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Study on Design and Static Analysis of Piston Head

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ABSTRACT:
I.C engine piston is one of the most important and complex component in the engine. It is also sometimes referred as the heart ofengine. It is widely used mainly in automotive and mechanical fields hence, a detailed study on its static behavior is important.This paper emphasizes on the static analysis of the piston head of a 4-stroke I.C engine. In the present work piston head isdesigned using CATIAV5R20 and this model is analyzed in ANSYS 14.5 and a study on its static behavior is performed. Aluminumalloy has been selected as piston material for structural analysis. The theoretical stress values obtained is compared with thestressvaluesobtainedafterthe analysisinANSYS 14.5.

Keywords: PistonHead,I.CEngine,CATIAV5R20,ANSYS14.5,Static Analysis.

I. INTRODUCTION

Piston is one of the most important components of engine. Itis a part in motion which is present in cylinder. In the enginethe expansion of gas occurs in cylinder up to crankshaftthrough connecting rod. The piston lasts this gas pressureandinertialforcesatworkandthismayleadtocrackformationandpistonwear.Thestudyreportsshowthatstress concentration is highest atupper portion and this isone of the main reasons for crack formation and wear. Thispaper describes stress distribution on piston head of an ICengine by using finite element method. It is achieved byCAD and CAE softwares. Our main purpose is to study thestaticbehaviorofpistonheadandanalyzethestressdistribution. By using CATIAV5R20 model of the pistonhead is developed. Stress analysis is carried out by usingANSYS 14.5. The results obtained from ANSYS 14.5 arecomparedwiththecalculatedtheoreticalstressvalues.

A lotof researchhas beenundertaken in optimizing thepiston head.Ashwani Kumar et al [1] the main objective ofthis research work is to investigate and analyze the stressdistribution of piston at actual engine condition. Analysis ofthe stressdistributionwas carriedout on different parts ofthepistonfordeterminingthestressesduetothegaspressure. S N Kurbet et al [2] studies related to the workingoftheengineparts,thepistonisconsideredasmainsourceof the vibration andnoise the emphasis is on the pistonvibrationandtofindoutthevariousmethodstopredictmechanical noise produced by the primary and secondarymotionofthe engine part.

II. MATERIAL PROPERTIES

Aluminium alloy is selected for the design and analysis ofthepistonhead.Propertiesofthealuminiumalloyarementioned below.
Density – 2770 (Kg/m^3)PoissonRatio–0.33
YoungModulus –7.1x10^{10}(Pa)
Tensile Ultimate Strength – 3.1x10^8 (Pa)Tensile Yield Strength – 2.8x10^8 (Pa)CompressiveYieldstrength–2.8x10^8(Pa)[3]

1. CALCULATIONS

Borediameter=100mm(D),Strokelength=120mm(L),Gaspressure=5MPa,BMEP=0.5MPa,Fuelconsumed= 0.15 (Kg) / Brake Power (W), Speed = 2200 rpm (N) [4]Step1:
Brakepower (BP).in KW

BP =PLAN/(1000×60)KW

Where,P=BEMP=0.5 MPa

L=Strokelengthm
A=CrossSectionaream^2
N=Speedrpm
BP=$0.5\times120\times100^2\times2200\times\pi/(1000\times4\times60)$

=17.275 KW

Step 2:
Thicknessofthepistonheadbyconsideringtheheatdissipation
$t_1=D^2q/[1600\times K\times(T_c-T_e)]$mm
Where,t_1=thicknessofpistonheadmm
q =HeatflowJ/s-m^2
k=HeatconductivityW- mm/(m^2-^{0}c)
T_c-T_e=differencebetweentheTemperatureatcentreandedges=222K
q=$K_1\times C\times W\times BP/(A)$J/s-m^2
Where,K_1=Constantwhichrepresentstheamountofheatsoakedbypiston.

C=Calorificvalueofthefuel=42000KJ/Kg
W=fuelconsumed=0.15 Kg-hr/KW
A= $\pi d^2/(4) = \pi\times (0.1)^2/(4) =7.85\times10^{-3}m^2$
q=$0.05\times(42000\times1000)\times(0.15/3600)\times17.278/(7.854\times10^{-3})$=192491 J/s-m^2
$t_1=100^2\times192491/(1600\times460\times222)$=11.78mm

Step 3:
ThethicknessofthepistonheadusingGrashof‟sformulat= 0.43D√(P/σ)mm

Step5:
Theoretical Stress Calculation$\sigma_b=M_b/W_b$MPa
Where$M_b$isthebendingmomentand$W_b$isthemomentofresistancetothe bending
$M_b=1/3\times P_{max}\times r_i^3$MNm
P_{max}=MaximumgaspressureinMPa.Thisvaluevariesbetween2-5MPaincase ofaluminiumalloys. [3]
r_i=crowninnerradiusm
$W_b=1/3\times G\times r_i^2$m^3

G=Thicknessofpistoncrownm

P =Gaspressurein MPa
r=[D/2-(s+t+dt)] m

σ_t=AllowabletensilestressMPa

=280/2.25
=124.4MPa
D= 100mm
=0.43×100√(5/124)
=8.7mm=9 mm
Adoptthegreater valueofthet_1i.e.t_1 =11.78mm

Step 4:
Pistonringproperties
Theradialthicknessoftheringt$_r$$t_r=D\times\sqrt{(3P_r/\sigma_t)}$mm
Where,$P_r$ispressureexertedbyfueloncylinderwallin N/mm^2.Its valuevariesfrom0.025 to0.042N/mm^2
=100×√(3×0.042/124)
=3.187mm
Thedistancefromtopto first groovet$_g$$t_g=1t_1to1.2t_1$

=1.2×11.78
= 14 mmNumberofringsii= 100/(10×h)
=100/(10×2.22)=4rings
The maximum thickness of piston barrel t_3t_3=0.03D+b+4.5mm
Where,b isthedepthoftheringgroovesinmm
b=t_r+0.4mm
=3.187+0.4
=3.587 mm
t_3=0.03×100+ 3.587 + 4.5
=11.08mm
Thickness of the wall towards the open end of the piston t_4t_4= 0.25$t_3$to0.35t_3
=0.25×11.08
=3.32mm
Diameterofthepistonpind = $\pi \times D^2 \times P_{max}$/ $(4 \times l_1 \times P_b)$Where$l_1$ = 1.5d
P_b is bearing pressure in MPawhich is 15.7 for aluminiumalloys.
=$\pi \times 100^2 \times 5/[4 \times (1.5d) \times 15.7]$
d=40.83mm
dt=Radialclearancebetweenpistonringsandchannelm
s=Thicknessofthesealingpartm
=[0.1/2-(0.005+0.0008+0.0031)]=0.0413m
$M_b=1/3 \times 5 \times 0.0413^3$
$=1.174 \times 10^{-4}$MNm
G=(0.08 to 0.1)Dm
=0.091×100
=9.1mm
$W_b=1/3 \times 0.0413 \times 0.0091^2$
$=1.14 \times 10^{-6} m^3$
$\sigma_b=1.17 \times 10^{-4}/1.14 \times 10^{-6}$
=103MPa

The theoretical stress value obtained is less than theallowablestress(103<124MPa).Hencethedesignissafe.

III. MODELLING IN CATIA V5R20

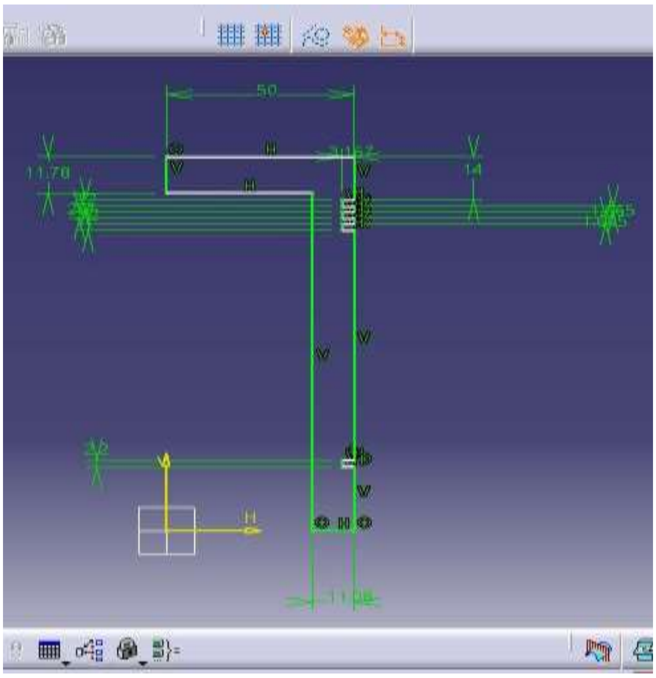


Fig.1 SketchinginCATIAV5R20

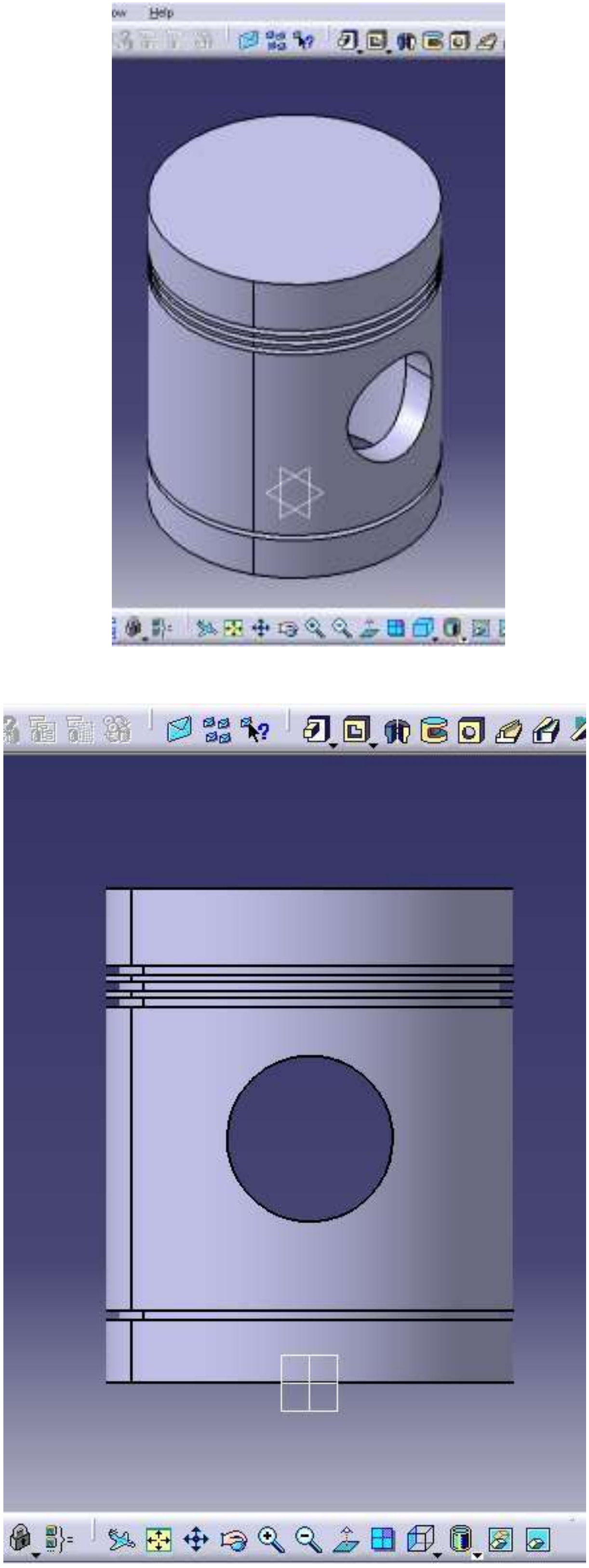
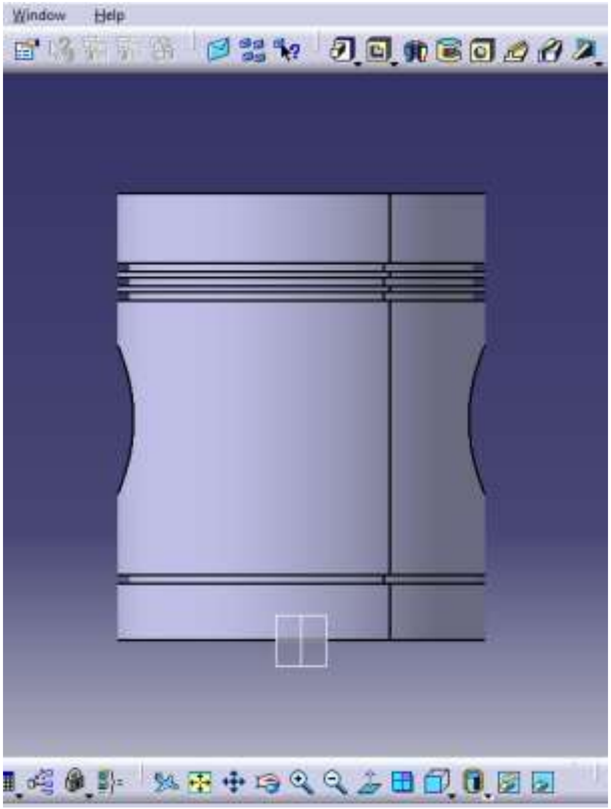


Fig.2 Piston head modeled in CATIA V5R20 based onabovecalculations

IV. ANALYSIS IN ANSYS14.5

After designing the model in CATIA V5R20 the model isconverted to STP file and imported to ANSYS 14.5. Thenanalysisiscarried outaccordinglyinfollowingsteps.



DefiningtheMaterial
Aluminumalloyischosenandappliedtotheimportedmodel. All the material properties of aluminum alloy arepredefined bythe software.

Meshingthe Model
In order to analyze the model by FEM meshing of the modelmust be done. The element size and shape of the mesh aredefined. Here we have considered the element size as 15 andshapeofthemeshastriangular.

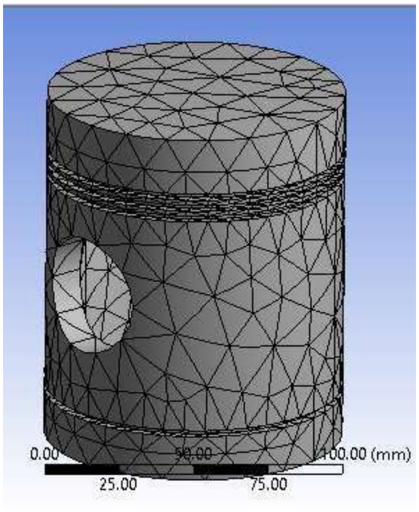


Fig.3 MeshingofthemodelinANSYS14.5

StructuralAnalysis

RestrainingtheModelatPistonPinHoles

Pistonpinholesareconsideredasfixedsupport.Hencefrictionless supportisappliedand itisrestrainedatitsholes.

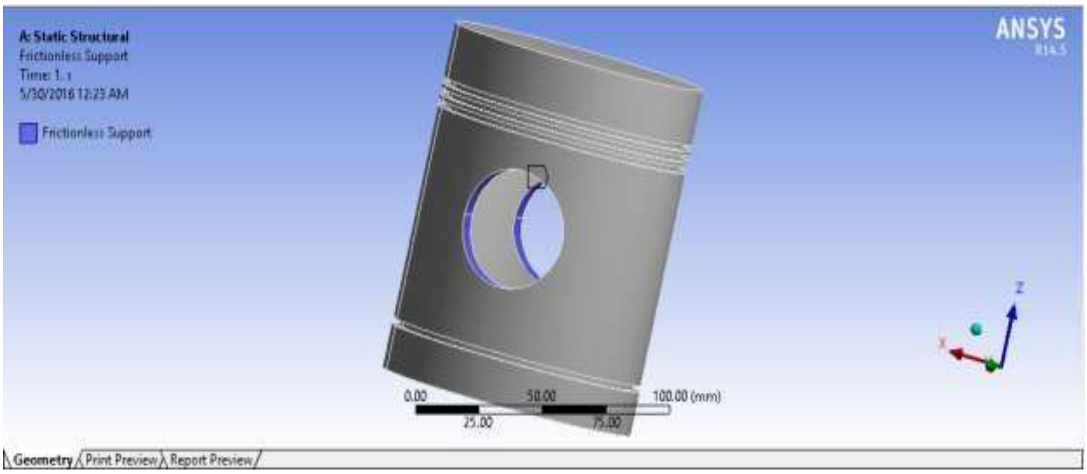


Fig.4 Restrainingthemodelat pistonpinholes

ApplyingPressure onTopSurface

For static structural analysis the pressure of magnitude 5MPais appliedon thetopsurface of the piston head.Thegascombustionpressure foraluminumalloyis5MPa.

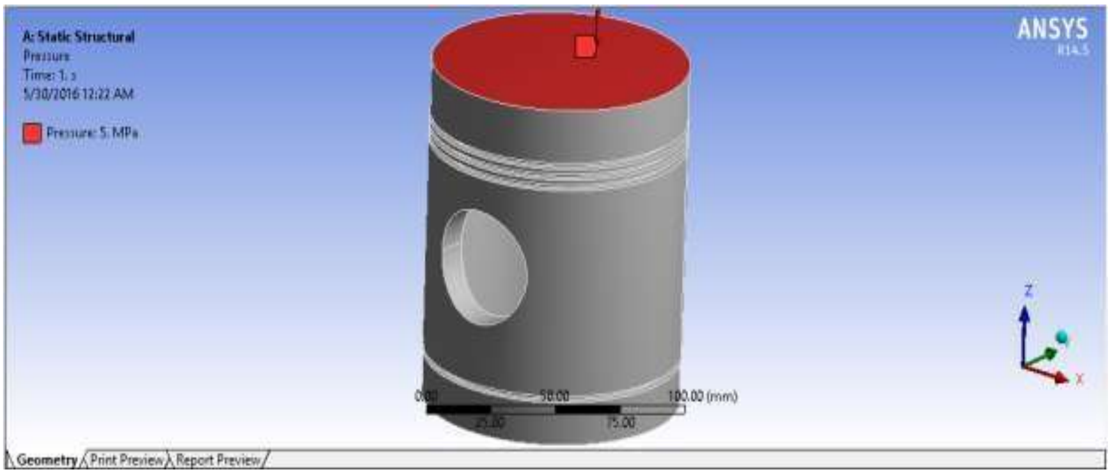


Fig.5applyingthepressureontopsurfaceofpistonhead

V. RESULTS

The model is solved after applying the pressure and resultsare obtained for Von-Mises stress and structural deformationwhich are shown below. The value of structural deformationobtained is 0.7314 mm and stress value obtained is 103.32MPa.

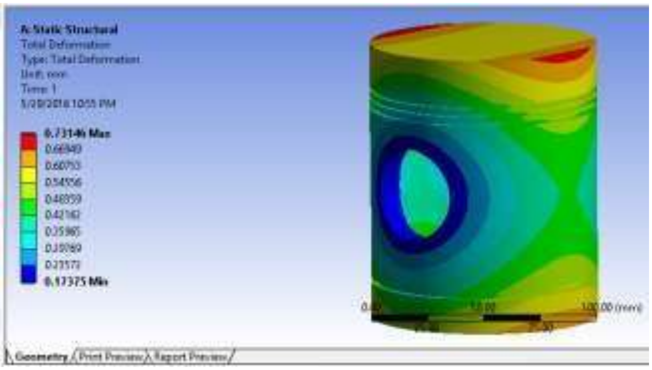


Fig.6 ResultsobtainedforStructuraldeformationofpistonhead

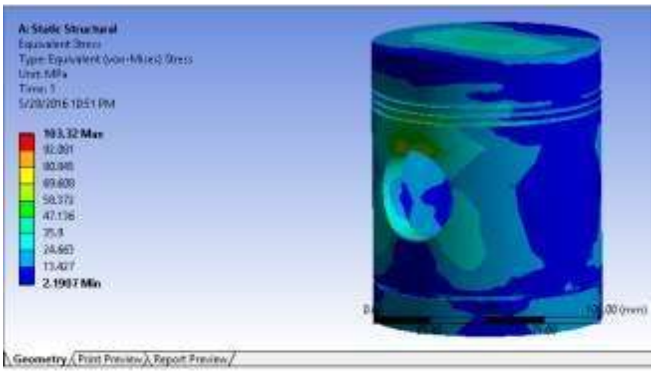


Fig.7 Resultsobtainedforstressinpistonhead

VI. CONCLUSION

Thefollowingconclusionscanbedrawnaftertheanalysis

- The theoretical stress value obtained is very close to thestressvaluesobtainedafteranalysisofthemodel inANSYS14.5.
- Thestructuraldeformationisleastatthepistonpinholesandmaximumatthe top surface.
- Thestressconcentrationis highestatpistonpinholes.

RECOMMENDATIONS

- Theanalysiscanbefurthercarriedoutforthermalanalysis from which we can compute the thermal stressinduced in variousportionsofpistonhead.
- Dynamic andvibrational analysis also can be carriedouttostudydynamic behavior.
- CFD analysis can be performed in order to compute thefluid forces, heat flow and impact of fluid pressure onpiston.

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