ISSN: 2348 - 2117

International Journal of Engineering Technology and Computer Research (IJETCR)
Available Online at www.ijetcr.org
Volume 3; Issue 4; July-August-2015; Page No. 242-251

Stress Analysis of Piston of Two stroke engine using Photo-Elasticity and Numerical Methods

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Abstract

This paper deals with the design of piston of a two stroke I C engine and its stress analysis through photo-elasticity and Numerical method. First the piston is designed for the specified load acting on the piston and induced stresses are determined. Three models of piston are considered with varied web thickness. The photo-elasticity models are prepared using photo-elastic materials. The models are tested for stress distribution at various key points through Polariscope. The same models are built in ANSY 12 and analyzed for stresses at various points. The results are compared and the results are closely related. The advantages of the photo-elasticity method are easy to understand, through visualization of stress pattern and determining stress at any point on the model since the fringe value of the material is known. The use of the design piston is suggested.

Index Terms: ANSY, fringe value, model, Photo-Elasticity, Piston, Polariscope, stress analysis etc.

1. INTRODUCTION

There are several types of transportation systems all around the world like automobiles, railways, ships, aero planes etc. almost all types depends on engines either two stroke or four stroke. The motive power of vehicle is its engine. The reciprocating engine mechanism converts reciprocating motion into rotary motion of crank shaft is very much important and power producing center. The vital parts of an engine are piston, cylinder, connecting rod, etc. Hence the designing of these parts is key step in engine design. The loads act on various members and lead to stress analysis.

The purpose of this paper is to design a two stroke piston and to analyze stresses. For this purpose Hero Honda Splendor 100cc is chosen. The displacement volume of this two stroke engine is increased from 100cc to 120cc. Three models of piston are designed and analyzed for stresses through photo-elastic method and FEM. It is also considered to optimize the web thickness by considering various web thicknesses.

1.1 Introduction to Piston

Piston is thought to be a standout amongst the most essential parts in a responding engine in which it serves and produces reciprocating motion. It is acted upon by a large amount of external force due to the combustion of air fuel mixture. Piston is basically a round and hollow attachment moves up & down in the cylinder. It is outfitted with piston rings to give a decent seal between the cylinder wall & Piston so that there is no leakage of gases.

1.2 Objectives

The main objective of the project work is to design a suitable piston for two stroke petrol engine to enhance the output power of the engine and to analyse the stress distribution through photo elasticity and ANSYS the analysis software. The other objectives are stated defined as follows;

- To design the piston for two stroke petrol engine of hero Honda to enhance its capacity to 120cc from 100cc
- To analyze the stress distribution through 2-D Photo elasticity.
- To model and stress analysis of piston through ANSYS-12
- To compare the stresses
- To draw conclusions from the results.
- To suggest application of the project work and future scope.

2 Reviews of Papers on Piston Stress Analysis

Swati S Chougule and Vinayak H Khatawate et al [17] The authors carried out modeling and stress analysis of piston SUZUKI Max100 bike. Vijay Kumar Paluri, P Satish Reddy and T S R Krishna et al [6] : presented a general study on the execution correlation of Silumin Piston and Aluminum Alloy Piston. Measurements and determinations utilized as a part of demonstrating are gathered from the genuine Piston of Hero-Honda Splendor Bike. Sandesh Subhash Awati,et al here Photograph Spectrometer utilized for directing test while applying (indicated) burdens to the example getting the hassles at the visual areas on the specimen [10]. J. M. Dulieu-Barton et al. School of Engineering Sciences University of Southampton, clarified the investigation of stress/strain by method for photoelasticity. This procedure includes fabricating a model of an from a birefringent material, more often than not a straightforward polymer, and applying an agent burden to the model to get periphery design which are corresponding to push [18] . S.K.Chakrabarti et al.discussed that complete photoelastic stress investigation [12]. A.J.Durelli et al. acquired stress circulation around a circular irregularity in a 2-89dimensional, uniform and pivotal arrangement of combined stress. He analyzed trial results from photoelastic and fragile covering tests with hypothetical qualities [13].

3 Analytical Design of Piston

The analytical design of piston is carried out using the data available for the Hero Honda engine specifications. The major steps involved are material selection and properties, gas load determination, piston pin design, and calculation of induced stresses. The following paragraph gives the details of analytical design process.

3.1 Material Selection of Piston

Weight reduction has been picking up significance in auto field on the grounds that reducing in weight reasons significant reduction of weight on engine. The original material used to fabricate HERO HONDA SPLENDOR bike is Ac 8A-T6 and Ac 8H-T7. In this paper the piston material used is aluminum alloy of 7075-T6, i.e the aluminum alloy is such that its weight is less [16].

3.2 Specifications of Hero Honda

Following are Specification of the 100cc Hero Honda Splendor

- Engine type – Air Cooled Two Stroke
- Bore- 50 mm
- Stroke- 49.5 mm
- Swept volume - 97.2 cc
- Maximum power- 5.74 KW (7.8 Ps) @7500 rpm
- Maximum torque-8.04 N-m @ 4500 rpm
- Compression ratio – 9:1
- Flash point for Petrol- -43˚C (-45˚ F)
- Auto ignition temperature- 280˚ C (536˚ F)
- Temperature- 60˚ F
- Material- Ac 8A-T6 (J iS H5202) and Ac 8H-T7 (HES C/02-030)
- Mass = density x volume = 737.22x10-9 x 97.22x103 =0.0716kg
- Molecular weight of petrol = 114.228 g / mole = 11423 kg / mole
- From the gas equation PV= mRT
- R_0 = universal gas constant=8314.8 Nm / mole K

$R=R_0/m=$ 72.87 Nm / kg K

P= 15.48 mpa

3.3 Design of Piston for the enhanced power

Aluminum alloy whose permissible stress is 50Mpa-90Mpa, the piston size considered here as follows [16]

From data D=50mm

L= D to 1.5D

Assuming L= 1.23 x D

Stroke L=1.23 x 50 = 61.5mm

Clearance is taken as 0.760mm

Now assuming [22]

D - B = 0.760

B = D- 0.760

B = 49.24mm

Length of Piston (Lp)

1.25 x B = 1.25 x 49.24 = 61.55mm

Top End of Piston to Center of Piston

0.67 x B= 0.67 x 49.24 = 32.99mm

Distance from Top to First Groove

0.2 x B = 0.2 x 49.24 = 9.848mm

Piston Pin Diameter

0.35 x B = 0.35 x 49.24 = 17.234mm

Distance between Circlips to Piston Head

0.22 x B = 0.22 x 49.24 = 10.83mm

Thickness of Piston Head

0.4 x B = 0.4 x 49.24 = 19.696mm

For grooves

3.4.8 Depth of Ring

0.025 x B to 0.033 x B [16]

1.25mm is chosen

Width of Ring

0.03 x B to 0.05 x B [16]

2.2mm is chosen

Maximum Thickness of Piston Barrel (t_3)

8.10mm [16]

The Wall Thickness of the Open End of the Piston (t_4)

$t_4 = 2.02$mm

Force on Piston due to Pressure or Gas Pressure

$F_p = \pi/4(D^2 \times P)$

$= \pi/4(50^2 \times 15.48)$

=30394.90 N

3.4 Design of Piston for 2mm Web Thickness

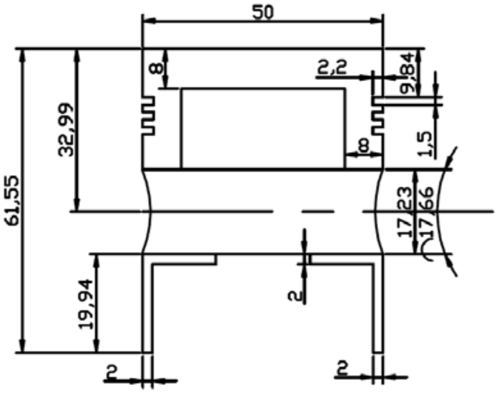

Fig 1: Front Sectional View of Designed Piston of 2mm web thickness.

Brake Power (B.P)

BP = PLAN/1000 X 60 =7.547 KW

Check for Strength of the Piston Pin

$\sigma = F_P X D/8Z$

Where $Z = \Pi d^3/32 = 12.27 \times 10^3$ mm^3

σ = 15.48 Mpa

Stresses at Centre of Web Thickness

For 6mm Web Thickness

σ = Fv/A

But A $= \pi/4 (D^2 - (d+t)^{2}$

A = 442.96 mm^2

σ = 17.025 N/mm^2

3.5 Design of Piston for Different Web Thickness

The actual value of piston web thickness is 2mm in Hero Honda Splendor motorbike. In this project work web thickness 6mm, 8mm and 10mm are considered for the designing of piston to get optimal results. Similar steps 3.4 are used to determine the dimension and the drawings are show in Fig 2, Fig 3 and Fig 4 respectively.

Three models of piston used for stress analysis are,

Model 1- 6mm web thickness

Model 2- 8mm web thickness

Model 3-10mm web thickness

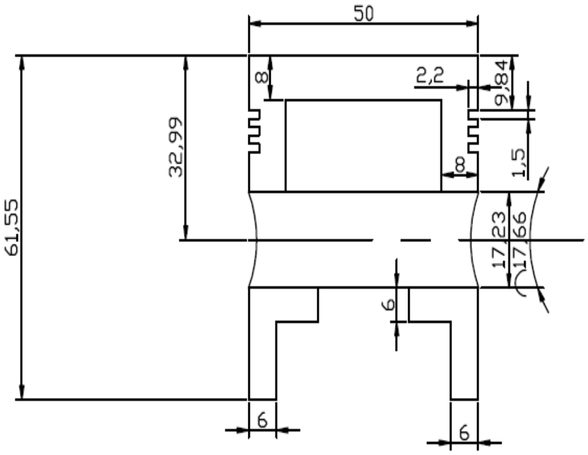

Fig 2: Front Sectional View of Model 1

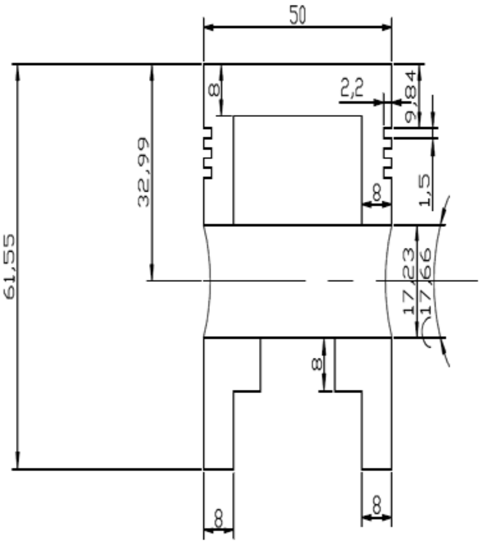

Fig 3: Front Sectional View of Model 2

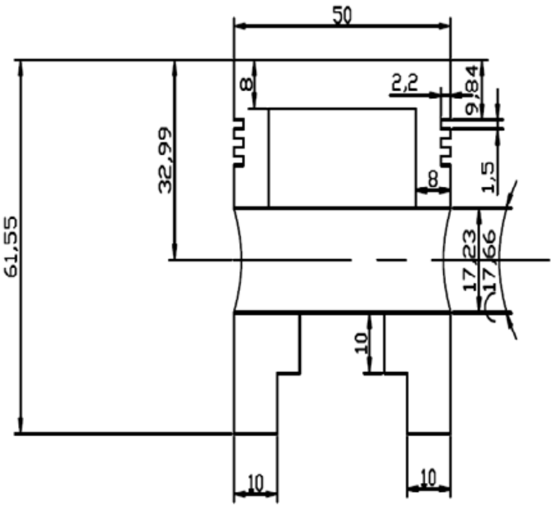

Fig 4: Front Sectional View of Model 3

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3. 7 Specification of Piston for enhanced power output

Hero Honda Splendor engine specifications for 120cc

- Engine type – Air Cooled Two Stroke
- Bore- 50 mm
- Stroke- 61.5 mm
- Displacement- 120.7cc
- Maximum power- 7.547 Kw@7500 rpm
- Flash point for Petrol- -43˚C (-45˚ F)
- Auto ignition temperature- 280˚ C (536˚ F)
- Temperature- 60˚ F
- Material- 7075-T6 Aluminum alloy

3.8 Check for Stresses

The induced stresses for piston and stresses at centre of web thickness are calculated. Table 3.1 shows the induced stresses at piston pin and web thickness respectively. To know the stress validation as the load or force acting on piston increases, the max load of 30394.90 N is equal to divided into 5 steps so that following are the minimum and maximum loads are that considered for stress analysis throughout the project work for other methods.

Fp min = 7541.6 N and Fp max = 30394.90 N.

4. Photoelastic Analysis

The photo-elastic model with above mentioned specification is prepared from Araldite CY230 and hardener HY951. The standard research polariscope is used for the investigation.

The stresses are calculated experimentally by photo-elasticity and the material fringe value is calculated by the calibration of circular disc and rectangular four point bend specimen, average material fringe value of both standard specimens is taken into account.

- Material fringe value (Fσ) = 6.77 N/mm
- Model thickness (t) = 6mm

Table 1: Stresses at various Web thicknesses

Sl. No.	Force acting on piston(N) Fp	Stresses at centre of web thickness		
		6mm	8mm	10mm
1	7541.6	17.02	10.66	7.97
2	13254.95	29.92	18.75	14.01
3	18968.0	42.82	26.83	20.05
4	24681.64	55.71	34.91	26.10
5	30394.90	68.61	43.00	32.14

Therefore photo elastic method is interesting and one may behave the real performance of the designed components.

The following paragraphs illustrate step by step procedure is determine the stresses in the existing model taken, i.e. three piston models. Now the average material fringe value is calculated to use it for stress analysis of Models

F mat = 6.775 N/mm

Fringes Obtained in Research Polariscope of Model-1

The piston models are taken for stress analysis one by one. First model-1 (6mm web thickness) is taken and mounted for stress analysis is the rectangular frame of research polariscope. The load acting on the mid top position of the model and gradually the loading operation is carried out. For each loading fringe orders are determined at various points on the model-1 using colors code chart

TABLE 2: Determinations of Stresses on various Points on Model-1.

Sl. No	load w (N)	Point 1		Point 2		Point 3		Point 4	
		N	σ	N	σ	N	σ	N	σ
1	25.8	0.60	0.67	0.79	0.89	1.06	1.19	1.20	1.35
2	45.5	1.00	1.12	1.00	1.12	1.20	1.35	1.62	1.82
3	65.1	1.38	1.55	1.00	1.12	1.38	1.55	1.62	1.82
4	84.7	2.00	2.25	2.00	2.25	1.62	1.82	2.67	3.01
5	104.3	3.00	3.38	2.33	2.63	2.50	2.82	3.10	3.50

TABLE 3: Determinations of Stresses on various Points on Model-2

Sl. No	load w (N)	Point 1		Point 2		Point 3		Point 4	
		N	σ	N	σ	N	σ	N	σ
1	25.8	0.45	0.50	0.60	0.67	1.06	1.19	1.06	1.19
2	45.5	1.00	1.12	1.00	1.12	1.20	1.35	1.38	1.55
3	65.1	2.00	2.25	1.38	1.55	1.62	1.82	2.50	2.82
4	84.7	2.00	2.25	2.33	2.63	2.50	2.82	2.67	3.01
5	104.3	4.00	4.51	3.00	3.38	2.67	3.01	3.10	3.50

TABLE 4: Determinations of Stresses on various Points on Model-3

Sl. No	load w (N)	Point 1		Point 2		Point 3		Point 4	
		N	σ	N	σ	N	σ	N	σ
1	25.8	0.60	0.67	1.00	1.12	1.06	1.19	1.20	1.35
2	45.5	1.00	1.12	1.38	1.55	1.38	1.55	2.33	2.63
3	65.1	2.00	2.25	2.00	2.25	2.33	2.63	2.50	2.82
4	84.7	3.00	3.38	3.00	3.38	3.10	3.50	4.10	4.62
5	104.3	4.00	4.51	4.00	4.51	4.13	4.66	4.13	4.66

Fig 5: Fringes at load 104.3784N for Mode-1

Fig 6: Fringes at load 104.3784N for Model-2

Fig 7: Fringes at load 104.3784N Model-3

5 ANSYS-12 Introductions

Finite element method is a numerical method, gives approximate answers for any engineering problems. Optimization using FEM is less time consuming compare to experimental technique. In present work we used ANSYS 12 to optimize the position, shape and orientation of the stress and also to validate experimental results .This piston structure is descretrized in to finite elements, which are Solid, 10-noded 187 isoperimetric elements.

TABLE 5: Analysis of Model-1 Results

Sl. No	Load in N	Von Mises stresses			
		At point 1	At point 2	At point 3	At point 4
1	5982	0.52	0.10	0.10	0.40
2	10514	0.91	0.186	0.18	0.73
3	15046	1.31	0.266	0.26	1.37
4	19579	1.71	0.346	0.34	1.60
5	24109	2.10	0.427	0.42	2.10

TABLE 6: Analysis of Model-2 Results

Sl. No	Load in N	Von Mises stresses			
		At point 1	At point 2	At point 3	At point 4
1	5982	0.739	0.20	0.18	0.27
2	10514	1.30	0.37	0.32	0.48
3	15046	1.86	0.70	0.45	0.90
4	19579	2.42	0.90	0.59	1.20
5	24109	2.98	1.12	0.70	1.80

TABLE 7: Analysis of Model-3 Results

Sl. No.	Load in N	Von Mises stresses			
		At point 1	At point 2	At point 3	At point 4
1	5982	0.841	0.20	0.18	0.27
2	10514	1.48	0.37	0.32	0.48
3	15046	2.12	0.70	0.46	0.90
4	19579	2.75	0.90	0.50	1.21
5	24109	3.39	1.12	0.60	1.81

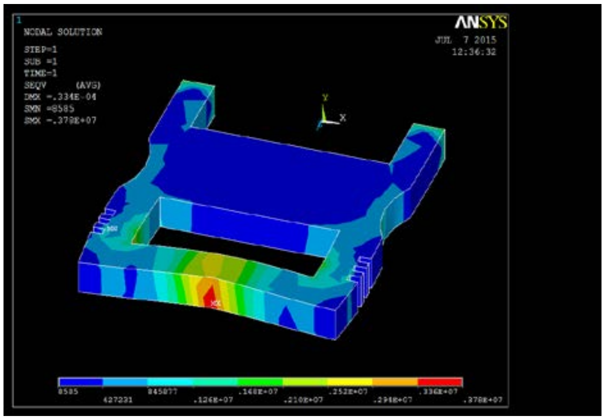

Fig 8: Model-1 Von-Mises Stress for the load 24109 N

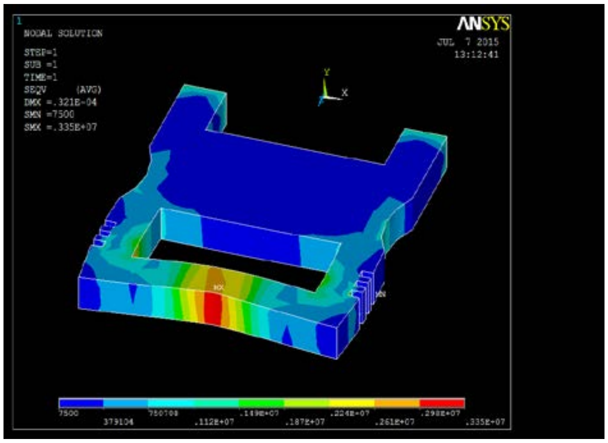

Fig 9: Model-2 Von-Mises Stress for the load 24109 N

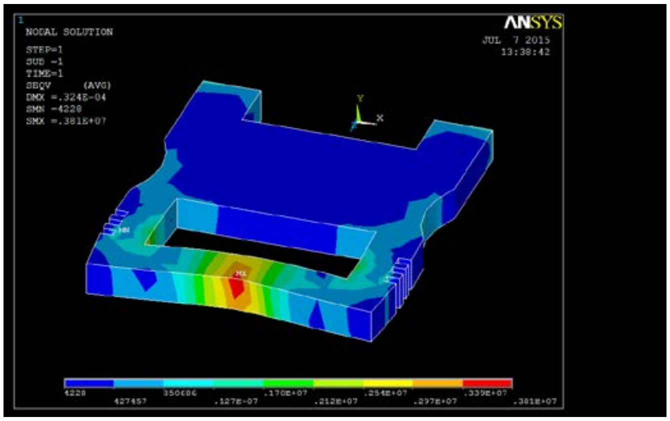

Fig 10: Model-3 Von-Mises Stress for the load 24109 N

6. Comparison of results

As the methodologies used in present work are three the induced stress results are compared with two methods i.e. the results from photo-elasticity and FEA are compared.

TABLE 8: Comparison of Results of Model-1

Sl. NO.	Load W (N)	Experimental method				load N	Numerical method			
		1	2	3	4		1	2	3	4
1	25.89	0.6	0.8	1.1	1.3	5982	0.5	0.1	0.1	0.4
2	45.51	1.1	1.1	1.3	1.8	10514	0.9	0.1	0.1	0.3
3	65.13	1.5	1.1	1.5	1.8	15046	1.3	0.2	0.2	1.3
4	84.75	2.2	2.2	1.8	3.1	19579	1.7	0.3	0.3	1.6
5	104.3	3.3	2.6	2.8	3.5	24109	2.1	0.4	0.4	2.1

TABLE 9: Comparison of Results of Model-2

Sl. No	load W (N)	Experimental method				load in N	Numerical method			
		1	2	3	4		1	2	3	4
1	25.8	0.5	0.6	1.1	1.1	5982	0.7	0.2	0.1	0.2
2	45.5	1.1	1.1	1.3	1.5	10514	1.3	0.3	0.3	0.4
3	65.1	2.2	1.5	1.8	2.8	15046	1.8	0.7	0.4	0.9
4	84.7	2.2	2.6	2.8	3.0	19579	2.4	0.9	0.5	1.2
5	104	4.5	3.3	3.0	3.5	24109	2.9	1.1	0.7	1.8

TABLE 10: Comparison of Results of Model-3

Sl. No	Load W (N)	Experimental method				load in N	Numerical method			
		1	2	3	4		1	2	3	4
1	25.8	0.6	1.1	1.1	1.3	5982	0.8	0.2	0.2	0.2
2	45.5	1.1	1.5	1.5	2.6	10514	1.4	0.3	0.3	0.4
3	65.1	2.2	2.2	2.6	2.8	15046	2.1	0.7	0.4	0.9
4	84.7	3.3	3.3	3.5	4.6	19579	2.7	0.9	0.5	1.2
5	104	4.5	4.5	4.6	4.6	24109	3.3	1.1	0.6	1.8

7. Advantages,Limitations and Application

7.1 Advantages

- The photo-elastic method of stress analysis is a visual method. The stresses induced in the model are inspected by human eye. The stresses induced are proportional to the fringe pattern of different colors and combination of colors.
- Stresses induced in piston model are determined by using photo elastic model.
- The piston is costly material where as piston rings are cheaper and is replaceable hence it is need to be find failure analysis of piston.
- Provides solid full-field estimations of the distinction between the principal normal stresses in the plane of the model.
- Gives exceptionally the estimation of the non-vanishing essential normal stresses along the perimeter(s) of the model, where stresses are by and large the biggest.
- Requires just a modest investment in equipment and materials for common work.
- Is fairly simple to use.
- Digitization of polariscope empowers quick picture obtaining and information preparing, which permits its modern applications to control nature of assembling procedure for materials, for example, glass and polymer.

7.2 Limitations

- Need to take care of fringe order. If taken fringe order is wrong then analysis may wrong.
- Requires rather tedious calculations in order to separate the values of principal stresses at a general interior point.
- Can require costly hardware and equipment for exact examination piston model.

7.3 Application

- Real time stress monitoring.
- Quality control.
- Material selection
- Design consideration
- The designed piston is checked for stresses using two methods and therefore the automobile industries may consider for their use.

8 Conclusions and Future Scope

In this chapter the conclusions are drawn from the project work carried out for the piston design and analysis through Photo-elasticity and Numerical Method.

8.1 Conclusion

In this paper design and analysis of stresses for the piston of a two stroke engine Hero Honda for its enhanced capacity from 100cc to 120cc is carried out and the results obtained through photo-elasticity and FEM are closely related. The analysis shows that Model-2 is an optimal and suitable for use.

8.2 Future work to be considered

The same methodology may be adopted for the other components of an engine.

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