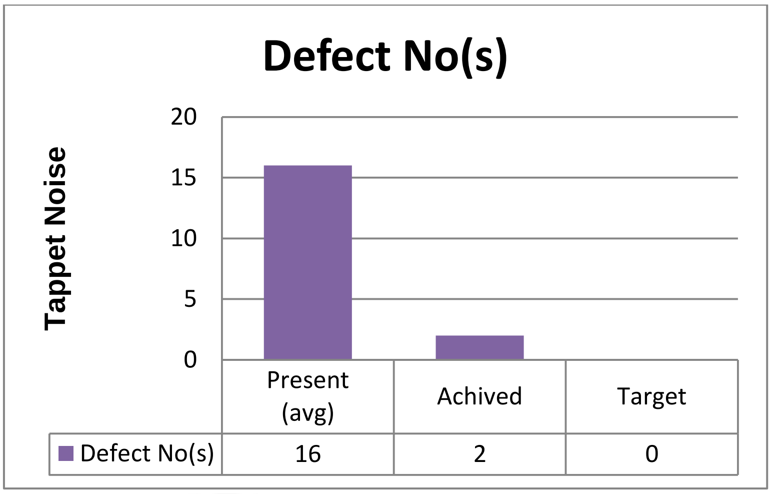


Figure 8.8 Result Conformation

This was the final countermeasure taken and no of cases reached near to the minimum no of cases.

IX. Conclusion

Thus, by the implementation of various corrective actions, the no of cases reduced near to the minimum i.e. from 40 to 2. The ideas were generated and implemented as per the current process. All the countermeasures or the corrective actions were taken as per the requirement of the process and under the supervision of the industry guide and the problem has reduced to the greater extant.

X. Future scope

Future scope for the project is:

- Use of variable platform during the tappet setting such as tappet setting becomes easy for operators of various heights.
- Use of a dial gauge to recheck the gap after the gap is set at main assembly and sub assembly station.
- Increase the tension of the timing gear chain for better and noiseless performance.

XI. REFERENCES

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