Design Of Engine Cylinder Using Matlab

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ABSTRACT

The function of a cylinder is to retain the working fluid and to guide the piston. The cylinders are usually made of cast iron or cast steel. Since the cylinder has to withstand high temperature due to the combustion of fuel, therefore, some arrangement must be provided to cool the cylinder. The single cylinder engines (such as scooters and motorcycles) are generally air cooled. They are provided with fins around the cylinder. The multi-cylinder engines (such as of cars) are provided with water jackets around the cylinders to cool it.

In this project "MATLAB" has been used to design engine cylinder. MATLAB is extensively used for scientific & research purposes. It is accurate & also has a number of built in functions which makes it versatile. Based on the work a CYLINDER can be designed. The program is a user friendly one & when executed it ask the inputs and performs the necessary design calculations and gives necessary output values. It also gives the design of engine cylinder with accurate safe dimensions. As computers are used to perform the task of piston design becomes simple, friendly & error free.

1. INTRODUCTION TO ENGINE CYLINDER

A **cylinder** is the central working part of a reciprocating engine or pump, the space in which a piston travels. Multiple cylinders are commonly arranged side by side in a bank, or engine block, which is typically cast from aluminum or cast iron before receiving precision machine work. Cylinders may be **sleeved** (*lined* with a harder metal) or **sleeveless** (with a wear-resistant coating such as Nikasil).

A cylinder's displacement, or swept volume, can be calculated by multiplying its cross-sectional area (the square of half the bore by pi) and again by the distance the piston travels within the cylinder (the stroke). The engine displacement can be calculated by multiplying the swept volume of one cylinder by the number of cylinders. Presented mathematically,

$$CylinderVolume = \pi * (\frac{bore}{2})^2 * Stroke$$

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A piston is seated inside each cylinder by several metal piston rings fitted around its outside surface in machined grooves; typically two for compressional sealing and one to seal the oil. The rings make near contact with the cylinder walls (sleeved or sleeveless), riding on a thin layer of lubricating oil; essential to keep the engine from seizing and necessitating a cylinder wall's durable surface.

During the earliest stage of an engine's life, its initial *breaking-in* or *running-in* period, tiny irregularities in the metals are encouraged to gradually form congruent grooves by avoiding extreme operating conditions. Later in its life, after mechanical wear has increased the spacing between the piston and the cylinder (with a consequent decrease in power output) the cylinders may be machined to a slightly larger diameter to receive new sleeves (where applicable) and piston rings, a process sometimes known as *reboring*.

1.1 Cylinder sleeving

Cylinder walls can become very worn or damaged from use. If the engine is not equipped with replaceable sleeves there is a limit to how far the cylinder walls can be bored or wear before the block must be sleeved or replaced. In such cases where the use of a sleeve or liner can restore proper clearances to an engine. Sleeves are made out of iron alloys and are very reliable. A sleeve is installed by a machinist at a machine shop. The engine block is mounted on a precision boring machine where the cylinder is then bored to a size much larger than normal and a new cast-iron sleeve can be inserted with an interference fit. The sleeves can be pressed into place, or they can be held in by an shrink fit. This is done by boring the cylinder (between 3 to 6 thousandths of an inch) smaller than the sleeve being installed, then heating the engine block and while hot, the cold sleeve can be inserted easily. When the engine block cools down it shrink fits around the sleeve holding it into place. Cylinder wall thickness is important to efficient thermal

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conductivity in the engine. When choosing sleeves, engines have specifications to how thick the cylinder walls should be to prevent overworking the coolant system. Each engine's needs are different, dependent on designed work load duty cycle and energy produced. After selecting and installing the sleeve, the cylinder needs to be finish bored and honed to match the piston. Care needs to be given to the finish of the cylinder walls to prevent improper ring seating at break in.

1.2 Seizing
Failed lubrication can cause the pistons or piston rings to seize to the cylinder walls. Seizing can occur during engine use, via overheating and lack of oil, or during storage via condensation and corrosion.

1.3 Cylinder and Cylinder Liner
The function of a cylinder is to retain the working fluid and to guide the piston. The cylinders are usually made of cast iron or cast steel. Since the cylinder has to withstand high temperature due to the combustion of fuel, therefore, some arrangement must be provided to cool the cylinder. The single cylinder engines (such as scooters and motorcycles) are generally air cooled. They are provided with fins around the cylinder. The multi-cylinder engines (such as of cars) are provided with water jackets around the cylinders to cool it. In smaller engines. The cylinder, water jacket and the frame are made as one piece, but for all the larger engines, these parts are manufactured separately. The cylinders are provided with cylinder liners so that in case of wear, they can be easily replaced. The cylinder liners are of the following two types: **1.** Dry liner and **2.** Wet liner**.**
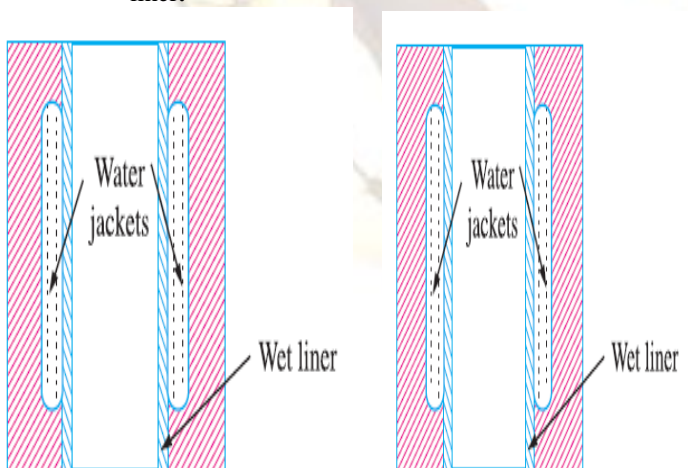
A cylinder liner which does not have any direct contact with the engine cooling water, is known as *dry liner,* as shown in Fig. 32.2 (*a*). A cylinder liner which has its outer surface in direct contact with the engine cooling water is known as *wet liner,* as shown in Fig. 32.2 (*b*). The cylinder liners are made from good quality close grained cast

iron (*i.e.* pearlitic cast iron), nickel cast iron, and nickel chromium cast iron. In some cases, nickel chromium cast steel with molybdenum may be used. The inner surface of the liner should be properly heat-treated in order to obtain a hard surface to reduce wear.

2. DESIGN OF A CYLINDER
In designing a cylinder for an I. C. engine, it is required to determine the following values

2.1 *Thickness of the cylinder wall.* The cylinder wall is subjected to gas pressure and the piston side thrust. The gas pressure produces the following two types of stresses : (*a*) Longitudinal stress, and (*b*) Circumferential stress.

Since these two stressess act at right angles to each other, therefore, the net stress in each direction is reduced. The piston side thrust tends to bend the cylinder wall, but the stress in the wall due to side thrust is very small and hence it may be neglected. Let

D_o = Outside diameter of the cylinder in mm,

D = Inside diameter of the cylinder in mm,

p = Maximum pressure inside the engine cylinder in N/mm2,

t = Thickness of the cylinder wall in mm, and

$1/m$ = Poisson's ratio. It is usually taken as 0.25.

The apparent longitudinal stress is given by

$$\sigma l = \frac{force}{area} = \frac{\pi \times D^2 \times p}{\frac{\pi}{4}[(D_o^2)-D^2]} = \frac{D^2 \times p}{(D_o^2)-D^2]}$$

and the apparent circumferential stresss is given by

$$\sigma c = \frac{force}{area} = \frac{D \times l \times p}{2t \times l} = \frac{D \times l}{2t}$$

……(where l is the length of the cylinder and area is the projected area)

Net longitudinal stress $= \sigma l - \frac{\sigma c}{m}$

and net circumferential stress $= \sigma c - \frac{\sigma l}{m}$

The thickness of a cylinder wall (t) is usually obtained by using a thin cylindrical formula,i.e.,

$$t = \frac{p \times D}{2\sigma c} + C$$

where

p = Maximum pressure inside the cylinder in N/mm2,

D = Inside diameter of the cylinder or cylinder bore in mm,

σc = Permissible circumferential or hoop stress for the cylinder material in MPa or N/mm2. Its value may be taken from 35 MPa to 100 MPa depending upon the size and material of the cylinder.

C = Allowance for reboring.

The allowance for reboring (C) depending upon the cylinder bore (D) for I. C. engines is given

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in the following table :

ALLOWANCE FOR REBORING FOR I. C. ENGINE CYLINDERS.

D (mm)	75	100	150	200	250	300	350
C (mm)	1.5	2.4	4	6.3	8	9.5	11

The thickness of the cylinder wall usually varies from 4.5 mm to 25 mm or more depending upon the size of the cylinder. The thickness of the cylinder wall (*t*) may also be obtained from the following empirical relation, *i.e.*

$$t = 0.045 D + 1.6 \text{ mm}$$

The other empirical relations are as follows :
Thickness of the dry liner = 0.03 D to 0.035 D
Thickness of the water jacket wall = 0.032 D + 1.6 mm or $t / 3$ *m* for bigger cylinders and $3t /4$ for smaller cylinders
Water space between the outer cylinder wall and inner jacket wall = 10 mm for a 75 mm cylinder to 75 mm for a 750 mm cylinder or 0.08 D + 6.5 mm

2.2 *Bore and length of the cylinder.* The bore (*i.e.* inner diameter) and length of the cylinder may be determined as discussed below :
Let
    pm = Indicated mean effective pressure in N/mm2,
    D = Cylinder bore in mm,
    A = Cross-sectional area of the cylinder in mm2,

$$= \frac{\pi}{4} \times D^2$$

    l = Length of stroke in metres,
    N = Speed of the engine in r.p.m., and

    n = Number of working strokes per min
        = N, for two stroke engine
        = N/2, for four stroke engine.

We know that the power produced inside the engine cylinder, i.e. indicated power,

$$\text{I.P} = \frac{pm \times l \times A \times n}{60} \text{ watts}$$

From this expression, the bore (*D*) and length of stroke (*l*) is determined. The length of stroke is generally taken as 1.25 *D* to 2*D*. Since there is a clearance on both sides of the cylinder, therefore length of the cylinder is taken as 15 percent greater than the length of stroke. In other words,
    Length of the cylinder, *L* = 1.15 × Length of stroke = 1.15 *l*

2.3 Cylinder flange and studs. The cylinders are cast integral with the upper half of the crankcase or they are attached to the crankcase by means of a flange with studs or bolts and nuts. The cylinder flange is integral with the cylinder and should be made thicker than the cylinder wall. The flange thickness should be taken as 1.2 t to 1.4 t, where t is the thickness of cylinder wall. The diameter of the studs or bolts may be obtained by equating the gas load due to the maximum pressure in the cylinder to the resisting force offered by all the studs or bolts. Mathematically,

$$\frac{\pi}{4} \times D^2 \times p = ns \times \frac{\pi}{4} \times (dc)^2 \times \sigma t$$

where
    D = Cylinder bore in mm,
    p = Maximum pressure in N/mm2,
    ns = Number of studs. It may be taken as 0.01 D + 4 to 0.02 D + 4
    dc = Core or minor diameter,
i.e. diameter at the root of the thread in mm,

σt = Allowable tensile stress for the material of studs or bolts in MPa or N/mm2
It may be taken as 35 to 70 MPa.
The nominal or major diameter of the stud or bolt (*d*) usually lies between 0.75 *tf* to *tf,* where *tf* is the thickness of flange. In no case, a stud or bolt less than 16 mm diameter should be used. The distance of the flange from the centre of the hole for the stud or bolt should not be less than *d* + 6 mm and not more than 1.5 *d,* where *d* is the nominal diameter of the stud or bolt. In order to make a leak proof joint, the pitch of the studs or bolts should lie between 19 *d* to 28.5 *d*, where *d* is in mm.

2.4 *Cylinder head.* Usually, a separate cylinder head or cover is provided with most of the engines. It is, usually, made of box type section of considerable depth to accommodate ports for air and gas passages, inlet valve, exhaust valve and spark plug (in case of petrol engines) or atomiser at the centre of the cover (in case of diesel engines). The cylinder head may be approximately taken as a flat circular plate whose thickness (*th*) may be determined from the following relation :

$$th = D\frac{\sqrt{c \times p}}{\sqrt{\sigma c}}$$

where
    D = Cylinder bore in mm,
    p = Maximum pressure inside the cylinder in N/mm2,
    σc = Allowable circumferential stress in MPa or N/mm2. It may be taken 30 to 50 MPa, and
    C = Constant whose value is taken as 0.1.
The studs or bolts are screwed up tightly along with a metal gasket or asbestos packing to provide a leak proof joint between the cylinder and cylinder head. The tightness of the joint also depends upon the pitch of the bolts or studs, which should lie between 19 d to 28.5 d. The pitch circle diameter (Dp) is usually taken as D + 3d.

3. INTRODUCTION TO MATLAB
3.1 History:

Cleve Moler, the chairman of the computer-science department at the University of New Mexico, started developing MATLAB in the late 1970s. He designed it to give his student's access to LINPACK and EISPACK without them having to learn FORTRAN. It soon spread to other universities and found a strong audience within the applied mathematics community. Jack Little, an engineer, was exposed to it during a visit Moler made to Stanford University in 1983. Recognizing its commercial potential, he joined with Moler and Steve Bangert. They rewrote MATLAB in C and founded MathWorks in 1984 to continue its development. These rewritten libraries were known as JACKPAC. In 2000, MATLAB was rewritten to use a newer set of libraries for matrix manipulation, LAPACK.

MATLAB was first adopted by researchers and practitioners in control engineering, Little's specialty, but quickly spread to many other domains. It is now also used in education, in particular the teaching of linear algebra and numerical analysis, and is popular amongst scientists involved in image processing.

MATLAB (Matrix Laboratory) is an interactive system for matrix-based computation, designed for scientific and engineering use. MATLAB is a high performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notations.
Typically uses include:
Math and computation
Algorithm development
Modeling, simulation, and prototyping
Data analyzing, exploration and visualization
Scientific and engineering graphics
Application development including graphical user interface building

3.2 What Is MATLAB?

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include:
- Math and computation
- Algorithm development
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics
- Application development, including Graphical User Interface building

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar no interactive language such as C or FORTRAN.

The name MATLAB stands for matrix laboratory. MATLAB was originally written to provide easy access to matrix software developed by the LINPACK and EISPACK projects, which together represent the state-of-the-art in software for matrix computation.

MATLAB has evolved over a period of years with input from many users. In university environments, it is the standard instructional tool for introductory and advanced courses in mathematics, engineering, and science. In industry, MATLAB is the tool of choice for high-productivity research, development, and analysis.

MATLAB features a family of application-specific solutions called toolboxes. Very important to most users of MATLAB, toolboxes allow you to *learn* and *apply* specialized technology. Toolboxes are comprehensive collections of MATLAB functions (M-files) that extend the MATLAB environment to solve particular classes of problems. Areas in which toolboxes are available include signal processing, control systems, neural networks, fuzzy logic, wavelets, simulation, and many others.

3.3 The MATLAB System
The MATLAB system consists of five main parts:
3.3.1 The MATLAB language.

This is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features. It allows both "programming in the small" to rapidly create quick and dirty throw-away programs, and "programming in the large" to create complete large and complex application programs.

3.3.2 The MATLAB working environment.

This is the set of tools and facilities that you work with as the MATLAB user or programmer. It includes facilities for managing the variables in your workspace and importing and exporting data. It also includes tools for developing, managing, debugging, and profiling M-files, MATLAB's applications.

3.3.3 Handle Graphics.

This is the MATLAB graphics system. It includes high-level commands for two-dimensional and three-dimensional data visualization, image processing, animation, and presentation graphics. It also includes low-level commands that allow you to fully customize the appearance of graphics as well as to build complete Graphical User Interfaces on your MATLAB applications.

3.3.4 The MATLAB mathematical function library.

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This is a vast collection of computational algorithms ranging from elementary functions like sum, sine, cosine, and complex arithmetic, to more sophisticated functions like matrix inverse, matrix eigenvalues, Bessel functions, and fast Fourier transforms.

3.3.5 The MATLAB Application Program Interface (API).

This is a library that allows you to write C and FORTRAN programs that interact with MATLAB. It include facilities for calling routines from MATLAB (dynamic linking),

calling MATLAB as a computational engine, and for reading and writing MAT-files.

3.4 MATRIX OPERATORS:

MATLAB has several operators for our use.

+ Addition

- Subtraction

* Matrix multiplication

/ Division

^ Exponentiation

.* term-by-term multiplication

For example if we choose second option the output is as shown below

. / term-by term division

MATLAB OUTPUT:

By using mat lab we can estimate the following options and the output will be obtained as per the option chosen.

CHOOSE OPTIONS FOR DESIGN OF CYLINDER
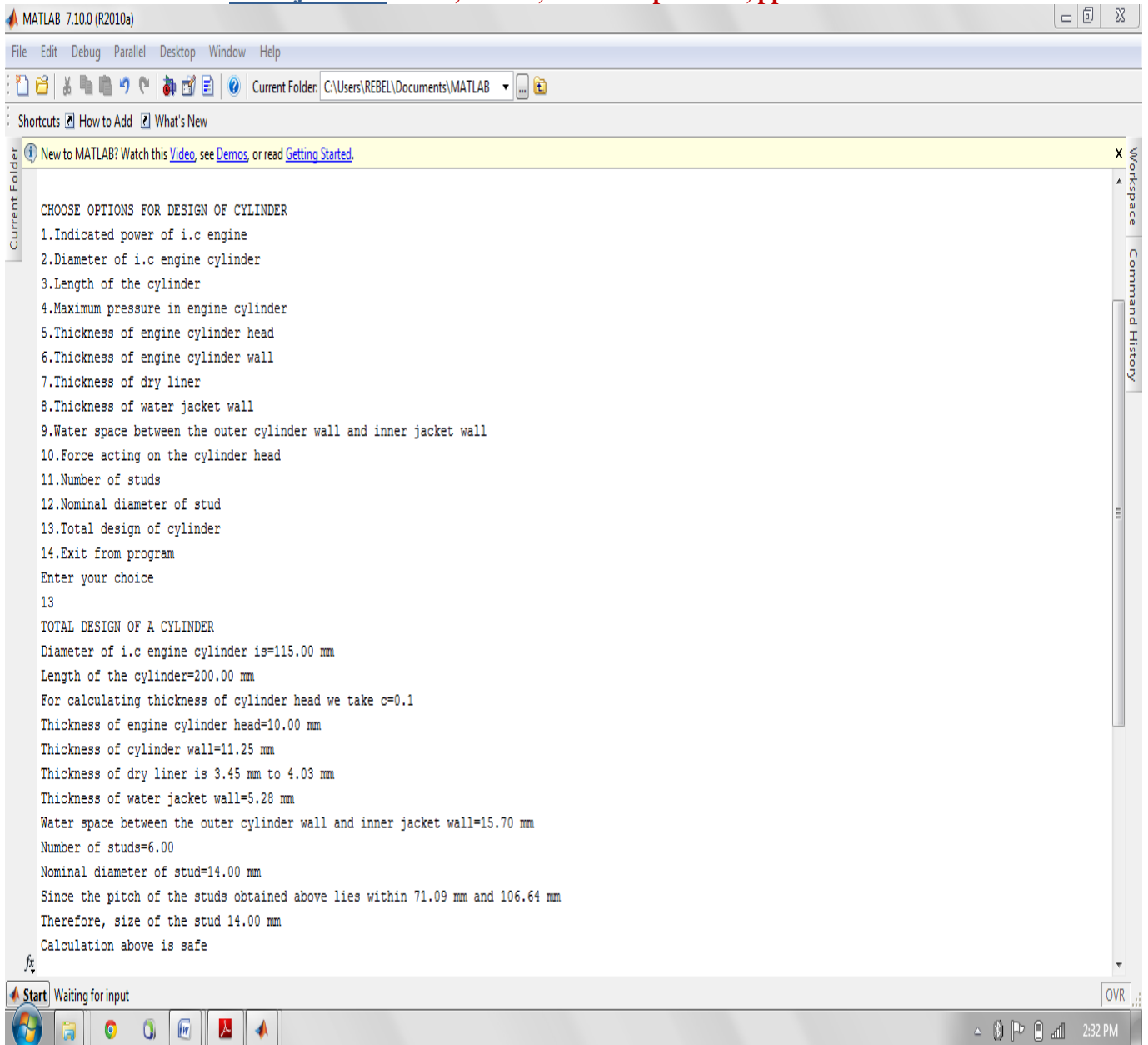
1.Indicated power of i.c engine
2.Diameter of i.c engine cylinder
3.Length of the cylinder
4.Maximum pressure in engine cylinder
5.Thickness of engine cylinder head
6.Thickness of engine cylinder wall
7.Thickness of dry liner
8.Thickness of water jacket wall
9.Water space between the outer cylinder wall and inner jacket wall
10.Force acting on the cylinder head
11.Number of studs
12.Nominal diameter of stud
13.Total design of cylinder
14.Exit from program

For example if we choose 13th option the output is as shown below

MATLAB 7.10.0 (R2010a)

File Edit Debug Parallel Desktop Window Help

Current Folder: C:\Users\REBEL\Documents\MATLAB

Shortcuts How to Add What's New

New to MATLAB? Watch this Video, see Demos, or read Getting Started.

```
CHOOSE OPTIONS FOR DESIGN OF CYLINDER
1.Indicated power of i.c engine
2.Diameter of i.c engine cylinder
3.Length of the cylinder
4.Maximum pressure in engine cylinder
5.Thickness of engine cylinder head
6.Thickness of engine cylinder wall
7.Thickness of dry liner
8.Thickness of water jacket wall
9.Water space between the outer cylinder wall and inner jacket wall
10.Force acting on the cylinder head
11.Number of studs
12.Nominal diameter of stud
13.Total design of cylinder
14.Exit from program
Enter your choice
13
TOTAL DESIGN OF A CYLINDER
Diameter of i.c engine cylinder is=115.00 mm
Length of the cylinder=200.00 mm
For calculating thickness of cylinder head we take c=0.1
Thickness of engine cylinder head=10.00 mm
Thickness of cylinder wall=11.25 mm
Thickness of dry liner is 3.45 mm to 4.03 mm
Thickness of water jacket wall=5.28 mm
Water space between the outer cylinder wall and inner jacket wall=15.70 mm
Number of studs=6.00
Nominal diameter of stud=14.00 mm
Since the pitch of the studs obtained above lies within 71.09 mm and 106.64 mm
Therefore, size of the stud 14.00 mm
Calculation above is safe
```

Start Waiting for input

OVR

2:32 PM

CONCLUSION

The analytical outputs for the cylinder were obtained using Matlab and it also gives whether the design values are safe or unsafe. With this project we have gained an immense knowledge in MAT lab and its application in mechanical engineering.

The answers generated by MATLAB code are verified with the textbook answers and are proved to be correct. The design of any component can be done using mat lab and the results can be obtained with relative ease.