

Performance and Design Analysis of I. C. Engine

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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.

KEYWORDS: Cylinder head, Exhaust valve, Cylinder block, Turbocharger.

I. INTRODUCTION

DEFINITION OF IC ENGINE

“Heat engine is mechanical device in which the chemical energy of the fuel is converting into ⁴mechanical energy, and external combustion engine in which a separate combustion chamber is used to burn the fuel.”

1.1 Cylinder Block

The cylinder block is casted by gray iron or iron alloyed with other metals such as nickel, chromium. Some lightweight engine blocks are made from aluminum. Cylinders are also machined by grinding or boring to give them the desired true inner surface. Engine will wear out-of-round, and cylinder walls also wear during normal working or they may become cracked if not properly lubricated or cooled. Liners (sleeves) are made of metal alloys resistant to wear and used in many gasoline engines and practically all diesel engines to lessen wear. After that they have been worn beyond the maximum oversize, the liners can be replaced individually, which permits the use of standard pistons and rings. Thus, you can avoid replacing the whole cylinder block.

The liner is inserted into a hole in the block with either a SLIP FIT or a PRESS FIT. Liner is further designated as either a DRY-TYPE or WET-TYPE. The wet-type liner comes in direct contact with the coolant. The dry-type liner does not contact with the coolant.

Engine blocks for L-head engines have the passageways for the valves and ports. The lower part of the block (crankcase) supports the crankshaft (the main bearings and bearing caps) and provides a place to which the oil pan is fastened.

⁵The camshaft is supported in the cylinder block by bushings that fit into machined holes in the block. On L-head in-line engines, the intake and exhaust manifolds are attached to the side of the cylinder block. On L-head engines, the intake manifold is located between the two banks of cylinders; these engines have two exhaust manifolds, one on the outside of each bank.

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1.2 Cylinder Head

The cylinder head fitted on the combustion chambers for the engine cylinders. It is built to conform to the arrangement of the valves: L-head, I-head, or other. In the water-cooled engine, the cylinder head is bolted to the top of the cylinder block to close the upper end of the cylinders. It provides passages, matching those of the cylinder block, that allow cooling water to circulate in the head. The head also helps keep compression in the cylinders. The gasoline engine contains tapped holes in the cylinder head that lead into the combustion chamber. The spark plugs are fitted into these tapped holes.

In the diesel engine the cylinder head may be cast in a single unit, or it may be cast for a single cylinder or two or more cylinders.

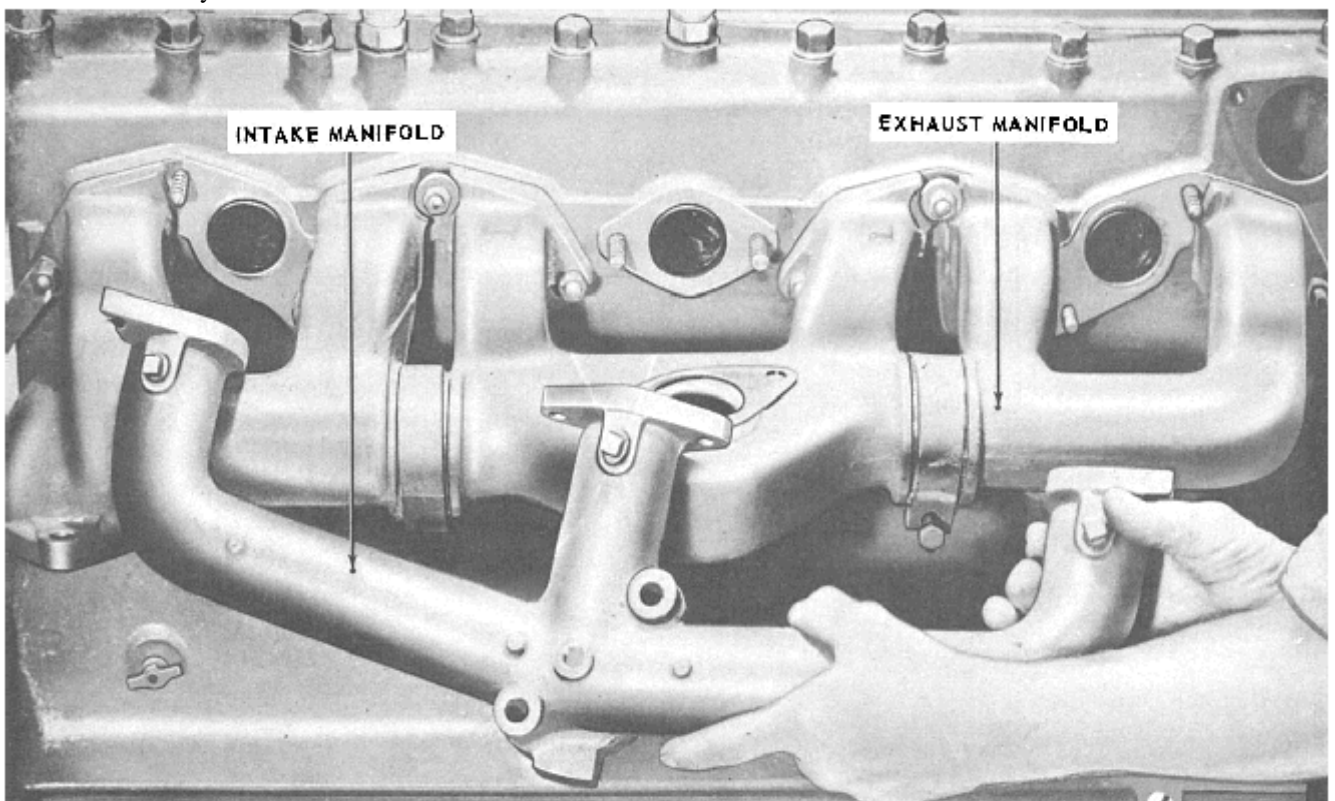


Fig 1.1

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DESIGN AND CALCULATION OF CYLINDER

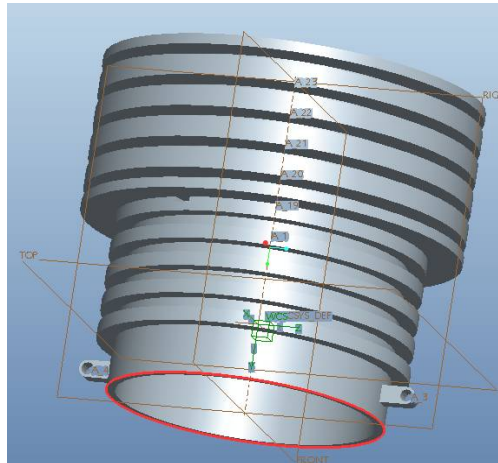


Fig.1.2 Cylinder

1.3 DESIGN OF CYLINDER

Bore and length of cylinder

P_m = Indicated mean effective pressure in N/mm^2

D = Cylinder bore in mm

A = Cross sectional area of the cylinder in $mm^2 = \pi D^2/4$

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, $p_m= 0.35N/mm^2$

I.P = $B.P./\eta_m = 425/0.8 = 531.25$ watt

$$I.P. = \frac{P_m * l * A * n}{60} \text{ watts}$$

$$531.25 = \frac{0.35 * 1.5D * \pi / 4 D^2 * 600}{60 * 1000}$$

BORE DIA $s= 50.5$ say 50 mm

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

Length of the cylinder= $1.15 * l = 1.15 * 75 = 86.25$ say 100 mm

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 $N/mm^2 = 9 * P_m$

σ_c = permissible circumferential or hoop stress for the cylinder material lies between $35 MP_a$ to $100 MP_a$

C =allowance for reboring depending upon cylinder bore

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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 MP_a

Flange thickness should be taken **1.2 t to 1.4 t** = 1.3 * 5

$$= 6.5 \text{ mm}$$

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,

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

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

$$d = 5.86 \text{ say } 6 \text{ mm}$$

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

CYLINDER HEAD

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

$$= 4.33 \text{ say } 4.5 \text{ mm}$$

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

C = constant whose value is taken as 0.1

1.4 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.

Mechanical Structure Model Summary

Principal System of Units: millimeter Newton Second (mmNs)

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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
-----	-----	-----
LoadSet1	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

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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	-3.33479e-09	
WCS Y: 9.72378e-10	2.37280e-04		1.00000e+00
WCS Z: -9.95623e-06	1.00000e+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+00	9.95623e-06	
WCS Y: 1.00000e+00	7.59815e-10		1.71879e-04
WCS Z: -1.71879e-04	-9.95623e-06	1.00000e+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

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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.

¹Analysis "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 January 05, 2017 13:28:21
  
```

```

-----
Mechanica Structure Version L-03-36:spg
Log for Design Study "CYLINDER"
Wed January 05, 2017 13:27:22
  
```

```

-----
Begin Creating Database for Design Study
Wed January 05, 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 Mar 02, 2011 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...
6These 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
  
```

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```

Wed January 05, 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 January 05, 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 January 05, 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 January 05, 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 January 05, 2017 13:27:2
Mechanica Structure Version L-03-36:spg
Diagnostic Log
Wed January 05, 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

```


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NOTES:

Solver RAM allocation can be done with a single parameter, called solram. If the Mechanical 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 January 05, 2017 13:28:21

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