International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 12, December - 2013

Thermal Analysis of Combustion Chamber of Two Stroke SI Engine

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ABSTRACT:-

Cylinder is the heart of internal combustion engine as combustion takes place inside the cylinder large amount of heat is produce inside the cylinder due to that heat distortion of cylinder wall May takes place. Due to inadequate heat transfer through the engine cylinder block the engine cylinder gets overheated, lead to knocking and some time result into structural failure. This also causes an increase in the thermal stresses in the liner wall which ultimately affects the strength of liner wall. The main objective of this project is to carry out thermal analysis of combustion chamber (Liner, piston,) in Ansys10 to predict temperature distribution across the combustion chamber of scavenged engine. For the analysis purpose firstly we modeling the liner and piston in Pro/E wildfire 4.0 and analyzed the temperature distribution in Ansys 10.

1. 1INTRODUCTION

Heat transfer is a very wide field used in analysis of internal combustion engine heat transfer effect parameter such as performance, emission and also efficiency. It is said that for a given mass of fuel higher the heat transfer to the combustion wall will reduce the average combustion pressure and temperature, this indirectly reduces the work done by the piston per cycle and these effects the specific power.

Temperature rise of the engine parts may cause a serious durability of the engine. The shape of isothermal lines and high temperature regions become more important in these studies. The experimental way will find these regions are costly and time consuming; Analytical methods are almost equally good for fast conformation of this region by using finite elements

Measuring the actual dimension of various components of two-stroke S.I engine (Bajaj bravo, 150cc). modeling of piston, liner along with combustion chamber are done using Pro/E wildfire4.0,then by using Ansys 10 we analyzed the temperature distribution and thermal stresses on above component, compare that thermal stresses with theoretically calculated thermal stresses.

1. 1 AIM AND OBJECTIVE:-

Aim: -

The main objective of this project is to carry out thermal analysis of combustion chamber in Ansys to predict temperature distribution across the liner wall and piston of two strokes SI engine also find out the thermal stresses.

Objective:-

- Modeling of liner and piston in pro/E; wildfire 4.0
- Performance evaluation of 150cc, two stroke SI engine with and without scavenging process.
- Find out the theoretical thermal stresses in liner and compare which found out by software.

- Analyze the heat distribution across the assembly of piston and liner considering both temperatures with and without scavenging with the help of ANSYS 10 software.

2. FACTOR AFFECTING HEAT TRANSFER IN ENGINE

It may be noted that the engine heat transfer depended upon parameter. Unless the effect of this parameter is known, the design of a proper cooling system will be difficult.

- **Fuel-air ratio:-**

A change in fuel-air ratio will change the temperature of the cylinder gases and affect the flame speed. The maximum gas temperature will occurs at an equivalence ratio of about 1.12 i.e., at a fuel-air ratio about 0.075. At this a fuel-air ratio ΔTwill be a maximum .However, from experimental observations the maximum heat rejection is found to occur for a maximum, slightly leaner than this value.

- **Compression ratio:-**

An increase in compression ratio causes only a slight increase in gas temperature near the top dead centre; but, because of greater expansion of the gases, there will be a considerable reduction in gas temperature near bottom dead centre where a large cylinder wall is exposed. The exhaust gas temperature will also be much lower because of greater expansion so that heat rejected during blow down will be less. In general, as compression ratio increase their tend to be a marginal reduction in heat rejection.

- **Spark advance:-**

A spark advances more than the optimum as well as less than the optimum will result in increased heat rejection to the cooling system. This is mainly due to the fact that the spark timing other then MBT value (minimum spark advance for best torque) will reduce the power output and thereby more heat is rejected.

- **Engine output:-**

Engines which are designed for high mean effective pressure or high piston speeds, heat rejection will be less. Less heat will be lost for the same indicated power in large engine.

- **Speeds and loads:-**

Prediction of spark ignition engine heat transfer as a function of speed and load. The cycle heat transfer is expressed as a percent of fuels chemical energy. The relative importance is of heat losses per cycle decrease as speed and load increase: the average heat transfer per unit time, however, increased as speed and load increase.

- **Spark timing:-**

Retarding the spark timing in as SI engine decreases the heat flux. The burned gas temperature is decreased as timing is retarded because combustion occurs latter when the cylinder volume is larger. Temperature trends vary component. Piston and spark plug electrode temperature change most with timing variation; exhaust wall temperature increases as timing as retarded due to higher exhausting gas temperature.

- **Inlet temperature**:-

The heat flux increases linearly with increases inlet temperature. The gas temperature throughout the cycle is increased. An increase of 100K gives a 13 percent increases in heat flux.

- **Cylinder gas temperature**:-

The average cylinder gas temperature is much higher in comparison to the cylinder wall temperature. Hence, any marginal change in cylinder gas temperature will have very little effect on the temperature difference and thus on heat rejection.

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2.1 MAXIMUM TEMPERATURE INSIDE COMBUSTION CHAMBER

Given Data:-

Compression ratio (r) = 8 , Room Temp. (T_1) = 300 k., Ratio of specific heat (γ) = 1.4

$$r = (T3 / T_1)^{1/2.(\gamma-1)}$$

$$T_3 / T_1 = (r)^{2.(\gamma-1)}$$
$$T_3 = T_1 \times (r)^{2.(\gamma-1)}$$
$$= 300 \times (8)^{2(1.4-1)}$$
$$= 300 \times (5.27)$$
$$= \mathbf{1581^\circ k.}$$
$$\mathbf{T_3 = 1308^\circ c.}$$

It is the highest temperature inside the engine.

From the above derivation we find out the maximum temperature inside the combustion chamber, at speed 5500 rpm. Here we consider the compression ratio 8 and at room temperature 300◦k.

2. 2 EXPEIMENTAL SETUP AND CALCULATION

Engine Specification under Study

✓ Type	2-stroke 5-ports single cylinder S.I engine
✓ Cooling	Air cooled
✓ Bore	¢ 57 mm
✓ Stroke	54 mm
✓ Displacement	145.5cc
✓ Compression ratio	8
✓ Connecting rod length	105mm
✓ Maximum engine output	5.9kw@5500rpm

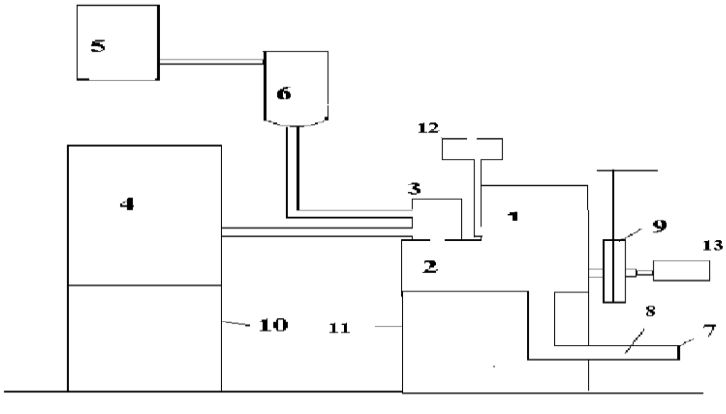

Fig. 2.1 Experimental setup.

LEGENDS

1-Engine Frame, 2-Crank Case, 3-Caburetor, 4-Air Box, 5-Fuel Tank, 6-Burrete, 7-Exhaust Of Engine, 8-PUC Machine Setup, 9-Rope Brake Dynamometer, 10-Air Box Stand, 11-Machine Stand, 12-Hole Provided For Direct Air Injection, 13-Tachometer

- **Test Procedures**

1. Start the engine by cranking the kick provided for cranking.
2. Adjust the burret level up to 25ml.
3. Then close the tank fuel valve and open burette valve & measure the fuel consumption for 10 sec with the help of stopwatch. .
4. Note down the speed of engine by the tachometer.
5. Note down the manometric reading from u-tube manometer.

- **Reading:-**

Sr.no.	Speed (r.p.m.)	Manometric reading(ΔH) (cm)	Mass of fuel(ml)	Time(sec.)	Velocity (m/s)
1	1160	8	0.9	10	36.62
2	1300	9	1	10	38.84
3	1600	13	1.2	10	46.49
4	2000	16	1.5	10	51.79
5	2750	20	1.7	10	57.91

- Table 2.1 Readings with scavenging

Sr.no	Speed (r.p.m.)	Manometric reading(ΔH) (mm)	Mass of fuel(ml)	Time(sec.)	Velocity (m/s)
1	1000	6	1	10	10.03
2	1550	8	1.4	10	11.58
3	1700	12	1.9	10	14.18
4	2100	20	2.3	10	18.31
5	2400	28	2.8	10	21.66

- Table 2.2 Readings without scavenging
- $V= \sqrt{2gh}$

- Where,
- V= velocity of air, g = acceleration due to gravity, h= manometric head
- When considering the readings with direct injection of air and without direct injection of air, there is a difference in fuel consumption rate. The velocity of air is increased in direct air injection mean there is better burning of fuel are take place due to the better burning of fuel temperature inside the combustion chamber has been increased. We considering the 50°**c** increased in temperature with direct injection of air

3] CALCULATION

3.1] Theoretical Thermal Stresses.

Whenever there is some increase or decrease in the temperature of a body, it causes the body to expand or contract. A little consideration will show that if the body is allowed to expand or contract freely, with the rise or fall of the temperature, no stresses are induced in the body. But, if the deformation of the body is prevented, some stresses are induced in the body. Such stresses are known as thermal stresses.

Let

l = Original length of the body, t = Rise or fall of temperature, and α = Coefficient of thermal expansion,

Increase or decrease in length,

$$\delta l = l.\ \alpha.\ t$$

If the ends of the body are fixed to rigid supports, so that its expansion is prevented, then compressive strain induced in the body,

$$\xi_c = \delta l\ /\ l$$

$$= l.\ \alpha.\ t/\ l$$

$$= \alpha.\ t$$

Therefore

$$\text{Thermal stress, } \sigma_{th} = \xi_c .E$$

$$= \alpha.\ t.\ E$$

- **Thermal Stresses For Without Scavenging:-**

Given data;-

$$l = 0.124\text{m},\ t = 1281^0\text{k},\ \alpha = 23.3\times10^{-6}/^0\text{c},\ E = 2\times10^{11}\ \text{N/m}^2$$

Increase or decrease in length,

$$\delta l = l.\ \alpha.\ t$$

$$= 0.124\times 23.3\times10^{-6}\times 1281$$

$$= 0.00365\ \text{m}$$

$$\xi_c = \delta l\ /\ l$$

$$= 0.00365/0.124$$

$$= 0.0294$$

$$\text{Thermal stress, } \sigma_{th} = \xi_c .E$$

$$= 0.02796\times 2\times10^{11}$$

$$\mathbf{= 0.58\times 10^{10}\ N/m^2}$$

- **Thermal Stresses For With Scavenging:-**

Given data;- $l = 0.124\text{m},\ t = 1331^0\text{k},\ \alpha = 23.3\times10^{-6}/^0\text{c},\ E = 2\times10^{11}\ \text{N/m}^2$

Increase or decrease in length,

$\delta l = l.\ \alpha.\ t$

$= 0.124 \times 23.3{\times}10^{-6} \times 1331$

$= 0.00384$ m

$\xi_c = \delta l\ /\ l$

$= 0.00384/0.124$

$= 0.0310$

Thermal stress, $\sigma_{th} = \xi_c E$

$= 0.0291 \times 2{\times}10^{11}$

$\mathbf{= 0.62{\times}10^{10}\ N/m^2.}$

3.2 Thermal Stresses from Analysis

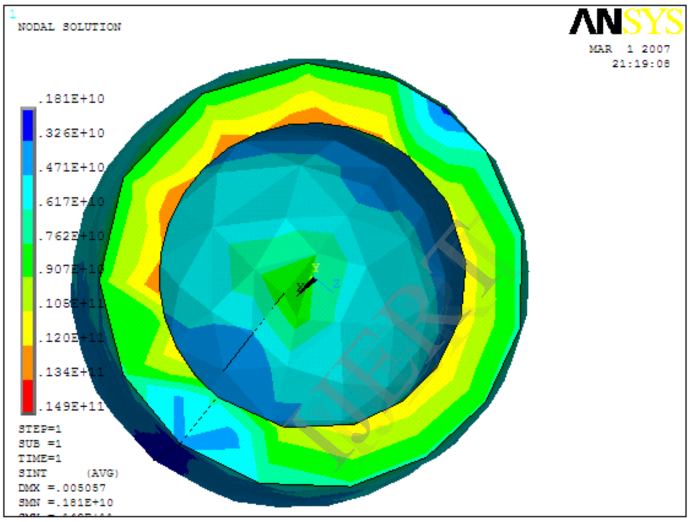

Fig. 3.1 Thermal Stresses on color scale.

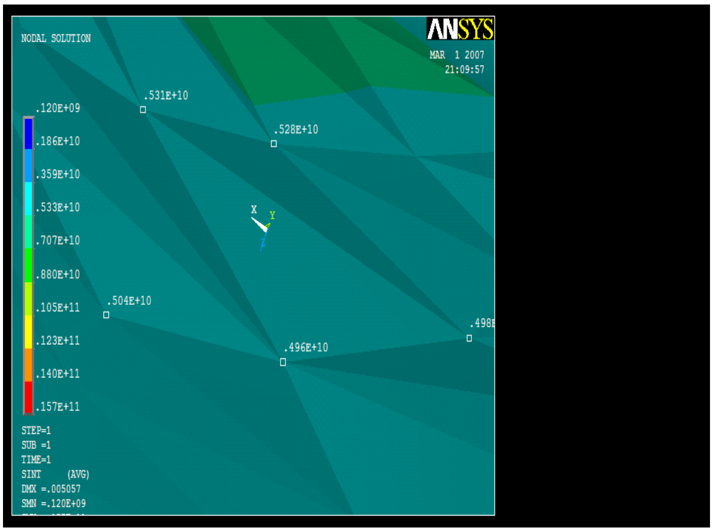

Fig. 3.1 Thermal Stresses on color scale by zoomed view.

The theoretical thermal stresses and by using software ansys10 are nearly equal.

3. 3 Material Properties:

SR.NO	PART	MATERIAL	THERMAL COMDUCTIVITY	DENSITY(kg/m³)
1	PISTON	CAST IRON	60 (W/m °k)	7200
2	PISTON RING	HIGH SPEED STEEL	54 (W/m °k)	7750
3	LINER	CAST IRON	60 (W/m °k)	7200
4	PISTON	ALUMINIUM	225(W/m °k)	2750

Table 3.1: Material Properties

4. GEOMETRY DEFINITION OF ASSEMBLY

A 3D model of engine (liner, piston, and combustion chamber) has been drawn using CAD software pro/E; wildfire 3.0 as shown in the figure.

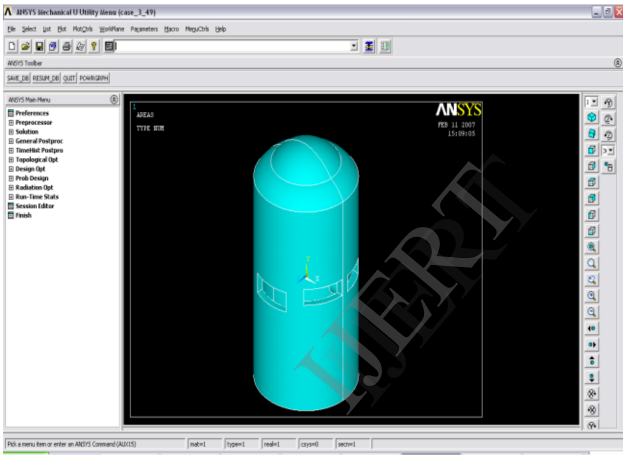

Fig 4.1 Assembly in ansys window

This model have very complicated shape, therefore it always difficult to mesh and there is lot of geometry loss take place when importing it to the analysis software ANSYS from different CAD software i.e. As an IGES file format. Our results do not match with realistic model due to element shape quality therefore it is necessary to simplify the model in ANSYS for maintaining the element shape quality as well as controlling the number of element for reducing the time for analysis figure shows the simplified (liner, piston, and combustion chamber) model in ANSYS.

4. 1 BOUNDARY CONDITION AT THE COMBUSTION CHAMBER

A variety of thermal boundary conditions is necessary to complete the application of FEM models for the prediction of temperature and heat flux distribution on engine structure. Since the application of these conditions introduce a factor of uncertainty on to the final results, a detailed knowledge of physical mechanisms become essential. For our model we used three boundary conditions, first condition is applied inside the combustion chamber and top of the piston, when the position of piston is 8 after TDC.The temperature applied at that condition is 1581 ◦k for without direct injection which is calculated in. earlier. And for direct injection we assume temperature increased 50◦c .The second boundary condition is applied at piston skirt, the temperature applied at that condition which is to be assume is 423◦k .And third boundary condition is applied at bottom of liner which is to be at 300 ◦k. Also on piston ring 1000◦k temperature is applied. There are some assumption are made like, Effect of piston motion on the heat transfer is neglected. The ring does not twist.

4. 2 TEMPERATURE DISTRIBUTION IN ASSEMBLY

Result from the ANSYS program gives us a temperature distribution of engine liner. To review this result general post processor has been used. Post processor enables to review results at one time step over the entire model.

- **Temperature Distribution Considering Without Scavenging For C.I**

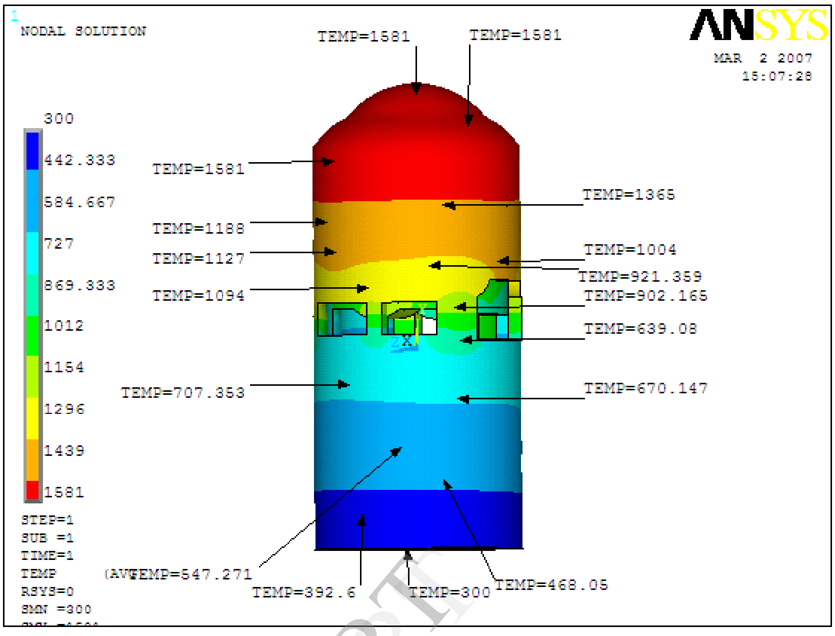

Fig. 4.2 Temperature distribution for CI

The above figure shows temperature distribution from higher temperature to lower temperature ranging between 1581 to 300^0k. The distribution of temperature on assembly shown by various color. Various ports affect the temperature distribution on assembly.

- **Temperature Distribution Considering With Scavenging For C.I**

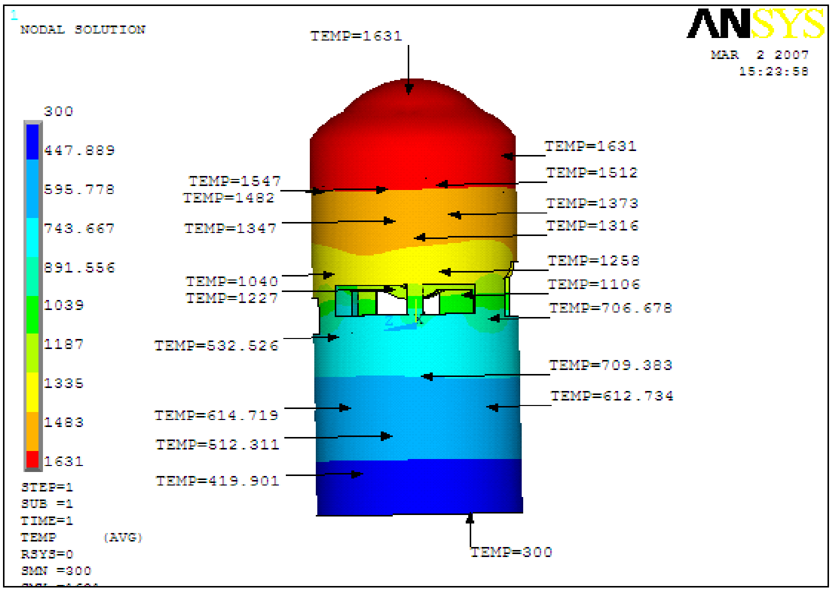

Fig .4.3 Temperature distribution for CI

- **Temperature Distribution Considering Without Scavenging For Aluminium**

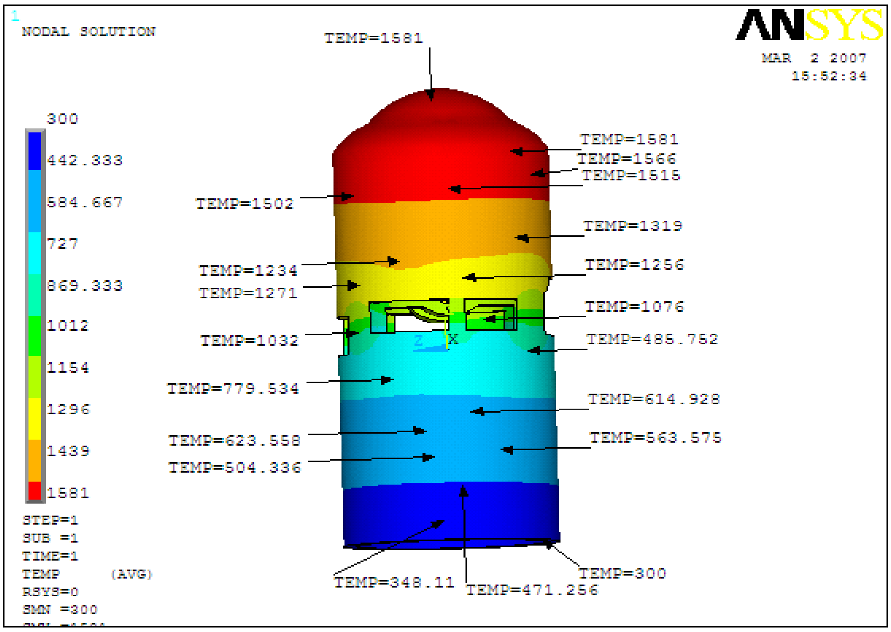

Fig.4. 4 Temperature distribution for Al

- **Temperature Distribution Considering With Scavenging For Aluminium**

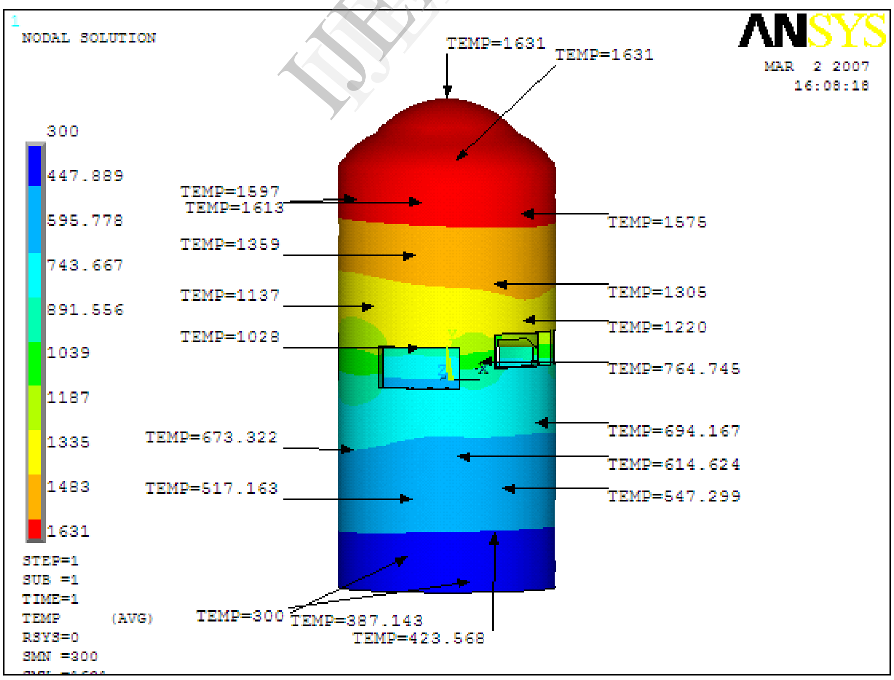

Fig. 4.5 Temperature distribution in Al

From the analysis we find out that the heat distribution in aluminium piston is better than cast iron due to its high thermal conductivity. Hence it increases the heat transfer rate and it can reduce the tendency of knocking.

4. 3 NODAL TEMPERATURE DISTRIBUTION

TEMPERATURE DISTRIBUTION ON EACH NODE WITHOUT SCAVENGING ON PISTON FOR CI

NODE NUMBER AND TEMPERATURE	NODE NUMBER AND TEMPERATURE	NODE NUMBER AND TEMPERATURE	NODE NUMBER AND TEMPERATURE	NODE NUMBER AND TEMPERATURE
391 1003.2	414 1000.5	437 995.95	460 1014.7	483 1145.1
392 1005.4	415 999.85	438 995.80	461 1027.6	484 1153.4
393 1009.7	416 999.24	439 995.67	462 1044.8	485 1155.0
394 1015.3	417 999.03	440 995.58	463 1059.0	486 1148.1
395 1021.9	418 998.57	441 995.41	464 1078.3	487 1154.3
396 1034.1	419 998.30	442 995.28	465 1082.4	488 1156.7
397 1049.1	420 998.08	443 994.92	466 1084.5	489 1154.1
398 1072.0	421 997.83	444 994.79	467 1201.6	490 1148.0
399 1075.4	422 997.57	445 994.64	468 1185.3	491 1158.3
400 1076.9	423 997.25	446 994.67	469 1172.5	492 1156.7
401 1065.3	424 997.10	447 994.69	470 1156.9	493 1156.0
402 1050.5	425 997.06	448 994.90	471 1154.0	494 1152.9
403 1033.4	426 997.04	449 995.05	472 1145.7	495 1165.3
404 1022.5	427 996.79	450 995.64	473 1153.6	496 1166.9
405 1016.2	428 996.77	451 996.10	474 1153.8	497 1164.8
406 1011.6	429 996.64	452 996.64	475 1150.6	498 1152.7
407 1008.6	430 996.42	453 997.44	476 1137.1	499 1155.1
408 1006.7	431 996.47	454 998.39	477 1149.1	500 1156.5
409 1004.7	432 996.45	455 999.70	478 1155.1	501 1158.0
410 1003.0	433 996.22	456 1001.2	479 1156.8	503 1153.7
411 1002.3	434 995.86	457 1003.5	480 1153.0	504 1152.0
412 1001.6	435 995.96	458 1006.4	481 1142.5	505 1151.1
413 1000.9	436 995.97	459 1010.3	482 1131.0	506 1150.0

TEMPERATURE DISTRIBUTION ON EACH NODE WITHOUT SCAVENGING ON PISTON FOR ALUMINIUM

NODE NUMBER AND TEMPERATURE	NODE NUMBER AND TEMPERATURE	NODE NUMBER AND TEMPERATURE	NODE NUMBER AND TEMPERATURE	NODE NUMBER AND TEMPERATURE
391 1427.9	414 1450.8	437 1444.9	460 1419.3	483 1531.3
392 1427.1	415 1451.4	438 1444.2	461 1418.3	484 1532.0
393 1426.6	416 1451.6	439 1443.3	462 1417.5	485 1532.0
394 1426.2	417 1451.7	440 1442.7	463 1418.1	486 1531.8
395 1425.9	418 1451.6	441 1441.3	464 1454.4	487 1532.6
396 1425.8	419 1451.9	442 1440.6	465 1452.4	488 1532.4
397 1425.4	420 1452.2	443 1437.2	466 1450.3	489 1531.9
398 1424.5	421 1451.4	444 1435.0	467 1532.1	490 1531.1
399 1421.8	422 1451.3	445 1435.2	468 1532.2	491 1531.9
400 1419.2	423 1451.2	446 1435.3	469 1532.1	492 1531.8
401 1449.7	424 1450.5	447 1432.6	470 1531.4	493 1531.6
402 1449.5	425 1450.6	448 1430.2	471 1531.6	494 1531.1
403 1449.7	426 1450.3	449 1430.0	472 1530.9	495 1531.7
404 1449.7	427 1450.1	450 1429.5	473 1531.7	496 1531.7
405 1449.6	428 1449.4	451 1428.2	474 1531.9	497 1531.4
406 1449.7	429 1448.7	452 1427.1	475 1531.8	498 1530.3
407 1449.9	430 1447.8	453 1425.6	476 1530.5	499 1530.6
408 1449.6	431 1447.7	454 1424.5	477 1531.6	500 1530.6
409 1450.3	432 1447.4	455 1423.2	478 1532.1	501 1530.3
410 1450.5	433 1446.6	456 1421.1	479 1532.3	502 1529.3
411 1450.9	434 1445.3	457 1421.0	480 1532.0	503 1529.6
412 1451.2	435 1445.6	458 1421.3	481 1531.1	504 1529.5
413 1451.2	436 1445.6	459 1419.9	482 1529.8	505 1529.1

TEMPERATURE DISTRIBUTION WITH SCAVENGING ON PISTON FOR C.I.

NODE NUMBER AND TEMPERATURE	NODE NUMBER AND TEMPERATURE	NODE NUMBER AND TEMPERATURE	NODE NUMBER AND TEMPERATURE	NODE NUMBER AND TEMPERATURE
391 1464.1	414 1489.1	437 1482.7	460 1454.7	483 1576.8
392 1463.3	415 1489.7	438 1481.8	461 1453.6	484 1577.6
393 1462.6	416 1489.9	439 1480.9	462 1452.7	485 1577.5
394 1462.2	417 1490.0	440 1480.2	463 1453.4	486 1577.3
395 1461.9	418 1489.9	441 1478.7	464 1493.0	487 1578.2
396 1461.8	419 1490.3	442 1477.9	465 1490.7	488 1578.0
397 1461.4	420 1490.6	443 1474.2	466 1488.5	489 1577.5
398 1460.4	421 1489.7	444 1471.9	467 1577.7	490 1576.6
399 1457.5	422 1489.6	445 1472.0	468 1577.7	491 1577.5
400 1454.6	423 1489.5	446 1472.1	469 1577.7	492 1577.4
401 1487.8	424 1488.8	447 1469.2	470 1576.9	493 1577.2
402 1487.6	425 1488.8	448 1466.6	471 1577.1	494 1576.6
403 1487.8	426 1488.5	449 1466.4	472 1576.4	495 1577.3
404 1487.8	427 1488.2	450 1465.8	473 1577.3	496 1577.2
405 1487.8	428 1487.5	451 1464.4	474 1577.5	497 1576.9
406 1487.9	429 1486.8	452 1463.2	475 1577.4	498 1575.7
407 1488.0	430 1485.8	453 1461.6	476 1576.0	499 1576.1
408 1487.7	431 1485.7	454 1460.4	477 1577.1	500 1576.0
409 1488.5	432 1485.4	455 1459.0	478 1577.7	501 1575.7
410 1488.7	433 1484.5	456 1456.6	479 1577.9	502 1574.6
411 1489.1	434 1483.1	457 1456.5	480 1577.6	503 1575.0
412 1489.5	435 1483.3	458 1456.9	481 1576.5	504 1574.8
413 1489.5	436 1483.4	459 1455.4	482 1575.2	505 1574.4

TEMPERATURE DISTRIBUTION WITH SCAVENGING ON PISTON FOR ALUMINIUM

NODE NUMBER AND TEMPERATURE	NODE NUMBER AND TEMPERATURE	NODE NUMBER AND TEMPERATURE	NODE NUMBER AND TEMPERATURE	NODE NUMBER AND TEMPERATURE
391 1471.0	414 1494.9	437 1488.8	460 1462.0	483 1579.1
392 1470.2	415 1495.5	438 1488.0	461 1461.0	484 1579.8
393 1469.6	416 1495.7	439 1487.1	462 1460.1	485 1579.8
394 1469.2	417 1495.8	440 1486.5	463 1460.7	486 1579.5
395 1468.9	418 1495.7	441 1485.0	464 1498.7	487 1580.4
396 1468.8	419 1496.1	442 1484.3	465 1496.5	488 1580.2
397 1468.4	420 1496.4	443 1480.7	466 1494.4	489 1579.7
398 1467.4	421 1495.6	444 1478.4	467 1579.9	490 1578.9
399 1464.6	422 1495.4	445 1478.6	468 1579.9	491 1579.7
400 1461.9	423 1495.4	446 1478.7	469 1579.9	492 1579.6
401 1493.7	424 1494.7	447 1475.9	470 1579.1	493 1579.4
402 1493.5	425 1494.7	448 1473.4	471 1579.4	494 1578.8
403 1493.7	426 1494.4	449 1473.2	472 1578.7	495 1579.5
404 1493.8	427 1494.1	450 1472.6	473 1579.5	496 1579.5
405 1493.7	428 1493.4	451 1471.3	474 1579.7	497 1579.1
406 1493.8	429 1492.7	452 1470.1	475 1579.6	498 1578.0
407 1493.9	430 1491.8	453 1468.6	476 1578.3	499 1578.4
408 1493.6	431 1491.7	454 1467.4	477 1579.4	500 1578.3
409 1494.4	432 1491.4	455 1466.1	478 1579.9	501 1578.0
410 1494.6	433 1490.6	456 1463.8	479 1580.1	502 1577.0
411 1495.0	434 1489.2	457 1463.7	480 1579.8	503 1577.3
412 1495.3	435 1489.4	458 1464.1	481 1578.8	504 1577.2
413 1495.4	436 1489.5	459 1462.6	482 1577.5	505 1576.8

CONCLUSION

The thermal stresses which are found in Ansys software are nearly equal to theoretical thermal stresses. The value of thermal stresses is $\sigma_{th} = 0.62\times10^{10}$ N/m^2.and according to material property of engines its safe. The ports present on the liner affect the temperature distribution across the liner body due to the reduction of area. The nodal temperature distribution table shows there is proportionality variation in nodal temperature for with and without scavenging. The temperature distribution in case of cast iron and aluminum piston show the variation due to the thermal conductivity difference, means aluminum piston are able to better heat distribution so we can say that aluminum piston gives better heat transfer than cast iron piston so it can reduced tendency of knocking**.**

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