Inspection for Precision Alignment of the piston Assembly used in the Upgradation of a Diesel Fired Engine Aimed for Increasing Efficiency

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Abstract

In this research work, it is proposed to reduce the fuel consumption of a diesel engine. The proposal aims on adding a stainless steel piston over the aluminium conventional piston through a piston rod. Firing takes place over the stainless steel piston. Between stainless steel piston and cylinder small gap only is maintained without physical contact and liquid lubrication is totally avoided. The expected overall efficiency improvement is 30% to 40%, as air-cooling totally avoided and this requires less fuel to be burnt. Here the dual piston needs to be perfectly aligned and hence an inspection procedure was thought of and the results arrived at are analyzed and concluded. The maximum misalignment of top cylinder piston axis found to be 12.5 microns and maximum out of cylindricity over outer diameter found to be 25 microns.

Keywords: Conventional piston, Efficiency Improvement, Diesel Engine, Engine Efficiency.

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I. INTRODUCTION

The conventional piston of a diesel engine, piston rod and top stainless cylinder have to be welded together in prefect alignment for the purpose of this research. The whole assembly is called a dual piston and the top piston was to reciprocate inside the top cylinder without physical contact. The bottom conventional piston reciprocates with physical contact and with liquid lubrication. The gap between the top cylinder and top piston is maintained very closely within 0.1 mm, to see that the exhaust gas does not leak through the gap between the respective piston & cylinder. The piston rod is aligned by six guide bearings to check that physical contact between top piston and top cylinder is totally avoided. **S. Adamczak. et al** tried to measure the cylindricity of a conventional piston using radial method in laboratory. They used V- blocks and dial gauge to measure the deviation in different orientation. He mounted the piston on V-block and measured the deviation over the diameter of the piston for different orientation. They evaluated form error due to many manufacturing processes and suggestions were made to improve the results using a co–ordinate measuring machine. For a torque shaft the parameters like of trueness, flatness, circularity, cylindricity and perpendicularity were established. **A. Antoni Jankowski, et.al** designed a piston made up of composite material for an internal combustion engine. For the composite metallographic analysis, tensile strength study and hardness study & measurement of coefficient of thermal expansion were made. Dimensional stability due to temperature variation was found not to exceed of 2μm. **Swathi M Bale,** showed that the form error in the cylinder, is distributed uniformly over the

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circumference.

II. Material used

The material selected for the piston assembly has the following chemical composition and physical and mechanical properties. Shown in table 1 & 2.

Table 1. Chemical Composition of SS304 grade stainless steel

304Grade Element	Copper	Manganese	Silicon	Sulfur	Phosphorus	Chromium	Nickel	Iron
Weight in %	Max 0.08	Max 2.0	Max 1.00	0.03	0.045	18.0-20.0	8.0-11.0	Balance

Table . 2. Physical and Mechanical Properties of SS304 grade stainless steel

Properties	Poisson ratio	Density g/cm^3	Melting point $^\circ C$	Modulus of elasticity Gpa	Electrical resistivity Ω.m	Thermal conductivity W. m- 1. K-1	Thermal expansion m/mK	Tensile strength min Mpa	Yield strength 0.2% proof min Mpa	Elongation (% in 50 mm) min
Value	0.265-0.275	8.00	1450	193	$0.72x10^{-6}$	16.2	$17.2x10^{-6}$	515	205	40

FABRICATION PROCEDURE FOR ACHIEVING ALIGNMENT OF PISTON ASSEMBLY

The welding fixture used for fabrication of piston assembly is shown in photograph, fig.1. This contains positioning rings inside it. The fabrication drawings for the fixture assembly are shown in Fig. 2a.

1. The piston rod shall be inserted into the piston rod cap and the 2 numbers load sharing pins shall also be inserted into piston rod and cap.
2. Split pins shall be inserted into load sharing pins for assembly reasons.
3. All the relevant parts, viz., the piston rod along with piston rod cap, load sharing pins and split pins, conventional piston and top piston with SS piston rod cap, shall be push assembled, inside the fixture pipe of 120 mm outside diameter and the end cover flanges are bolted, as shown in fig.2a. The top piston is shown in fig .2b1. The positioning rings [Fig .2b2 & Fig.2b3] placed between pistons & fixture pipe.
4. Aluminium piston rod, cap and conventional piston shall be tack welded, through the elliptical hole in the welding fixture.
5. SS piston rod shall be tack welded with SS pipe cap and in turn with top cylinder.
6. The aluminium cap projection shall be welded from inside the conventional piston.
7. The whole piston assembly shall now be withdrawn from the welding fixture and the welding shall be completed.

Thus, the perfect alignment of conventional piston, piston rod and top piston during fabrication was achieved using welding fixture.

Fig. 1. Piston assembly with corresponding welding fixture.

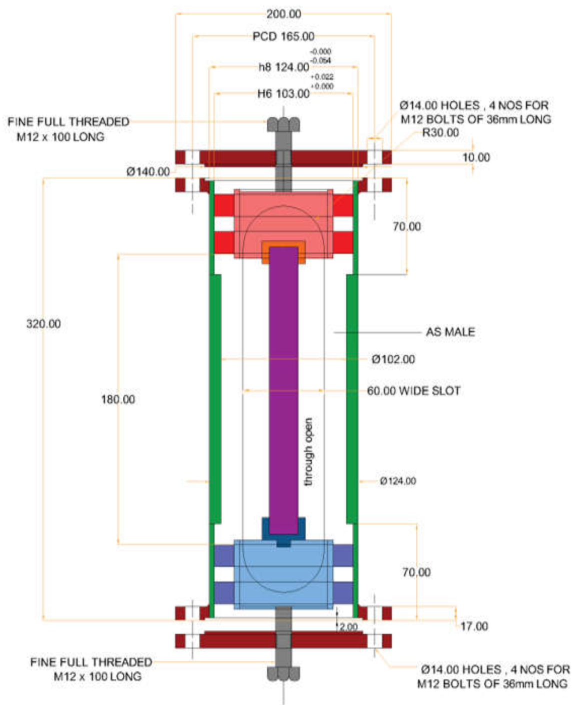

Fig. 2a. Fixtures for piston welding assembly (as made drawing)

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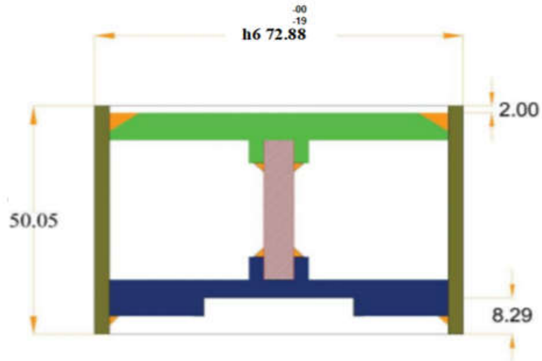

Fig. 2b1. Hot Piston – 1

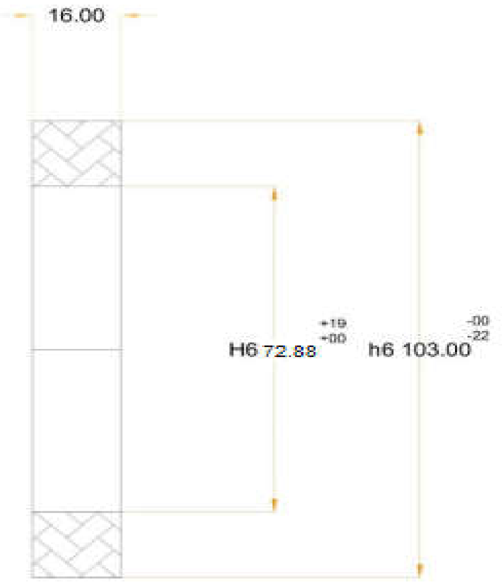

Fig. 2b2. Positioning ring for Hot Piston

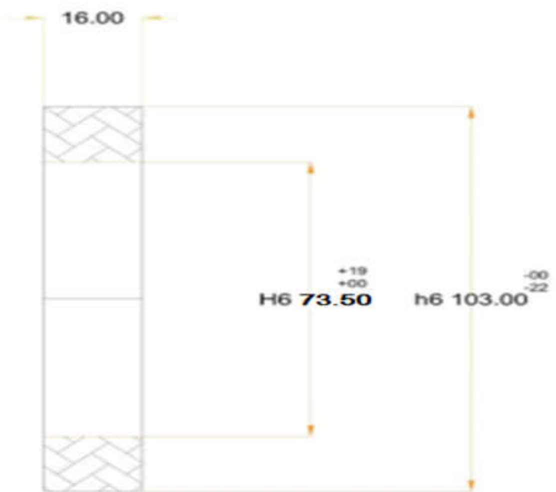

Fig. 2b3. Positioning ring for conventional Piston

A. TIG Welding Selected for Piston Assembly Fabrication

TIG welding is associated with low heat input and low distortion. TIG welding is very fine and hence weld nuggets will be very fine and TIG welded joints have higher fatigue life. TIG welding is generally done on a highly localized area and so fast thermal expansion/ contractions will be minimum leading to low distortion and heat affected area. Thus perfectly fabricated, piston assembly is shown in fig.3.

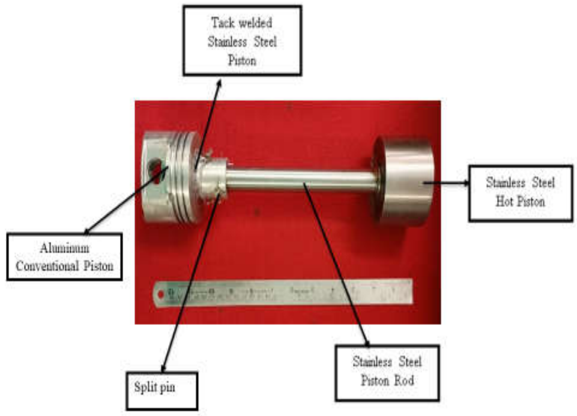

Fig. 3 Fabrication on welding Piston assembly

B. Measurement with Dial Gauge

Dial gauge found in fig.4, has a spring loaded probe that can move a pointer showing the linear variation to be measured. The sensitivity of the gauge is 0.01mm. The dial gauge is clamped on a vertical stand and the magnetic base is used to mount it on the DATUM. To measure the height variation of an item, the dial indicator stem is located over the item, which needs measurement of height variation and a reference is set by making the pointer read zero. By unlocking the magnetic stand and moving to the required location and locking the magnetic stand again, measure the height variations of other points.

Fig.4. Dial Gauge Apparatus

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Specification of Dial Gauge:

- Dial gauge used: Baker shock proof
- Least count: 0.01 mm
- Initial error: 0
- Type: J02
- S. No: E0309

C. measurement with Vernier gauge:

The vernier gauge used for the inspection is shown in fig.5

Specification of Vernier Gauge:

- Vernier used: Mitutoyo-made in Japan
- Least count: 0.02 mm
- Initial error = 0

Fig. 5. Vernier Used

C. V- block

V-Blocks as shown in Fig.6 are used for inspection of round rods and pipes. V-blocks are made rectangular forming channel in V-shape having 120° included angle. At the center of channel a small groove in made. In this research two V-blocks have been made use of to inspect the alignment of piston assembly consisting of conventional piston, piston rod and top SS piston welded together.

Fig.6. V-Block Support

III. INSPECTION METHODOLOGY

The piston assembly was placed over the V-blocks. The dial gauge was fixed in position on the surface plate using the magnetic face. The specimen was placed against the spindle of the dial gauge and dial gauge reading was noted. The specimen is rotated 45° and similar readings were noted. The cross section of the cylinder is divided into eight angular segment and 4 orientations. We are comparing orientations of 0-4 combination, 1-5 combination, 2-6 combination and 3-7 combination of the piston assembly as shown in fig. 7. Five circles are drawn on the piston at distances of 5 mm, 15 mm, 25 mm, 35 mm and 45 mm from the end face and they are denoted as circles A, B, C, D & E. After the deviations in circle A are noted down as entered in table-3, the dial gauge spindle is set in such a way that the pointer reads zero in circle B, and readings as noted down in circle A are entered in table-3 and the procedure is repeated for circles C, D, E. The isometric view of inspection procedure is shown in fig.8. The actual photography of the piston assembly inspection methodology is shown in fig.9

Fig. 7. Position and Orientation on the piston assembly.

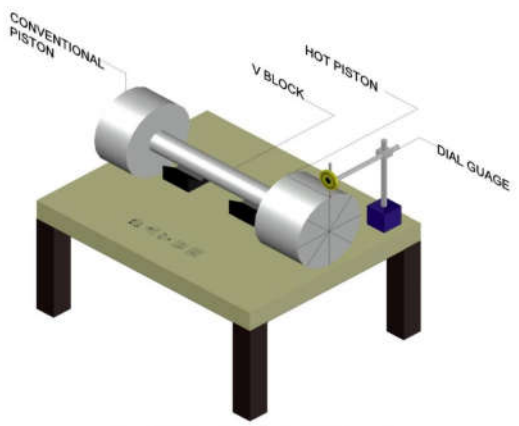

Fig.8. Isometric view

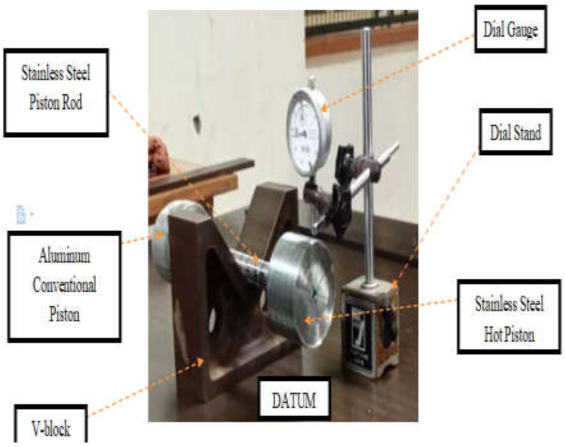

Fig .9. Piston assembly inspection setup used in metrology lab of Department of Manufacturing Engineering Annamalai University

IV. RESULT AND DISCUSSIONS

Piston rod is placed on two V-blocks placed above the DATUM. Orientations are 0-4 combination, 1-5 combination, 2-6 combination and 3-7 combination. Piston rod and top stainless steel piston are inspected for alignment. The maximum deviations found in different orientation of the assembly using dial gauge are shown in table.3

Table. 3. Top Piston/Piston Rod Inspection Details

Orientation	Deviation in Circles (microns)					Plane	Misalignment
	A	B	C	D	E		
0	0	0	0	0	0	0 - 4	5 microns
4	+10	+5	0	0	0		
1	0	0	-5	-10	-5	1 - 5	12.5 micron
5	+15	+10	+10	+15	+20		
2	0	+10	0	0	0	2 - 6	5 microns
6	+10	+5	+10	+5	+10		
3	+10	+5	0	0	0	3 - 7	12.5 micron

Inspection report:

- Maximum misalignment of top cylinder - piston rod axis=12.5 microns
- Error in outer diameter Cylindricity = 25 microns
- Nominal outer diameter of Top Piston= 72.88mm
- Nominal outer diameter of Piston Rod= 21.3mm
- Nominal outer diameter of Conventional Piston= 73.15mm

The misalignment is calculated by subtracting one deviation from the other in a particular orientation and dividing it by two and misalignment thus found is from the geometrical axis.

A. Piston Inspection Chart

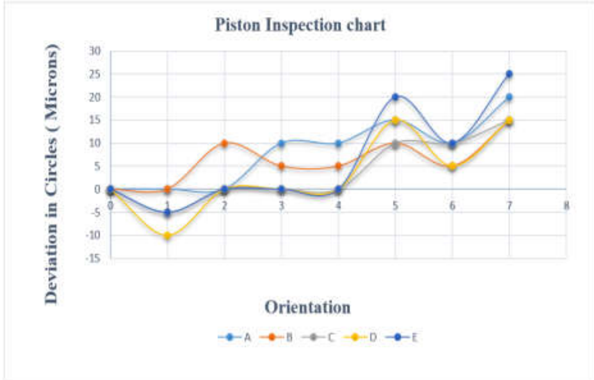

Fig .10. Inspection charts

Fig.10. shows the deviations with respect to axis in different orientation.

V. CONCLUSIONS

- Maximum misalignment of top cylinder - piston rod axis=12.5 microns
- Error in outer diameter Cylindricity = 25 microns
- The out of cylindricity is calculated as twice the maximum misalignment.
- The dual piston assembly is fabricated with very high accuracy than that is adopted in any conventional piston of a conventional engine.
- In conventional engine, the piston Cylindricity is not that serious as it has physical contact through piston rings.

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