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Design and Experimental Investigation of Lapping Process for Productivity Improvement of I-Section Piston Rings

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Abstract: ***Piston rings are the important components of a piston in an IC engine since it will seal the combustion chamber and regulate the oil consumption. In order to produce good quality of piston rings it is important to identify the defects in production process. In this project experimental survey has been carried out to identify the defects. From the survey by Pareto diagram flank chipping was identified as the major cause and from Ishikava diagram root cause has been identified that loading method in lapping process. The objective of this project work is to improve the productivity and decrees the scrap rate. FEA has been carried out in lapping process it is found that stresses was more than the yield strength of a material as a result flank chipping defect occurring in lapping process therefore design improvement is required. A new ring loading method has been developed in lapping process and FEA is carried out,it is found that stresses developed are closer to the yield strength and reduction of stress concentration. From experimental it is observed that there has been an increase in the productivity and reduction of flank chipping scrap rate from 2.46% to 1.10% is noticed.***

Keywords: I-Section Piston Rings, Lapping Process, Pareto Diagram, Ishikava Cause and Effect Diagram

1. Introduction

Piston ring is a split ring that fits into a groove on the outer diameter of a piston in an IC engine. The material used for the production of piston rings are cast iron which sustain its original shape and size under thermal, structural and dynamic forces. There are 3 types of piston rings they are compression ring, wiper ring and oil ring. The function of a compression rings is to seal the piston and cylinder wall by high amount of combustion gases that are generated inside the combustion chamber, oil rings will regulate the oil flow, Piston ring size, diameter and configuration varies depending on the design of engine and material used for the cylinder wall. The piston rings will seal the combustion chamber and regulate the oil consumption by the inherent as well as the applied pressure. In this project work flank chipping defect occurring in lapping process because of loading method has been discussed and FEA has been carried out to find out the stress distribution and new loading method has been developed in order to reduce the stress distribution in lapping process in order to increase the production and decrease the scrap rate.

2. Literature Survey

S.Suresh et al. [6], in this paper author discussed factor that are affecting the rejection of piston rings in an automobile production industry. They used Pareto diagram to identify and solve the problem in production process. From Pareto diagram it is found that rings carrying mandrel were run out as a result uneven thickness has been formed on the rings and leads to rejection they changed the mandrel and reduced the scrap rate.

Chiranjit Mukhopadhyay et al. [7], in this paper author discussed the Ishikawa cause and effect diagram in piston ring production company, from Ishikava diagram they identified the root cause as axial thickness variation in lapping process. They conducted trial and error method to identify the suitable lapping speed and pressure.

Cai et al. [8]. In this paper author discussed the pressure distribution in a lapping process. The distribution of the pressure in lapping process is not even. The pressure goes up significantly near the edge of the work material and leads to non-uniform pressure distribution. This leads to high stress concentration at a single point as a result material removing problems will occur. By providing equal pressure distribution can overcome the problem

Tanmai verma et al. [9]. In this paper discussed the critical process for the axial thickness variation in production of piston rings. They identified axial thickness variation problem occurring in first and finished grinding and lapping process in that finished lapping process identified as the critical process. By cause and effects diagram they identified the main six factors that are reason for the cause. Lapping plate rotating Speed, lapping time, lapping pressure, holding plate, dressing of wheel and coolant are the main factors in lapping process.

3. Working Methodology

- Scrap rate survey has been carried out to identify the defects in production of I-Section piston rings.
- Major cause and its effects has been identified by Pareto and Ishikava diagrams
- Create a 3D model of I-Section piston ring using Solid Works Software and FEA has been carried out in Ansys software by various loading condition.
- Apply the design changes in production shop and to note down the scrap percentage.
- Compare the result of before and after design changes for the various loading conditions.

4. Problem Identification

It is observed that 12 number of defects has been found during the survey. Out of these the maximum contribution to the overall cause should be find out. The Selection of the major problem among listed above is followed by three methods they are

a) Pareto Diagram
b) Cause and Effect Diagram

a) Selection of the Defect by Pareto diagram

Pareto diagram chart is one of the quality improvement tool used to identify the major defect among many number of defects by 80:20 principle by controlling 80% of the cause can overcome the overall defect. In this project work based on the survey a Pareto diagram has been plotted from the observation it is found that flank chipping and loose gap are the major cause to the problem.

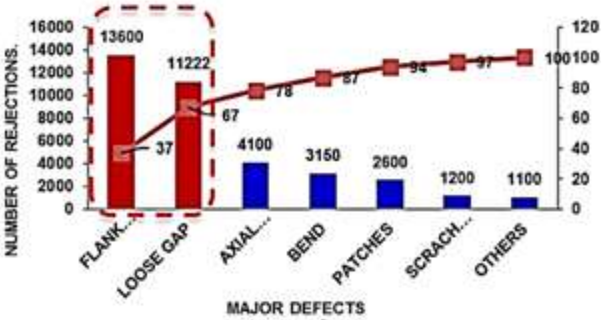

Figure 1: Pareto Diagram

b) Selection of root cause by Ishikava cause and effects Diagram

By Ishikawa diagram the possible cause and its effects are identified that are shown below in **Fig.2**

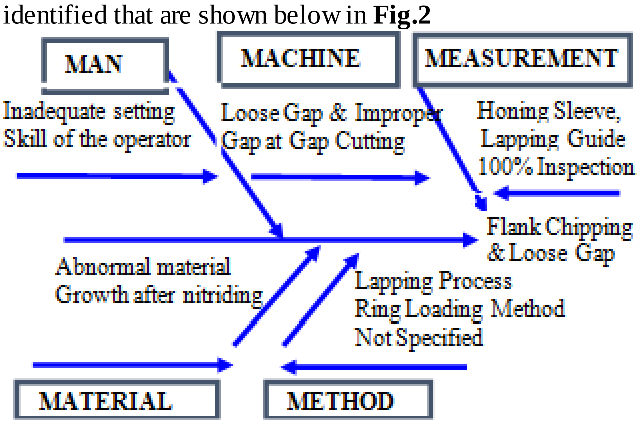

Figure 2: Cause and Effect Diagram

4.1 Validation of the Cause

Table 1 shows that different causes and its effects and validation of the causes as listed below.

The main potential cause for the flank chipping defect is ring loading method in lapping process. In this process rings loading method not specified in the control plan and all rings are loaded in a same direction that is ring gap is in the same direction placed one over the other, therefor there will be unequal pressure distribution on the ring and stress is concentrating at a single point and this leads to cause of flank chipping.

Table 1: Root Cause Analysis

Validation Of Cause					
S. No	Possible Cause	Cause	Specification	Actual	Result
1	Man	Inadequate setting skills	All operators must be well trained to run the machine	Verified operators are skilled& skill matrix existing	Not a cause
2	Machine	Loose Gap & Improper gap at gap cutting process	Gap 0.35 to 0.50 mm	Observed 0.75 mm	Yes it is cause
3	Material	Abnormal material growth after nitriding	Nitride depth maximum 100 microns	observed 95 microns	Not a cause
4	Measure ment	Honing sleeve, lapping guide 100% inspection constrain	100 % inspection to be carried out as per the schedule	100 % inspection done as per the schedule	Not a cause
5	Method	Rings loading method not specified in lapping	No specification for rings loading	Observed rings gap aligned in same line during lapping	Yes it is cause

5. Problem Statement

From the observation undertaken using two methods discussed, the problem identified is "Axial chipping defect in lapping process" Axial chipping is a type of defect that is occurring in a piston ring production process. A part of material is removed out on the axial surface of a piston ring. **Fig.3.** shows the flank chipping defect and loading method in lapping process shown in an I-section piston ring.

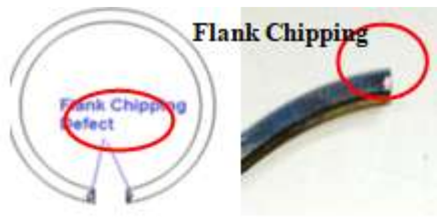

Figure 3: Flank Chipping Defect in I-Section Piston Ring

5.1 Scarp Trend Rate of I-Section Piston Rings

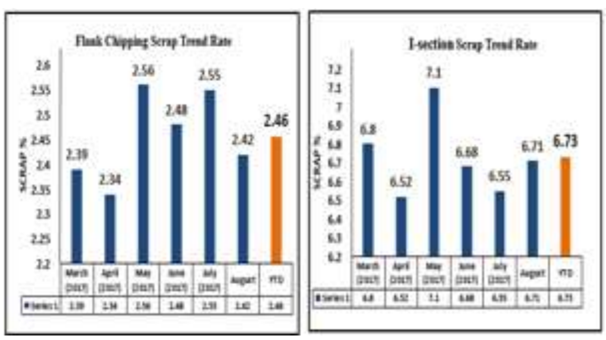

Figure 4: Scrap Trend Rate of I-Section Piston Rings

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6. Results and Discussion

FEA for Initial ring loading method in lapping process

6.1 Modelling

I-Section piston ring model has been created solid works software by of **100 x 93.1 x 3 mm.** specifications, assembly of the 10 number of rings is carried out. Since, analysis is carried out in initial ring loading method all the rings are mounted with same shoulder gap one over the other as shown in the below **Fig.5.**

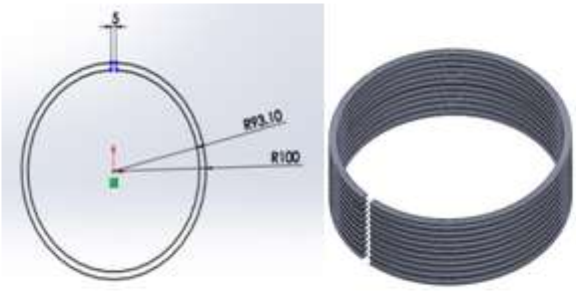

Figure 5: Modelling and Assembly of I-Section Rings in Lapping Process

6.2 Meshing

The meshed model with tetrahedron element is shown in **Fig.6.** The total number of elements are 18530 and nodes are 36356 in the component.

Figure 6: Meshed Model of I-Section Rings

6.3 Loads and Boundary Conditions

Loads and boundary condition in lapping process are shown in figures. Since rings are loaded in sleeve nominal diameter outside area will be constrained and inside ram will be reciprocating with 3.21 MPa pressure is acting inside the ring surface in order to remove the 40 micron of material in lapping process.

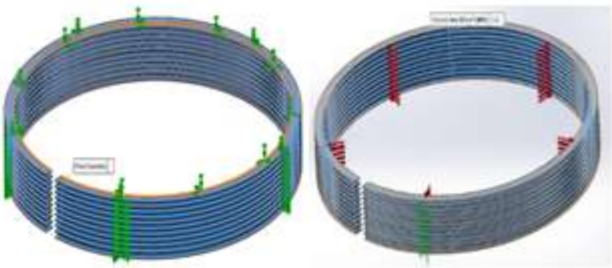

Figure 7: Loads and Boundary Condition of I-Section Rings

6.4 Static Structural Analysis

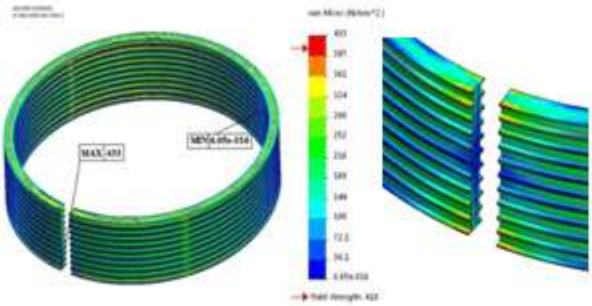

Figure 8: Von-Mises Stress Distribution

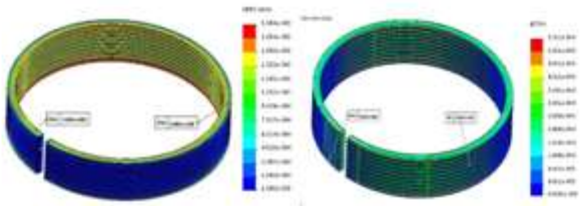

Figure 9: Deformation and Strain Results

From FEA of initial ring loading method in lapping process it is observed that von mises stress distribution was 413 MPa which was more than yield strength of material I.e. 410 MPa.

7. Design Improvement

From the structural analysis it is observed that, the von-mises stress is more than the yield stress and critical region identified near the ring gap.According to distortion theory of failure, von mises stress is more than the yield stress as a results flank chipping defect occurring near the ring gap. Design improvement is done by changing ring loading method in lapping process. Instead of loading the piston rings at same ring gap, by placing the rings at equal angle one over the other. As shown in the Fig.10.

Figure 10: Design Improvement

7.1 FEA Analysis Results – After Design Improvement

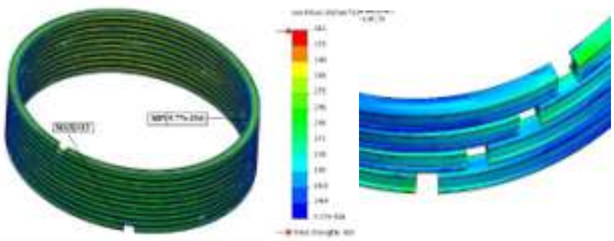

Figure 11: Von-Mises Stress Distribution

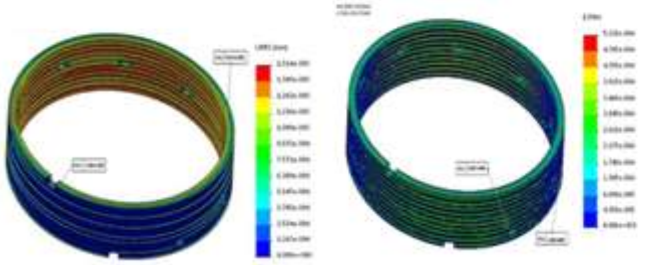

Figure 12: Deformation and Strain Results

8. Experimental Investigation of Design Improvement

Figure 13: I-Section Rings Loading Method in Lapping Process before and After the Design Improvement

8.1 Scrap Trend Rate of I-Section Piston Ring after Design Improvement

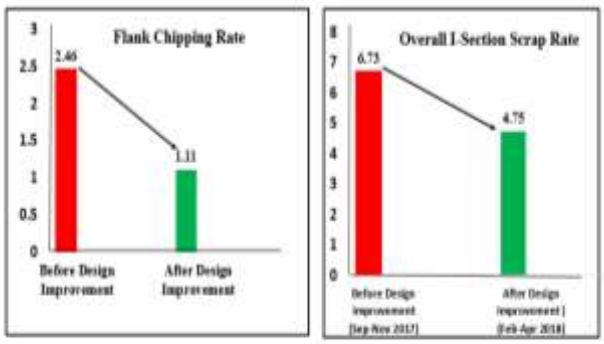

Figure 14: Scrap Trend Rate of I-Section Rings after Design Improvement

8.2 Comparison of Results

Table 2: Comparison of Results

Parameters	Before Design Improvement	After Design Improvement
Von-mises stress	433 MPa	413 MPa
Deformation	1.736E-003mm	1.577E-003mm
Strain rate	5.931E-004	5.597E-004
Flank chipping scrap rate	2.46%	1.10%
Overall scrap rate of I-section ring	6.73%	4.75%

9. Conclusion

1) The production process of I-section piston rings was observed to identify the defects.
2) The predominant defects were selected by using Pareto diagram, abstract method and cause and effect diagram.
3) The productivity and scrap rate was measured under a particular method of loading condition.
4) To improve the productivity and to reduce the scrap rate the analysis was carried out.
5) 3D modelling of I-Section Piston ring was created and analysed in SOLID WORK designing software.
6) Static structural analysis carried out in ANSYS Software to find out the maximum stress, deformation and critical region.
7) The obtained stress value before design improvement 433 MPa was more than yield stress value of 410 MPa. Because of non-uniform pressure distribution and stress is concentrating at same point near the gap.
8) After the design improvement the rings are mounted equal angle in lapping process, pressure distributed equally and obtained stress value is 413 MPa after the improvement, it was near to the yield strength value 410 MPa
9) After the design improvement, the improved ring loading technique is adopted in production process of I-Section piston rings for the experimental investigation.
10) In experimental investigation Flank chipping rate reduced from 2.46% to 1.10% and thereby overall scrap rate of I-Section oil ring reduced by 6.73% to 4.75%.

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