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Design and Analysis of Cylinder Liners by Using PRO-E

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ABSTRACT : Internal combustion (I.C.) engines generally perform a characteristic of low efficiency profile which varies with engine speed and operating load and their operating efficiency is poor, under low loading conditions. The objective of this research paper is to investigate whether an energy storing and recovering process, involving compressing air and subsequently using it for power stroke (Expansion stroke), could be used to achieve better overall efficiency. When using fuel, the engine operates as close to or tends to maximum efficiency in practicable, with the excess of engine output over driving requirements being absorbed by air-compression loading - driving any other compressor, charging air into the cylinder. Heat transfer from the exhaust gases to the stored compressed air is used to improve engine efficiency. Through design, simulation and also proper utilization of exhaust gases, an overall efficiency improvement by 10% over standard engine operation is predicted to be reliable by applying to this concept, and scope exists to further improve this figure through improved heat recovery from exhaust gases and improved loading capacity. In this present work a piston and piston ring are designed for a single cylinder four stroke petrol engine using Pro E WILD FIRE 5.0 MECHANICA software. Complete design is imported to Pro E WILD FIRE 5.0 MECHANICA software then analysis is performed. The whole analysis of I.C.Engine depends upon the FEA (Finite Element Analysis) that is consist of a computer model of a material or design stressed and analysis. Materials have been selected for structural and thermal analysis of piston & piston ring by using Pro E WILD FIRE 5.0 MECHANICA software. Results are shown and a comparison is made to find the most suited design.

***Key words: Piston, Piston-Ring, Cylinder head, Exhaust valve, Cylinder block, Turbocharger, Pro* E
WILD FIRE 5.0 MECHANICA.**

1. INTRODUCTION

DEFINITION OF IC ENGINE

"It is type of heat engine in which the chemical energy of the fuel is released inside the engine and used directly for mechanical work, as opposed to an external combustion engine in which a separate combustor is used to burn the fuel."

2. THEORETICAL ANALYSIS AND DATA COLLECTION

Analysis & Calculation

DESIGN AND CALCULATION OF CYLINDER

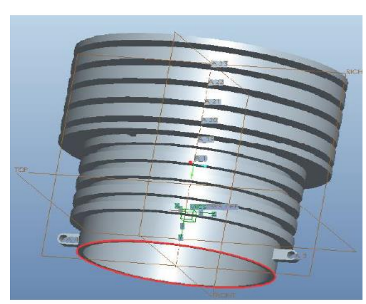

Fig.1 Cylinder

DESIGN OF CYLINDER

Bore and length of cylinder

Pm = Indicated mean effective pressure in N/mm2

D = Cylinder bore in mm

A = Cross sectional area of the cylinder in mm2

= $\pi D^2/4$

l = Length of stroke in meter

= 1.5D

N = Speed of the engine in R.P.M

n = Number of working strokes per min

= N, for two stroke engine

= N/2, for four stroke engine

I.P. = Indicated power in watt

B.P. = Brake power

(The approximate data for a 100 CC Honda engine for normal running conditions)

B.P. = 425watt, N =1200 r.p.m, pm= 0.35N/mm2

I.P = B.P./ήm= 425/0.8 = 53 1.25watt

531.25 = (0.35x15D*π/4D²*600)/(60*1000)

BORE DIA s= 50.5 say 50mm

(LENGTH OF STROKE) l = 1.5D = 1.5 x 50 = 75mm

Length of the cylinder= 1.15 x l = 1.15 x 75 = 86.25say100mm

Thickness of the Cylinder wall

$$t = \frac{P * D}{2\sigma c} + C = \frac{3.15 * 50}{2 * 65} + 1$$

= 4.65 say 5 mm

p = max pressure inside the cylinder in N/mm2

= 9 * Pm

σ c = permissible circumferential or hoop stress for the cylinder material lies between 35 MPa to 100 MPa

C = Allowance for reboring depending upon cylinder bore.

Cylinder flange and studs

d = Nominal diameter of stud in mm

d_c = core diameter of stud in mm

= 0.84 d

σ_t = allowable tensile stress for the material of the stud N/mm2, it may be taken as 35 to 70 MPa

Flange thickness should be taken **1.2 t to 1.4 t**

= 1.3 * 5

= 6.5 mm

The diameter of stud may be obtained by equating the gas load due to max. Pressure in the cylinder to the resisting force offered by all the stud.

Mathematically,

$$\frac{\pi}{4} D^2 * P = n_s * \frac{\pi}{4} dc^2 * \sigma_t$$

$$\frac{\pi}{4} 50^2 * 3.15 = 5 * \frac{\pi}{4} (0.84 * d)^2 * 65$$

D = 5.86 say 6 mm

n_s = number of stud lies between 0.01D +4 to 0.02D + 4

CYLINDER HEAD

$$t_h = D\sqrt{\frac{C.p.}{\sigma_c}} = 50\sqrt{\frac{0.1 * 3.15}{42}}$$

= 4.33 say 4.5 mm

σ_c = allowable circumferential stress in MP a or N/mm2, it may be taken as 30 to 50 MPa

C = constant whose value is taken as 0.1

ANALYSIS OF CYLINDER IN PRO-E WILD FIRE 5.0 MECHANICA

$$t_h = D\sqrt{\frac{C.p.}{\sigma_c}} = 50\sqrt{\frac{0.1 * 3.15}{42}}$$

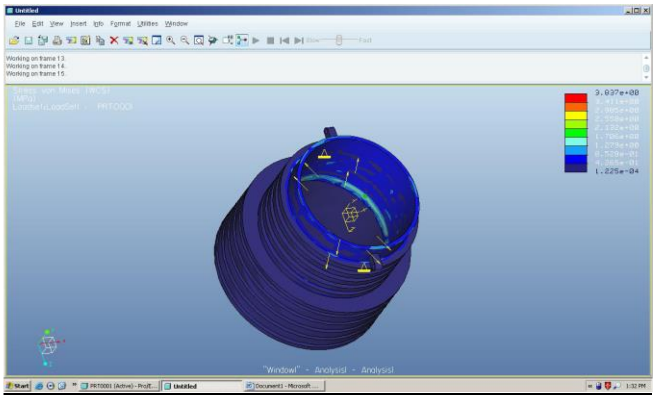

Fig.2 Stress Von Mises(WCS)

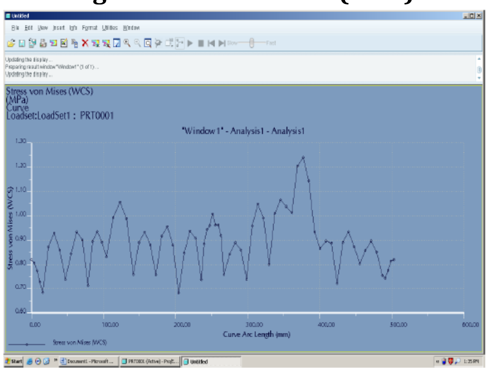

Fig.3 Stress Von Mises (WCS) Curve

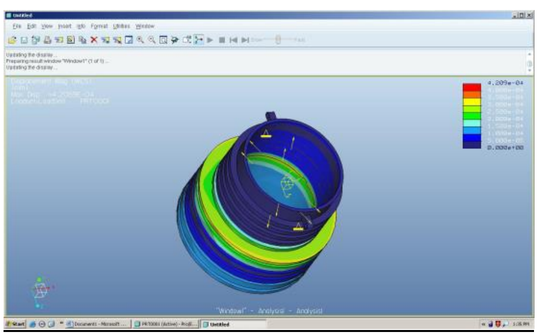

Fig.4 Displacement Mag.(WCS)

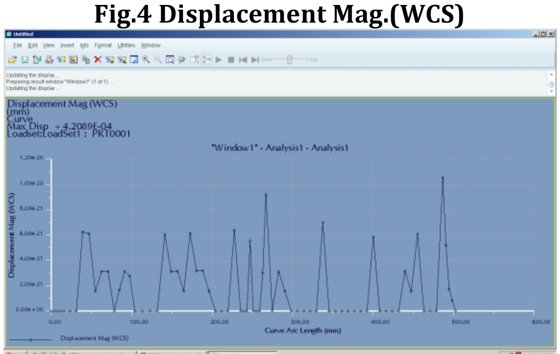

Fig.5 Displacement Mag.(WCS) Curve

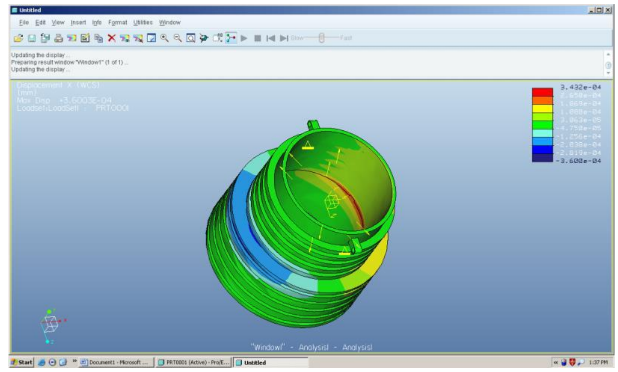

Fig.6 Displacement "X" Direction (WCS)

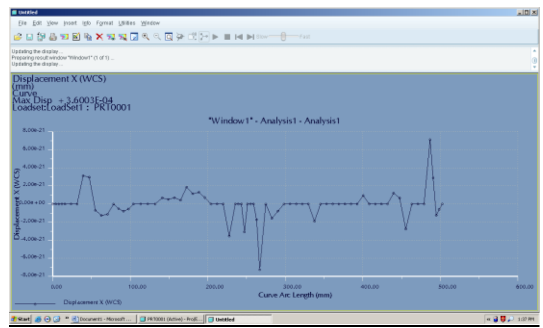

Fig.7 Displacement "X" Direction (WCS) Curve

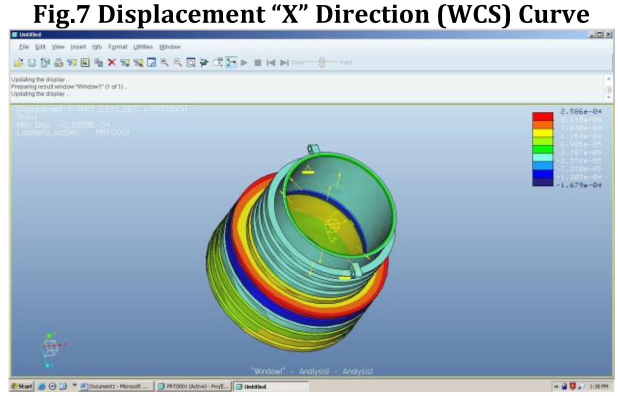

Fig.8 Displacement "Y" Direction (WCS)

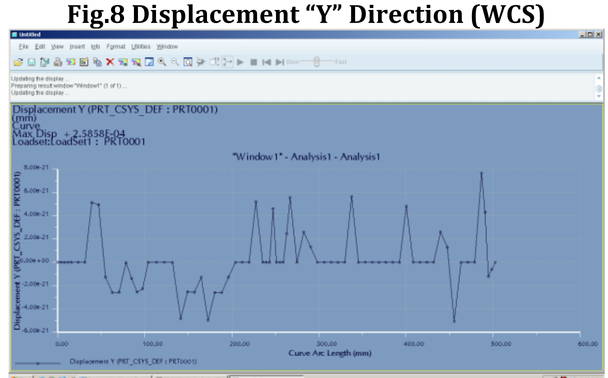

Fig.9Displacement Y" Direction (WCS) Curve

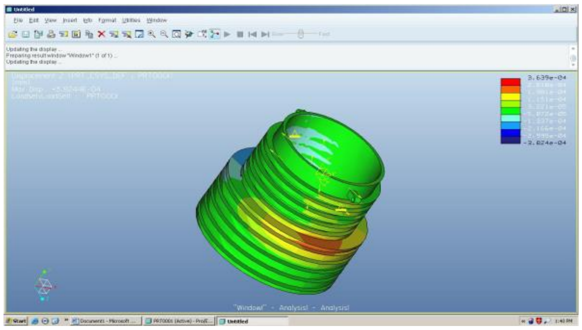

Fig.10 Displacement "Z" Direction (WCS) Curve

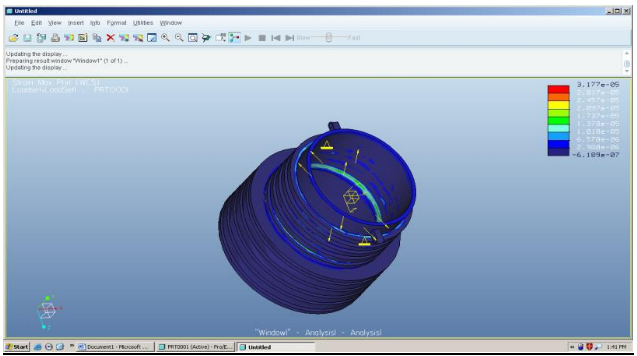

Fig.11 Strain Max. Prin.(WCS)

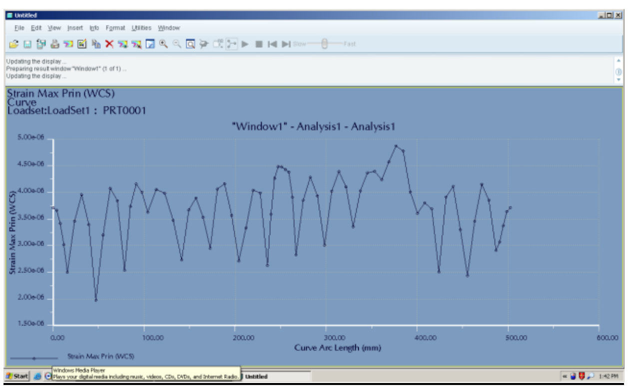

Fig.12 Strain Max. Prin. (WCS) Curve

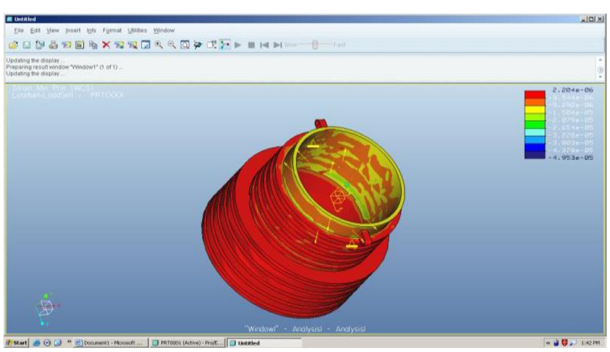

Fig.13 Strain Min. Prin. (WCS)

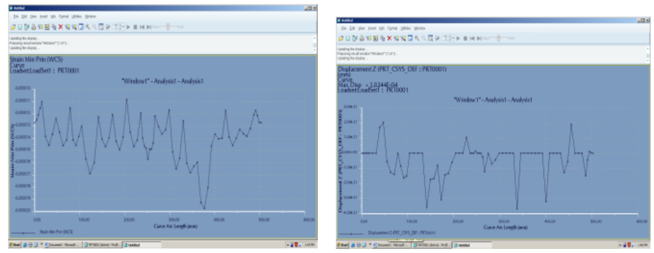

Fig.14 Strain Min. Prin.(WCS) Curve

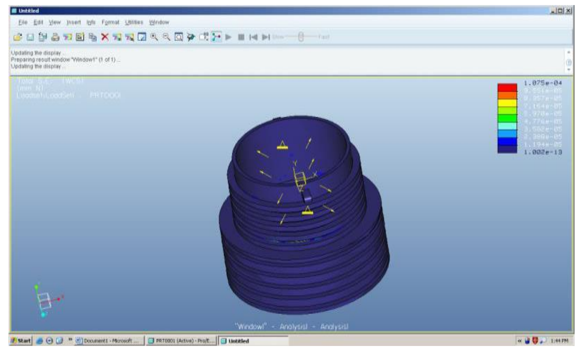

Fig.15 Total Strain Energy (WCS)

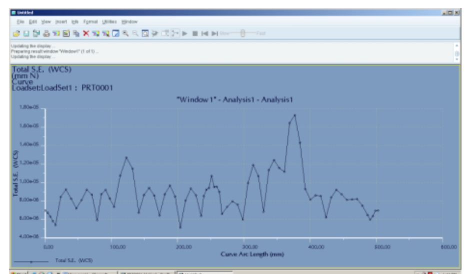

Fig. 16 Total Strain Energy (WCS) Curve

3. REPORT

Mechanica Structure Version L-03-34:spg

Summary for Design Study "Analysis1"

Run Settings

Memory allocation for block solver: 128.0

Parallel Processing Status

Parallel task limit for current run: 2

Parallel task limit for current platform: 64

Number of processors detected automatically

: 2

Checking the model before creating elements...

These checks take into account the fact that Auto GEM will automatically create elements in volumes with material properties, on surfaces with shell properties, and on curves with beam section properties. Generate elements automatically.

Checking the model after creating elements...

No errors were found in the model.

Mechanica Structure Model Summary

Principal System of Units: mmNewton Second (mmNs)

Length : mm

Force : N

Time : sec

Temperature : C

Model Type : Three Dimensional

Points : 992

Edges : 5039

Faces : 7107

Springs : 0

Masses : 0

Beams : 0

Shells : 0

Solids : 3064

Elements: 3064

Static Analysis "CYLINDER":

Convergence Method: Single-Pass Adaptive

Plotting Grid: 4

Convergence Loop Log: (13:27:26)

>> Pass 1 <<

Calculating Element Equations : (13:27:27)

Total Number of Equations: 50811

Maximum Edge Order : 3

Solving Equations : (13:27:30)

Post-Processing Solution: (13:27:34)

Checking Convergence : (13:27:36)

Resource Check : (13:27:40)

Elapsed Time (sec) : 18.46

CPU Time (sec) : 19.77

Memory Usage (kb) : 245165

Wrk Dir Dsk Usage (kb) : 59392

>> Pass 2 <<

Calculating Element Equations :(13:27:40)

Total Number of Equations : 97830

Maximum Edge Order : 7

Solving Equations : (13:27:48)

Post-Processing Solution: (13:28:06)

Checking Convergence : (13:28:10)

Calculating Disp. and Stress Results : (13:28:15)

RMS Stress Error Estimates:

Load Set	Stress Error	% of Max Prin Str
Load Set1	3.00e-01	6.4% of 4.66e+00

Resource Check (13:28:21)

Elapsed Time (sec): 59.40

CPU Time (sec) : 60.70

Memory Usage (kb) : 267480

Wrk Dir Dsk Usage(kb) : 419840

Total Mass of Model: 4.638192e-03

Total Cost of Model: 0.000000e+00

Mass Moments of Inertia about WCS Origin:

Ixx: 5.29761e+01

Ixy: 4.73183e-08 Iyy: 3.87308e+01

Ixz: -7.87249e-07 Iyz : 3.36136e-03

Izz: 5.28970e+01

Principal MMOI and Principal Axes Relative to WCS Origin:

Max Prin	Mid Prin	Min Prin
5.29761e+01	5.28970e+01	3.87308e+01

WCS X: 1.00000e+00 9.95623e-06 -479e-09

WCS Y:9.72378e-102.37280e-041 .00000e+00

WCS Z: -9.95623e-06 .00000e+00-2.37280e-04

Center of Mass Location Relative to WCS Origin:
(2.11556e-07, -7.04353e+01, 1.49423e-02)
Mass Moments of Inertia about the Center of Mass:
Ixx: 2.99654e+01
Ixy: -2.17953e-08 Iyy: 3.87308e+01
Ixz: -7.87235e-07 Iyz: -1.52017e-03
Izz: 2.98863e+01
Principal MMOI and Principal Axes Relative to COM:
Max Prin Mid Prin Min Prin
3.87308e+01 2.99654e+01 2.98863e+01
WCS X: -2.47108e-09 1.00000e+009.95623e-06
WCS Y: 1.00000e+00 7.59815e-10 1.71879e-04
WCS Z: -1.71879e-04 -9.95623e-061.00000e+00
Constraint Set: ConstraintSet1: PRT0001
Load Set: LoadSet1 : PRT0001
Resultant Load on Model:
In global X direction : 1.343301e-08

In global Y direction: 3.967569e-12
In global Z direction: 1.836048e+01
Measures:
max_beam_bending: 0.000000e+00
max_beam_tensile: 0.000000e+00
max_beam_torsion: 0.000000e+00
max_beam_total: 0.000000e+00
max_disp_mag: 4.208923e-04
max_disp_x: -3.600281e-04
max_disp_y: 2.585794e-04
max_disp_z: -3.824384e-04
max_prin_mag*: -4.662971e+00
max_rot_mag: 0.000000e+00
max_rot_x: 0.000000e+00
max_rot_y: 0.000000e+00
max_rot_z: 0.000000e+00
max_stress_prin*: 2.600815e+00
max_stress_vm*: 3.837235e+00
max_stress_xx*: -3.171374e+00
max_stress_xy*: -1.706243e+00
max_stress_xz*: -9.837487e-01
max_stress_yy*: -3.391550e+00
max_stress_yz*: -2.105324e+00
max_stress_zz*: -2.484693e+00
min_stress_prin*: -4.662971e+00
strain_energy: 1.494446e+00
** Warning: The measures marked by an asterisk (*) were evaluated at (or close to) results singularities. The values of these measures may be inaccurate, and you must use engineering judgment when interpreting them.
Analysis "CYLINDER" Completed (13:28:21)
-- Memory and Disk Usage:Machine Type: Windows NT/x86
RAM Allocation for Solver (megabytes): 128.0
Total Elapsed Time (seconds): 59.68
Total CPU Time (seconds): 60.88
Maximum Memory Usage (kilobytes): 267480
Working Directory Disk Usage (kilobytes): 419840
Results Directory Size (kilobytes):
31488 .\CYLINDER
Maximum Data Base Working File Sizes (kilobytes):
276480 .\CYLINDER.tmp\kblk1.bas
123904 .\CYLINDER.tmp\kel1.bas
19456 .\CYLINDER.tmp\oel1.bas

Run Completed
Wed Jan 5, 2017 13:28:21
-- Mechanica Structure Version L-03-36:spg
Log for Design Study "CYLINDER"
Wed Jan 5, 2017 13:27:22

Begin Creating Database for Design Study

Wed Jan 5, 2017 13:27:22

Elapsed Time (sec) : 0.22

CPU Time (sec) : 0.19

Memory Usage (kb) : 28099

Work Dir Disk Usage (kb) : 0

Step Elapsed Time (sec) : 0.00

Step CPU Time (sec) : 0.00

Begin Integrated Mode Error Checking

Wed Jan 5, 2017 13:27:22

Elapsed Time (sec) : 0.23

CPU Time (sec) : 0.19

Memory Usage (kb) : 28099

Work Dir Disk Usage (kb) : 0

Checking the model before creating elements...

These checks take into account the fact that Auto GEM will automatically create elements in volumes with material properties, on surfaces with shell properties, and on curves

with beam section properties.

Step Elapsed Time (sec) : 0.05

Step CPU Time (sec) : 0.05

Begin Generating Elements

Wed Jan 5, 2017 13:27:22

Elapsed Time (sec) : 0.27

CPU Time (sec) : 0.23

Memory Usage (kb) : 28111

Work Dir Disk Usage (kb) : 0

Copying elements from an existing mesh file...

Successfully copied elements from an existing mesh file.

A complete set of elements already exists.

OK

Step Elapsed Time (sec) : 2.28

Step CPU Time (sec) : 2.27

Begin Integrated Mode Error Checking

Wed Jan 5, 2017 13:27:24

Elapsed Time (sec) : 2.56

CPU Time (sec) : 2.50

Memory Usage (kb) : 50335

Work Dir Disk Usage (kb) : 0

Checking the model after creating elements...

No errors were found in the model.

Step Elapsed Time (sec) : 0.58

Step CPU Time (sec) : 0.53

Begin Engine Bookkeeping

Wed Jan 5, 2017 13:27:24

Elapsed Time (sec) : 3.13

CPU Time (sec) : 3.03

Memory Usage (kb) : 50355

Work Dir Disk Usage (kb) : 0

Step Elapsed Time (sec) : 0.78

Step CPU Time (sec) : 0.75

Begin Analysis: "CYLINDER"

Wed Jan 5, 2017 13:27:25

Elapsed Time (sec) : 3.91

CPU Time (sec) : 3.78

Memory Usage (kb) : 52615

Work Dir Disk Usage (kb) : 0

Step Elapsed Time (sec) : 0.64

Step CPU Time (sec) : 0.64

Begin Mass Calculation

Wed Jan 5, 2017 13:27:2

Mechanica Structure Version L-03-36:spg

Diagnostic Log

Wed Jan 5, 2017 13:27:22

-- Number of equations: 50811

Average bandwidth: 303.774

Maximum bandwidth: 1727

Size of global matrix profile (mb): 123.481

Number of terms in global matrix profile: 15435084

Minimum recommended solram for direct solver: 12
Size of element file (mb): 44.857
Maximum element matrix size (kb): 14.64
Average element matrix size (kb): 14.64

NOTES:

Solver RAM allocation can be done with a single parameter, called solram. If the Mechanica Structure/Thermal engine is the only memory-intensive application running on your computer, performance will usually be best if you set solram equal to half of your machine RAM. For example, sol ram 60 is a good choice for a machine with 128 MB of RAM.

If you are running other memory-intensive applications on your computer, decrease the solram allocation accordingly. For example, set solram to 0.25 times machine RAM if you are running two large applications at once. However, you often can run two large jobs faster one after another than if you try to run both jobs at once.

Completed Analysis: CYLINDER
Wed Jan 5, 2017 13:28:21

4. CONCLUSIONS

Internal combustion engines are among the most important engineering applications. The theory of application either depends upon Diesel or Otto cycles. They are categorized either according to the operating cycle, or due to the mechanism of working. Each type of engines has some advantages over the other one .Thus; the selection of the appropriate engine requires determining the condition of the application. For the Analysis purpose, we use mainly Finite Element Analysis.

The whole analysis of I.C ENGINE depends upon the FEA (Finite Element Analysis) that is consist of a computer model of a material or design that's stressed and analyzed for specific results. Its used in new product design and existing product modifying an existing product or structure is utilized to qualify the product or structure for a new condition.

It's of two type:

1) 2D MODELING
2) 3D MODELING

5. REFERENCES:-

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