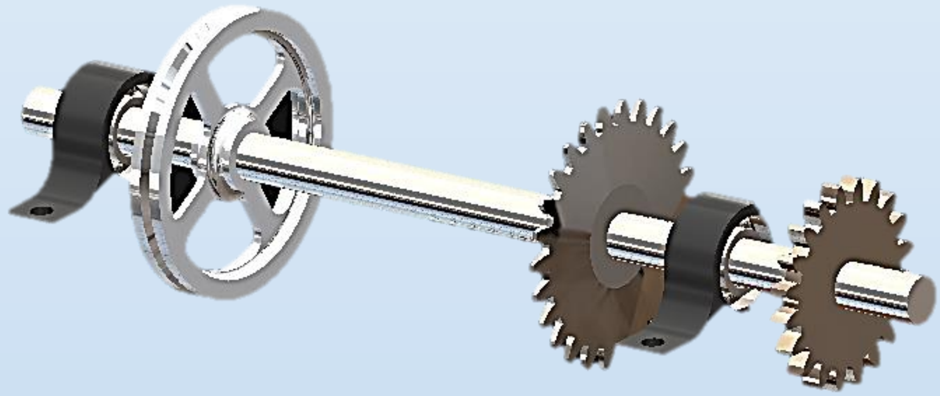
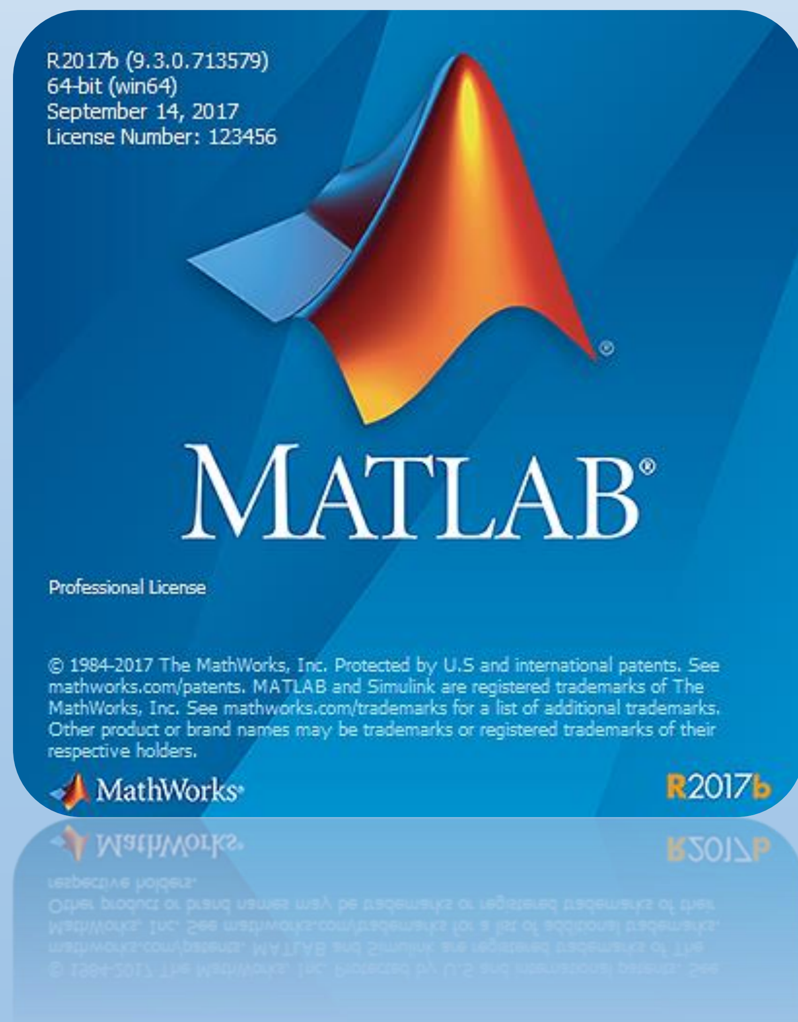
Design of Power Transmission Shafts Using MATLAB



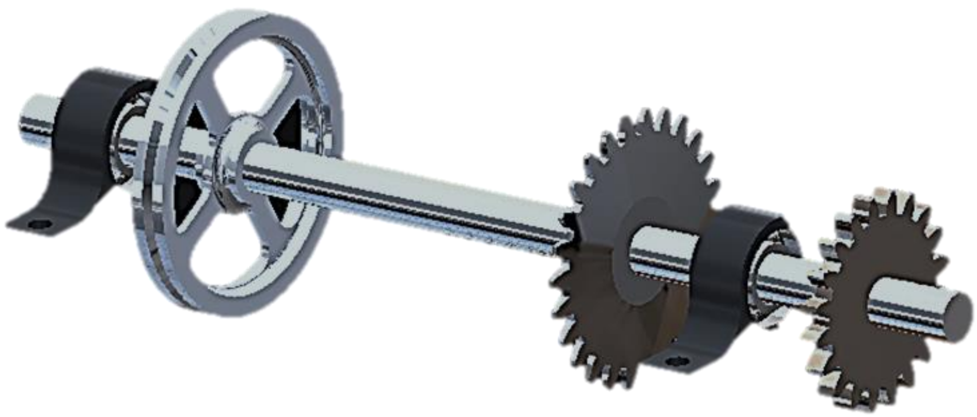


by: Desta Syoum

Introduction

A shaft is a rotating machine element, which is used to transmit power from one place to another. The power is delivered to the shaft by some tangential force and the resultant torque (or twisting moment) set up within the shaft permits the power to be transferred to various machines linked up to the shaft. In order to transfer the power from one shaft to another, the various members such as pulleys, gears etc., are mounted on it. These members along with the forces exerted upon them causes the shaft to bending. In other words, we may say that a shaft is used for the transmission of torque and bending moment. The shafts are usually cylindrical, but may be square or cross-shaped in section. They are solid in cross-section but sometimes-hollow shafts are also used.so this project is focused on development of program for design of solid and hollow cylindrical shafts.

Based on their application there are two types of shafts, Transmission shafts and Machine shafts. Transmission shafts transmit power between the source and the machines absorbing power. The counter shafts, line shafts, overhead shafts and most of factory shafts are transmission shafts. Since these shafts carry machine parts such as pulleys, gears etc., therefore they are subjected to bending in addition to twisting. Machine shafts. These shafts form an integral part of the machine itself. The crankshaft is an example of machine shaft.



Shaft design consists primarily of the determination of the correct diameter to ensure satisfactory strength and rigidity when the shaft is transmitting power under various operating and loading conditions. Shafts are manufactured from different types of materials which can be grouped in to two categories, Ductile and Brittle. Shafts made up of ductile material like mild steel are designed based on Maximum shear stress theory or Guest's theory, whereas, shafts made up of brittle materials like cast iron are designed based on Maximum normal stress theory or Rankine's theory.so this project focuses in the design of circular transmission shafts based on the above two theorems. In most cases transmission shafts are subjected to bending and twisting which are caused due to gear, pulley and sprocket so in my project, I have considered those three types of loads as the sources for the bending and twisting moment and I have assumed that there is no axial load applied in the shaft. Before going directly to the programing part first let us see how those three power transmission components affect let's see the general algorithms that has to be followed while designing the shaft.

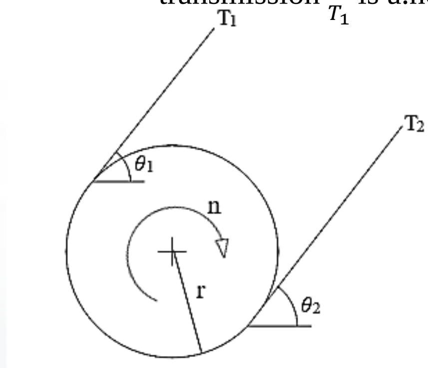
Loads in the shaft due to different machine elements

1. Loads in the shaft due to the pulley mounted on the shaft

The tourque generated by the pulley transfwering a power p in at a given speed n is given by

$$T = \frac{60P}{2\pi n}$$

let the tension ratio of the tension side of the belt transmision to the slack side of the belt transmission $\frac{T_1}{T_1}$ is a.now the torque transferd by the pulley to the shaft is given by



$$T = (T_1 - T_2)r \text{ but } T_1 = aT_2$$

$$T = (aT_2 - T_2)r$$

$$T = T_2(a-1)r$$

Now let' solve the above equation for the two tension loads T_1 & T_2,

$$T_2 = \frac{T}{(a-1)r}$$

$$T_1 = aT_2$$

Having T_1 &T_2 in terms of T and a, let us resolve them in to vertical and horizontal components. The horizontal and vertical loads applied at the shaft by the tension T_1 are given by;

$$T_{1h} = T_1 cos\theta_1$$

$$T_{1v} = T_1 sin\theta_1$$

And the horizontal and vertical loads applied at the shaft by the tension T_2 are given by;

$$T_{2h} = T_2 cos\theta_2$$

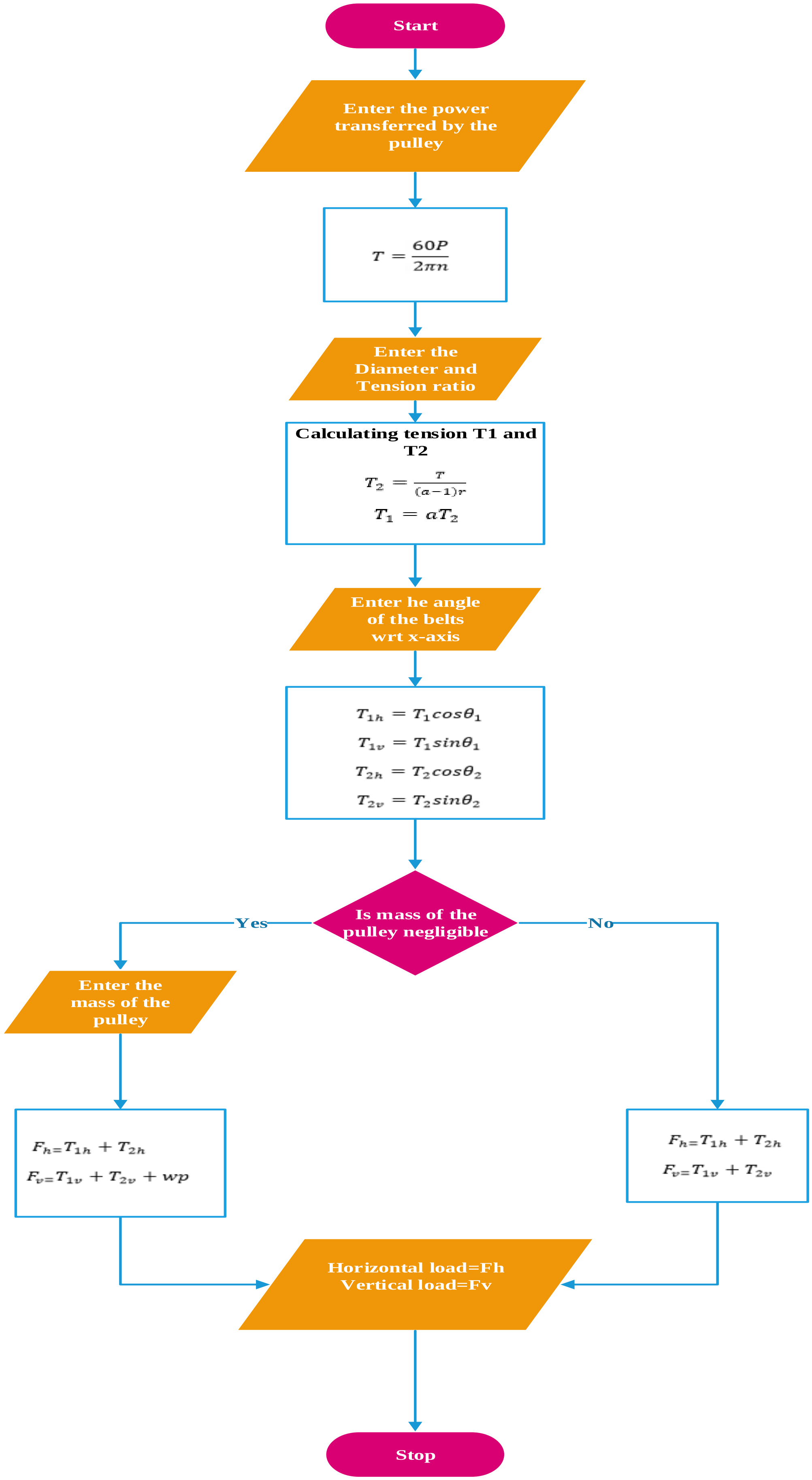
$$T_{2v} = T_2 sin\theta_2$$

In addition to the above loads , if the mass of the pulley is going to considered the weight wp of the pulley is also one vertical load applied on the shaft so The total horizontal and vertical loads applied at the shaft due to the belt transmission are given by;

$$F_{h=}T_{1h} + T_{2h}$$

$$F_{v=}T_{1v} + T_{2v} - mg$$

The direction of the tensions depend on the angle of the belt whereas the direction of the weight is always downward. Now keeping the above things in mind the flow chart or the algorithm for solving the vertical and horizontal loads applied on the shaft due to the pulley mounted at a given point is given bellow;


Start
Enter the power transferred by the pulley
$T = \frac{60P}{2\pi n}$
Enter the Diameter and Tension ratio
Calculating tension T1 and T2
$T_2 = \frac{T}{(a-1)r}$
$T_1 = aT_2$
Enter he angle of the belts wrt x-axis
$T_{1h} = T_1 cos\theta_1$
$T_{1v} = T_1 sin\theta_1$
$T_{2h} = T_2 cos\theta_2$
$T_{2v} = T_2 sin\theta_2$
Is mass of the pulley negligible
Yes
No
Enter the mass of the pulley
$F_h = T_{1h} + T_{2h}$
$F_v = T_{1v} + T_{2v} + wp$
$F_h = T_{1h} + T_{2h}$
$F_v = T_{1v} + T_{2v}$
Horizontal load=Fh
Vertical load=Fv
Stop

2. Loads in the shaft due to the gear mounted on the shaft

The torque generated by a given gear transferring a power p at a given speed n is given by;

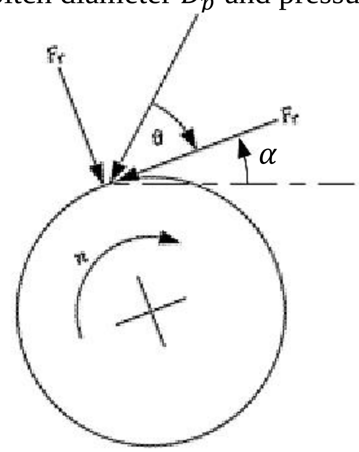
$$T = \frac{60P}{2\pi n}$$

The tangential load, acting at the shaft due to a given gear with a pitch diameter D_p and pressure angle θ is given by;

$$T = F_t \frac{D_p}{2}$$

$$F_t = \frac{2T}{D_p}$$

$$F_t = \frac{2}{D_p} \frac{60P}{2\pi n}$$



The normal (radial) load acting in the shaft due to a mounted gear with a pitch diameter $D_p$and pressure angle , is given by;

$$F_r = F_t tan\theta$$

In addition to the above loads, if the mass effect of the gear is to considered the vertical load acting at the shaft due to the gear transmission is given by;

$$F_v = F_t sin\alpha + F_r cos\alpha - mg$$

And the horizontal load acting at the shaft due to the gear drive is given by;

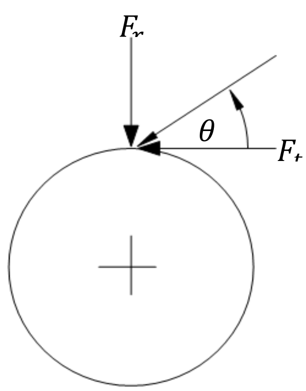
$$F_h = F_t cos\alpha + F_r sin\alpha$$

The direction of the loads depends on the angle , α that the tangential load makes with x-axis. For example, let us see the following two common case.

When $\alpha = 180$

$$F_t = \frac{2T}{D_p}$$

$$F_r = F_t tan\theta$$

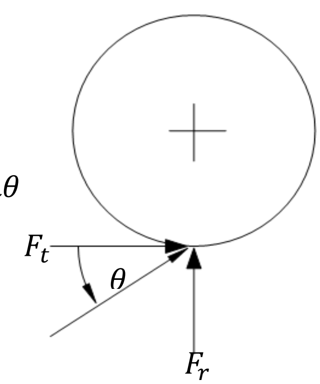


$$F_v = \cancel{F_t sin180} + F_r cos180 = -F_r$$
$$F_h = F_t cos180 + \cancel{F_r sin180} = -F_t$$

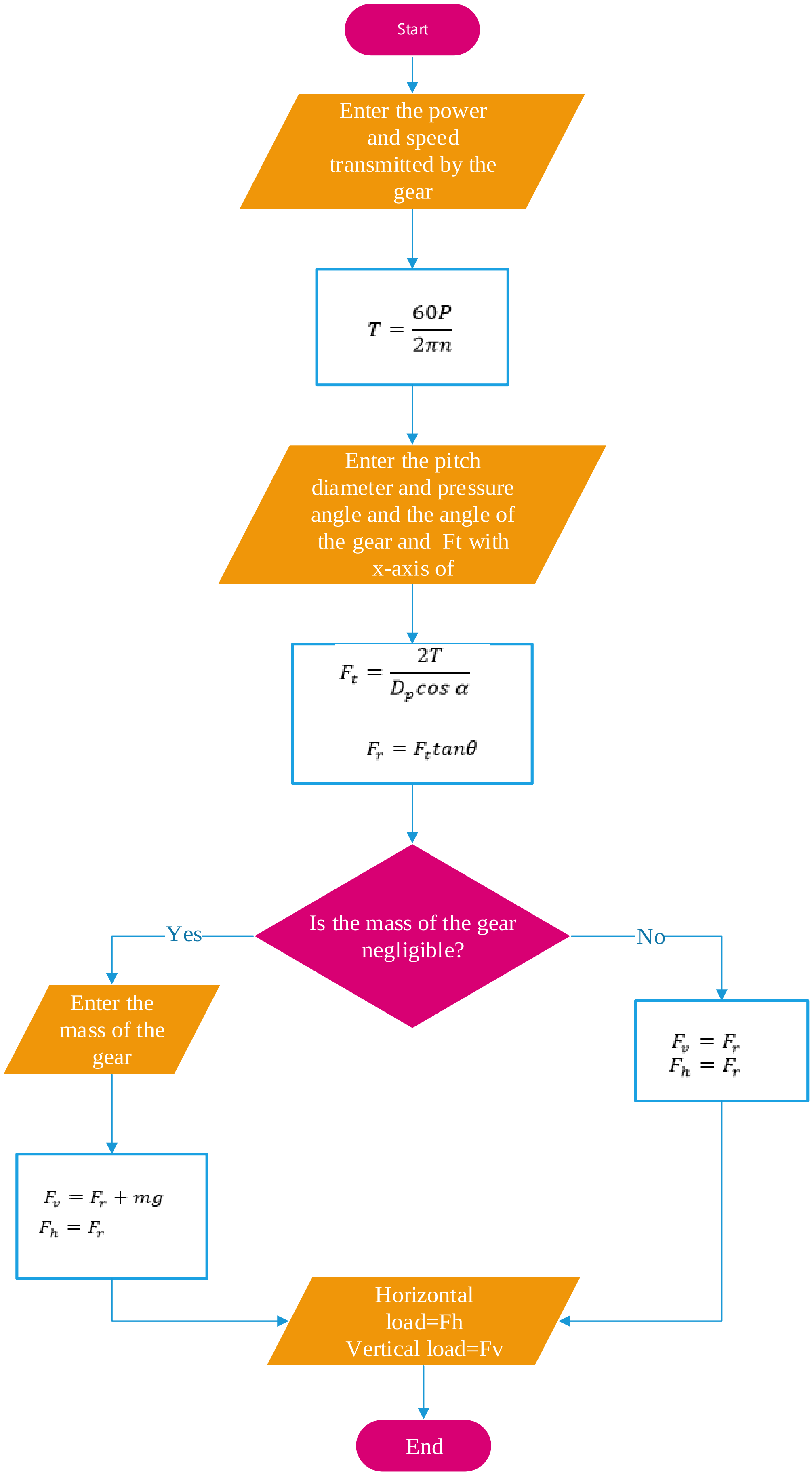
When $\alpha = 0$

$$F_t = \frac{2T}{D_p}$$

$$F_r = F_t tan\theta$$



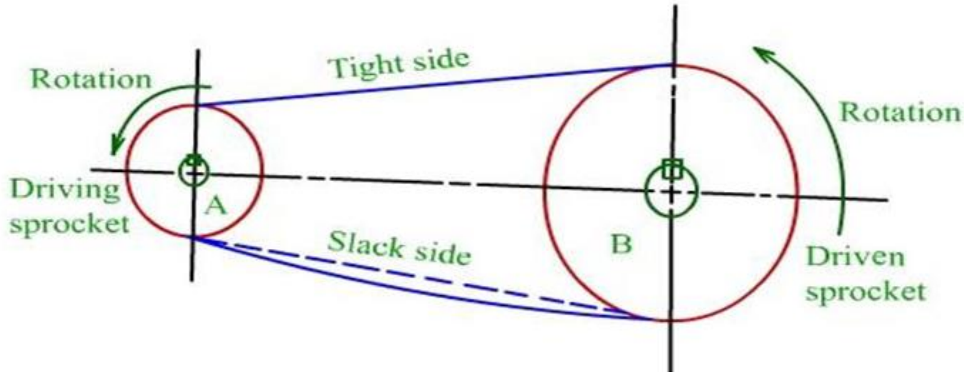
$$F_v = \cancel{F_t sin0} + F_r cos0 = F_r$$
$$F_h = F_t cos0 + \cancel{F_r sin0} = F_t$$


Start
Enter the power and speed transmitted by the gear
$T = \frac{60P}{2\pi n}$
Enter the pitch diameter and pressure angle and the angle of the gear and Ft with x-axis of
$F_t = \frac{2T}{D_p \cos\alpha}$
$F_r = F_t \tan\theta$
Is the mass of the gear negligible?
Yes
No
Enter the mass of the gear
$F_v = F_r + mg$
$F_h = F_r$
$F_v = F_r$
$F_h = F_r$
Horizontal load=Fh
Vertical load=Fv
End

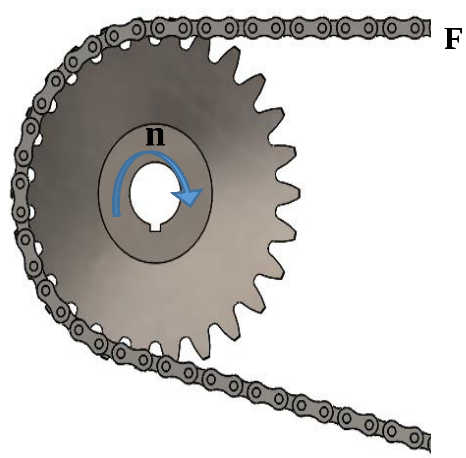
3. Loads in the shaft due to the sprocket mounted on the shaft

The torque transmitted by a sprocket transmitting power p at speed n is given by;

$$T = \frac{60P}{2\pi n}$$



The upper part of the chain is in tension and produces the torque on either sprocket. The lower part of the chain is slack and exerts no force on either sprocket. Therefore, the total bending force on the shaft carrying the sprocket is equal to the tension on the tight side of chain.



$$F = \frac{2T}{D}$$

If the tension side of the chain mechanism makes an angle of θ with positive x-axis the vertical and the horizontal loads acting in the shaft due to the chain transmission.

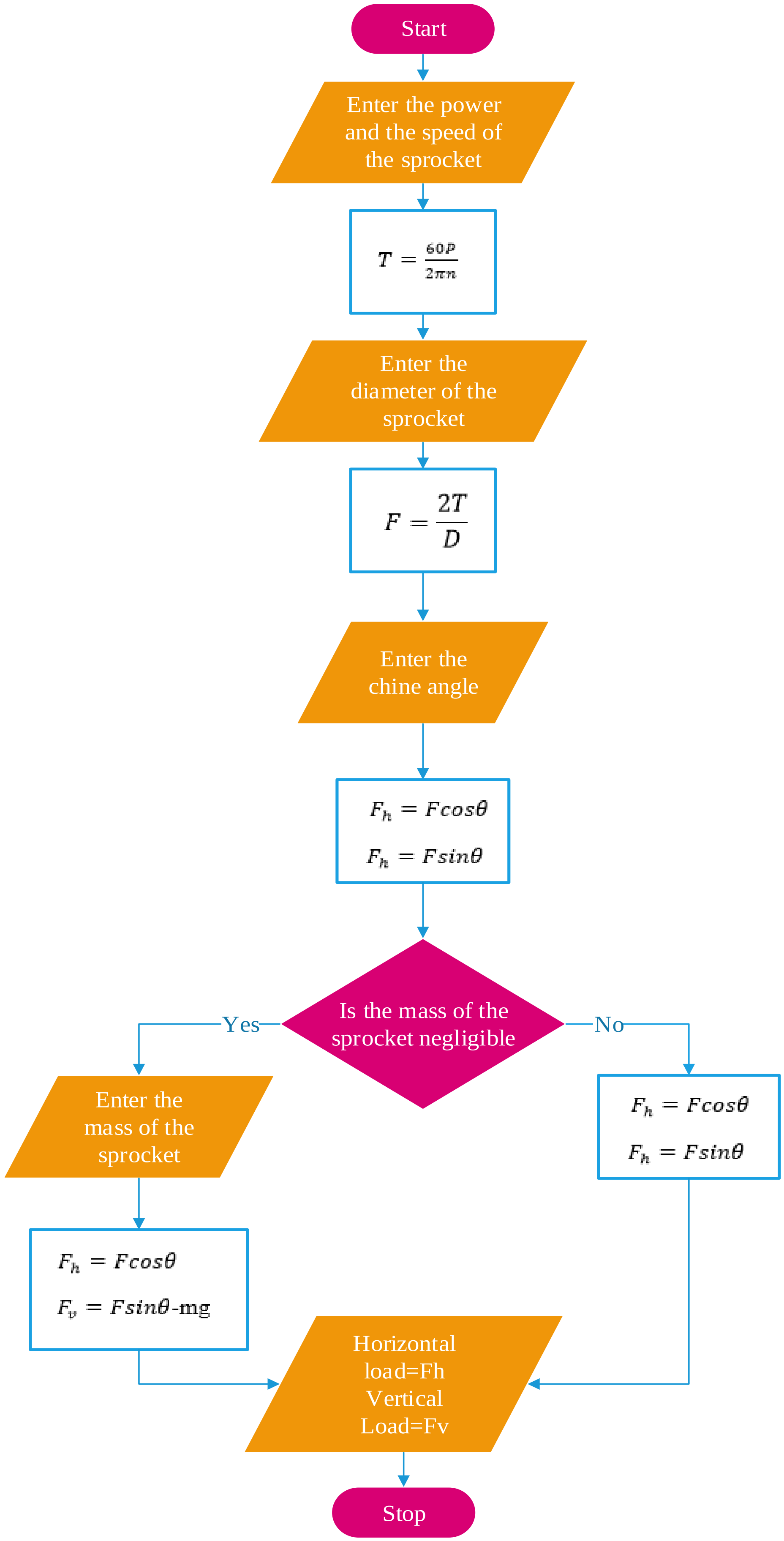
$$F_h = Fcos\theta$$

$$F_h = Fsin\theta$$

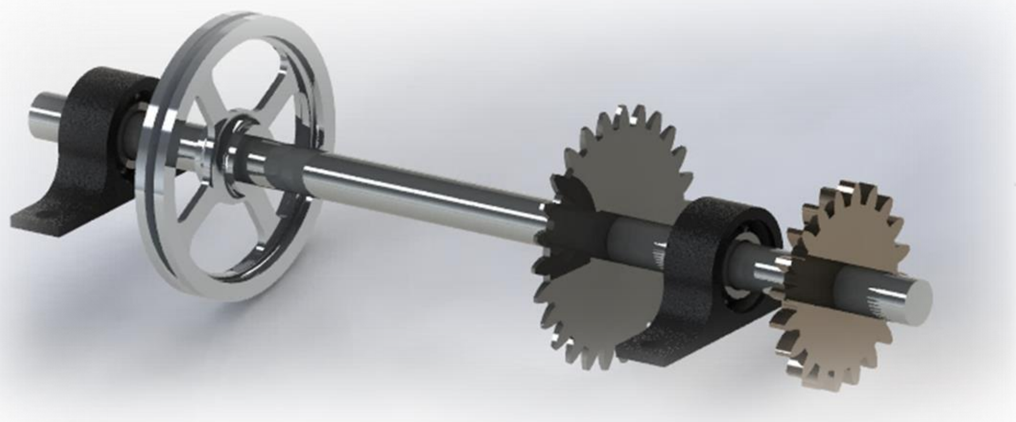
If the mass of the sprocket is not negligible, the vertical load applied at the shaft is given by;

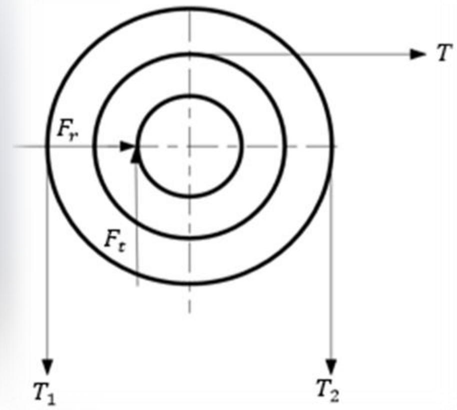
$$F_h = Fcos\theta$$

$$F_v = Fsin\theta\text{-mg}$$

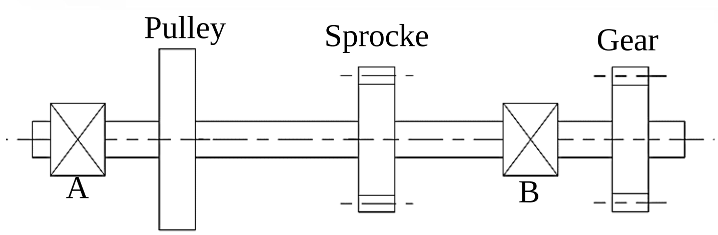

Start
Enter the power and the speed of the sprocket
$T = \frac{60P}{2\pi n}$
Enter the diameter of the sprocket
$F = \frac{2T}{D}$
Enter the chine angle
$F_h = Fcos\theta$
$F_h = Fsin\theta$
Is the mass of the sprocket negligible
Yes
No
Enter the mass of the sprocket
$F_h = Fcos\theta$
$F_v = Fsin\theta$-mg
$F_h = Fcos\theta$
$F_h = Fsin\theta$
Horizontal load=Fh Vertical Load=Fv
Stop

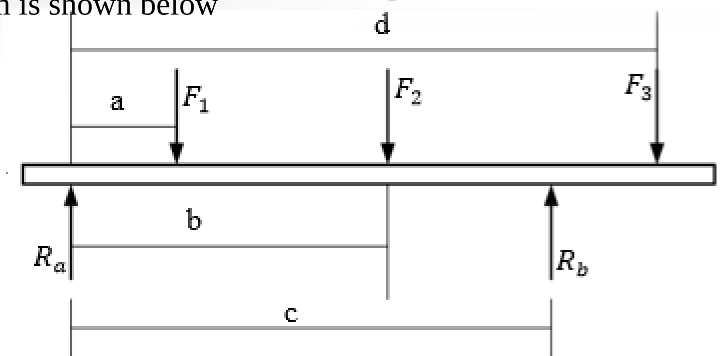
After having the vertical and horizontal loads applied in the shaft at each point the next task is to calculate, the maximum bending moment and its location in the shaft.to do this first we have to find the horizontal and vertical reaction forces at each bearing and their bending moment diagram. To develop the algorithm to solve for the reaction forces let us assume the following shaft, which contains pulley sprocket and gear mounted as shown below.





The free body diagram of the above drive system is shown below





Now let's find the reaction forces in terms of the remain reaction forces

$$\sum F_y = 0;\ R_a + R_b - F_1 - F_2 - F_3 = 0$$

Since there are two variables, we need two equations so we have to take the bending moment equilibrium at one of the bearings.by taking clockwise momentum as positive.

$$\sum M_a = 0; aF_1 + bF_2 + cF_3 - dR_b = 0$$

$$dR_b = aF_1 + bF_2 + cF_3$$

$$\boldsymbol{R_b = \frac{aF_1 + bF_2 + cF_3}{d}}$$

$$\boldsymbol{R_a = F_1 + F_2 + F_3 - R_b}$$

After this we have to draw the bending moment diagram to do this I have used the singularity method to take the advantage of theire simplicity for programing.

$$\boldsymbol{M(x) = R_b < x - 0 >^1 - F_1 < x - a >^1 - F_2 < x - b >^1 - F_3 < x - c >^1 + R_b < x - d >^1}$$

From this we will have the bending moment diagram and we will take the maximum bending moment diagram and its location which is the most vital information for the design of shafts.

Having the location of the maximum bending moment we have to find the torque T at that point and using those values we have to find the equivalent twisting moment , T_e and the equivalent bending moment M_e.

$$T_e = \sqrt{(K_t T)^2 + (K_m M)^2}$$

$$M_e = \frac{1}{2}(K_m M + \sqrt{K_t T^2 + (K_m M)^2})$$

K_t and K_m the combined shock and fatigue factors for twisting moment and bending moment. Based on the Maximum Shear Stress (MSS) Theory the equivalent twisting moment T_e for solid shafts is given by;

$$T_e = \frac{\pi}{16}\tau d^3$$

From this the diameter is given by;

$$d^3 = \frac{16T_e}{\pi\tau}$$

$$d = \sqrt[3]{\frac{16T_e}{\pi\tau}}$$

And for hollow shafts the equivalent bending moment is given by;

$$d_o{}^3(1-k^4) = \frac{16T_e}{\pi\tau}$$

$$d_o = \sqrt[3]{\frac{16T_e}{\pi\tau(1-k^4)}} \text{ And } d_i = kd_o$$

Based on the Maximum Normal Stress (MNS) Theory the equivalent bending moment M_e for solid shafts is given by;

$$M_e = \frac{\pi}{16}\sigma_b d^3$$

From this the diameter is given by;

$$d^3 = \frac{16M_e}{\pi\sigma_b}$$

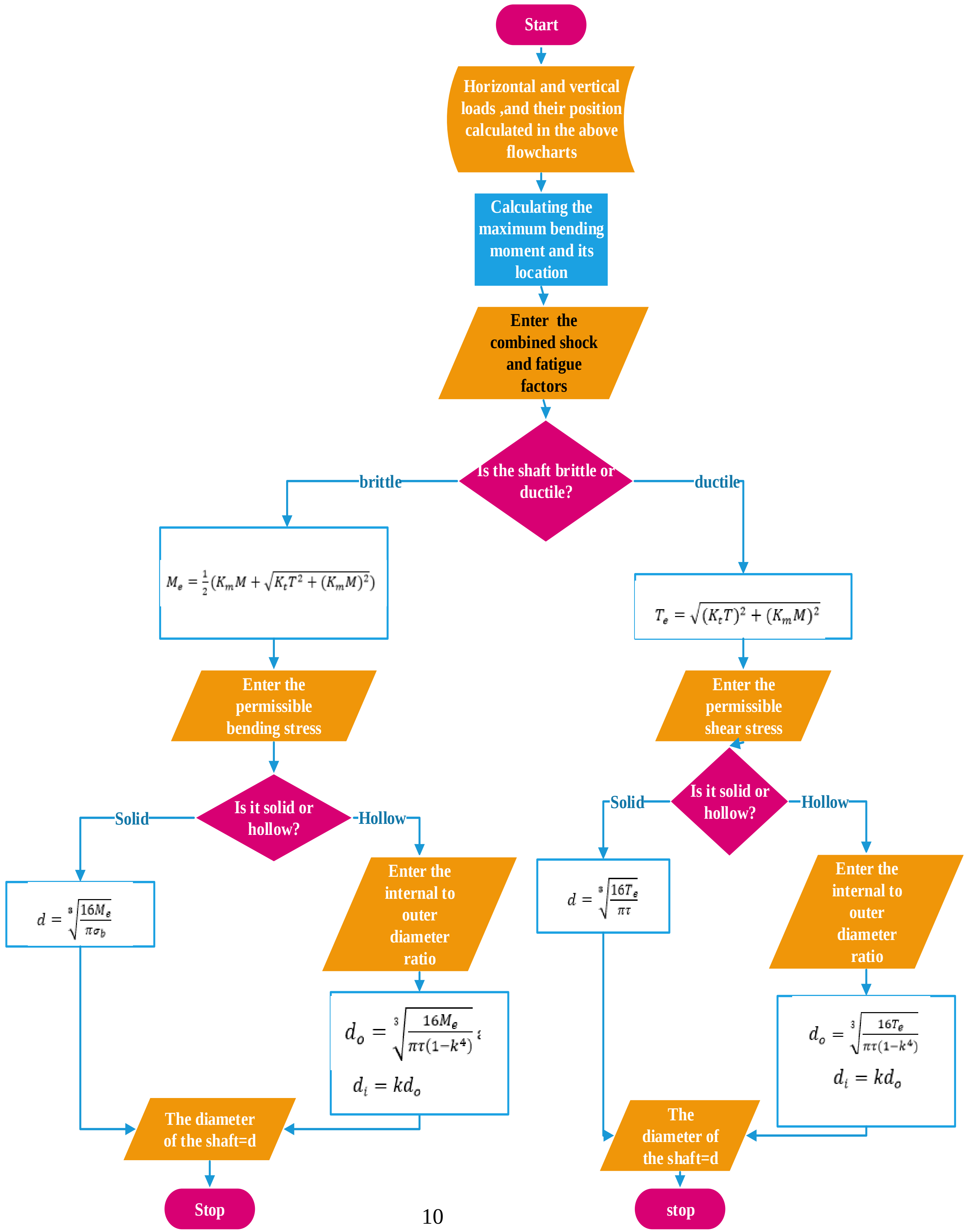
$$d = \sqrt[3]{\frac{16M_e}{\pi\sigma_b}}$$

And for hollow shafts the equivalent bending moment is given by;

$$d_o{}^3(1-k^4) = \frac{16M_e}{\pi\tau}$$

$$d_o = \sqrt[3]{\frac{16M_e}{\pi\tau(1-k^4)}} \text{ And } d_i = kd_o$$

Now after having the outputs of the above flow charts let us develop the algorithm to find the diameter.



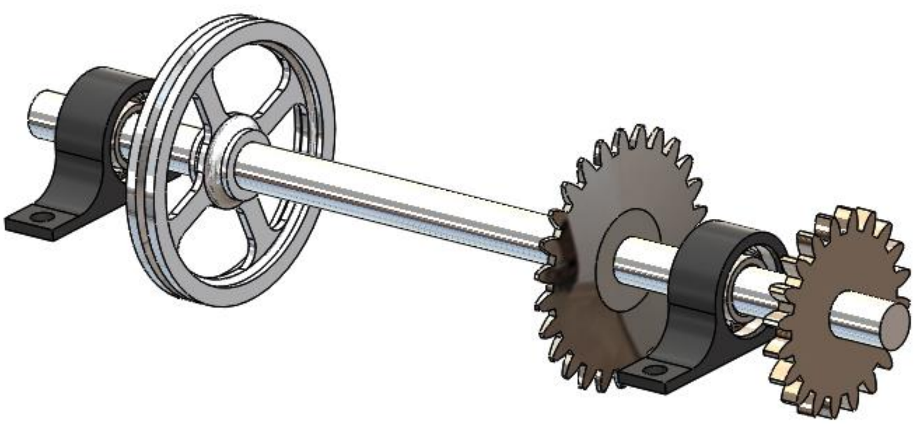
Start
Horizontal and vertical loads ,and their position calculated in the above flowcharts
Calculating the maximum bending moment and its location
Enter the combined shock and fatigue factors
Is the shaft brittle or ductile?
brittle
ductile
$M_e = \frac{1}{2}(K_m M + \sqrt{K_t T^2 + (K_m M)^2})$
$T_e = \sqrt{(K_t T)^2 + (K_m M)^2}$
Enter the permissible bending stress
Enter the permissible shear stress
Is it solid or hollow?
Solid
Hollow
$d = \sqrt[3]{\frac{16M_e}{\pi\sigma_b}}$
Enter the internal to outer diameter ratio
$d_o = \sqrt[3]{\frac{16M_e}{\pi\tau(1-k^4)}}$
$d_i = kd_o$
The diameter of the shaft=d
Stop
Is it solid or hollow?
Solid
Hollow
$d = \sqrt[3]{\frac{16T_e}{\pi\tau}}$
Enter the internal to outer diameter ratio
$d_o = \sqrt[3]{\frac{16T_e}{\pi\tau(1-k^4)}}$
$d_i = kd_o$
The diameter of the shaft=d
stop

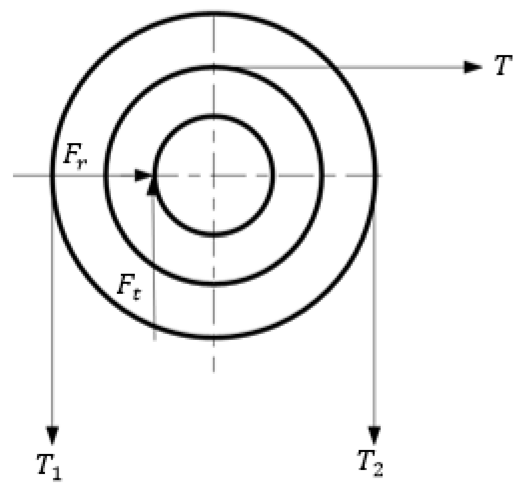
By using the above algorithms, I have developed a MATLAB program, which is capable of designing shaft based on the inputs from user. The programing part contains a function called 'Load_with_positin' with 468 line of codes and one m-file called 'shaft_design'. The function 'Load_with_positin' accepts the inputs from the user and does the calculations required based on the user inputs. The MATLAB codes are listed under **appendix A and appendix B**. The program works correctly for shafts that supports up to four different or similar types of the common power transmitting machine elements i.e. pulley, gear and sprocket. The program also contains useful instructions on how to use the program and how to insert the inputs in to the program.

How to use the code?

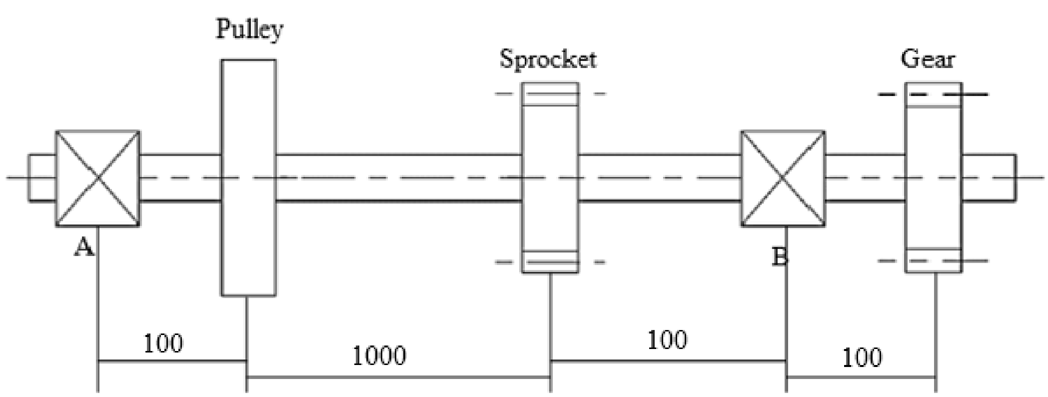
To show how the code works we will do the following question manually and after, using the MATLAB program.

Find the diameter of the shaft if it is subjected to load as shown below. Gear g1 takes $50Kw$ at $1000rpm$ from another gear. Gear $G1$ is of $300mm$ pitch diameter having 20^0 pressure angle involute. The ratio of belt tensions for pulley p_1 is 2:1 and the diameter of the pulley is $700mm$ which transmits $25Kw$.The sprocket Ds is $400mm$ diameter with negligible tension in the chain on the slack side and transmits remaining power. Take,$Kb = 1.75,\ \ Kt = 1.25$ and $\tau = 65Mpa$ for the shaft material.





First let us solve the problem manually then we will do it by using the program I have developed

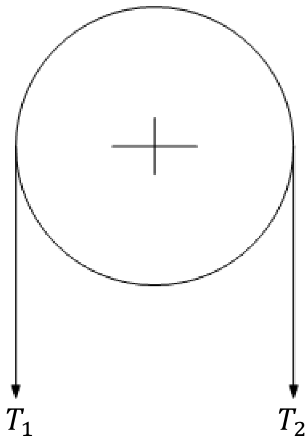


Now let us calculate the vertical and horizontal loads applied at on the shaft due to the power transmission.

<u>Loads on the shaft due to the first pulley located at x=0.1</u>

The power transmitted by the first pulley is, $p = 25Kw$ and the diameter of the pulley is, $D = 700mm.$ Now let us find the torque transmitted by the pulley and the tensions at the belt.

\



$$T = \frac{60P}{2\pi n}$$

$$T = \frac{60x25Kw}{2x\pi x1000rpm}$$

$$T = 238.7324Nm$$

The tension ratio is 2:1 so the torque in terms of the tensions is given by

$$T = (T_1 - T_2)r \text{ but } T_1 = aT_2$$

$$T = (aT_2 - T_2)r$$

$$T = T_2(2-1)r$$

$$T_2 = \frac{T}{r}$$

$$T_2 = \frac{238.7324Nm}{0.35m}$$

$$T_2 = 682.0925N$$

$$T_1 = 2T_2$$

$$T_1 = 2x682.0925N$$

$$T_1 = 1364.1851N$$

The angle that the T_1 &T_2 with positive x-axis is -90^0 .and the mass of the pulley is negligible so the loads applied at the shaft due to this pulley is,

$$F_h = 0N$$

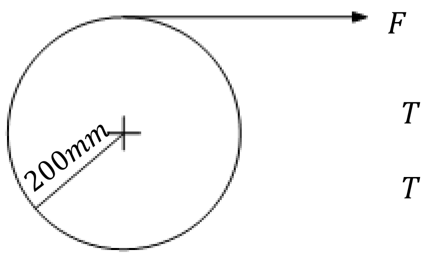
$$F_v = -(T_1 + T_2)$$

$$F_v = -2046.277N$$

<u>Loads on the shaft due to the sprocket</u>

The power transmitted by the sprocket is, $p = 25Kw$ and the diameter of the sprocket is $D = 400m$. The torque on the shaft due to the sprocket is given by,

$$T = \frac{60P}{2\pi n}$$



$$T = \frac{60x25Kw}{2x\pi x1000rpm}$$

$$T = 238.7324N$$

The tension at the tension side of the chain transmission is given by,

$$F = \frac{2T}{D}$$

$$F = \frac{2x238.7324Nm}{0.4m}$$

$$F = 1193.662N$$

The angle that the F with positive x-axis is 0^0 .and the mass of the sprocket is negligible so the loads applied at the shaft due to this sprocket are,

$$F_v = 0N$$

$$F_h = 1193.662N$$

<u>Loads on the shaft due to the gear</u>

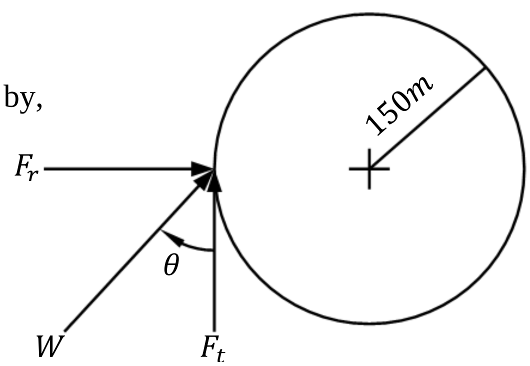
The power transmitted by the gear is, $p = 50Kw$ and the pitch diameter of the gear is $D_p = 300m$. The torque on the shaft due to the gear is given by,

$$T = \frac{60P}{2\pi n}$$

$$T = \frac{60x50Kw}{2x\pi x1000rpm}$$

$$T = 477.4648Nm$$

And the tangential and radial forces acting on the shaft are given by,



$$T = F_t \frac{D_p}{2}$$

$$F_t = \frac{2T}{D_p}$$

$$F_t = \frac{2x477.4648Nm}{0.3m}$$

$$F_t = 3183.0987N$$

The normal (radial) load acting in the shaft due to a mounted gear with a pitch diameter $D_p$and pressure angle , is given by;

$$F_r = F_t tan\theta$$

$$F_r = 3183.0987Nmxtan20$$

$$F_r = 1158.5532N$$

The mass of the gear is negligible so the vertical and horizontal loads acting on the shaft due to the gear are,

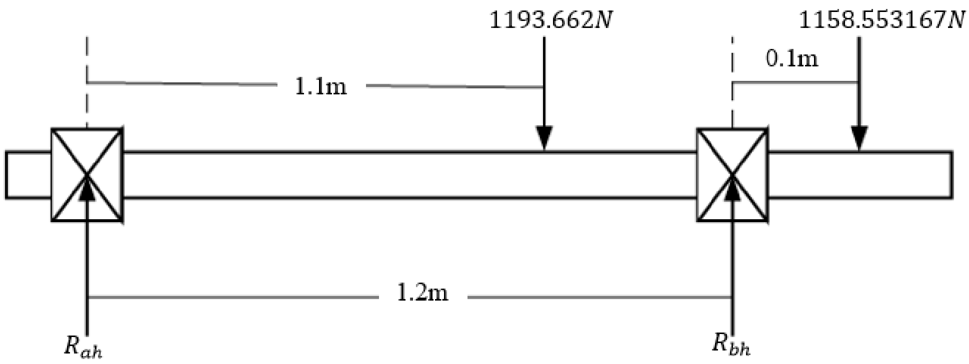
$$F_v = 3183.0987N$$

$$F_h = 1158.5532N$$

Now let us summarize the loads acting on the shaft due to the power transmission and theire location,

	At 0.1m(due to pulley)	**At 1.1m due to the gear**	**1.3m due to the sprocket**
Horizontal Load	$0N$	$1193.662N$	$1158.5532N$
Vertical load	$-2046.277N$	$0N$	$3183.0987N$

Now let us find the horizontal and vertical bearing reactions. To find the horizontal bearing reactions let us draw the free body diagram of the shaft holding the loads.



$\sum F_h = o,$

$$R_{ah} + R_{bh} - 1193.662N - 1158.5532N = 0$$

$\sum M_A = 0\,,$

$$(1.1x1193.662) + (1.3x1158.553167) - (1.2 * R_{bh}) = 0$$

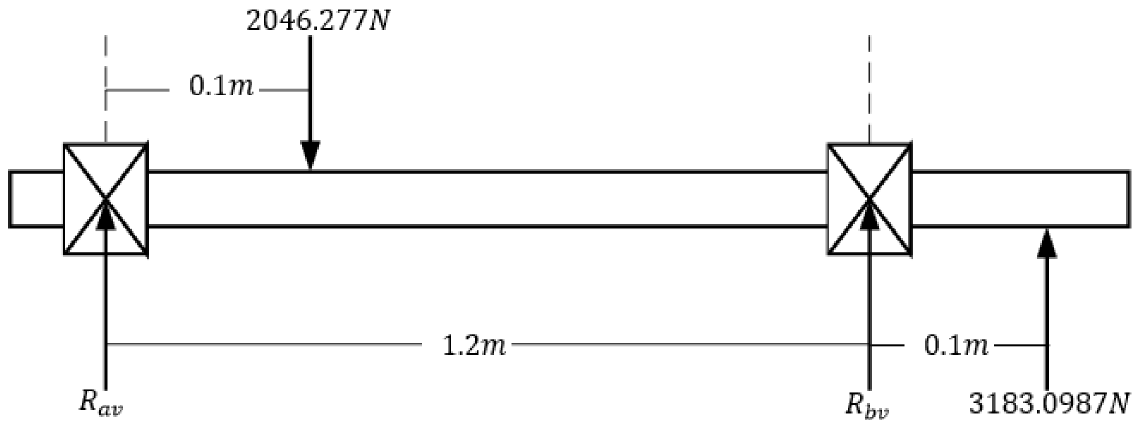
$$R_{bh} = \frac{(1.1x1193.662)+(1.3x1158.553167)}{1.2}$$

$$R_{bh} = 2349.289976N \text{ And}$$

$$R_{ah} = 1193.662N + 1158.5532N - 2349.289976N$$

$$R_{ah} = 2.925224N$$

And let's find the bearing reactions in the vertical direction



$\sum F_h = o,$

$$R_{av} + R_{bv} - 2046.277N + 3183.0987N = 0$$

$\sum M_A = 0\,,$

$$(0.1x2046.277N) - (1.2xR_{bv}) - (1.3 * 3183.0987N) = 0$$

$$R_{bv} = \frac{(0.1x2046.277N)-(1.3*3183.0987N)}{1.2}$$

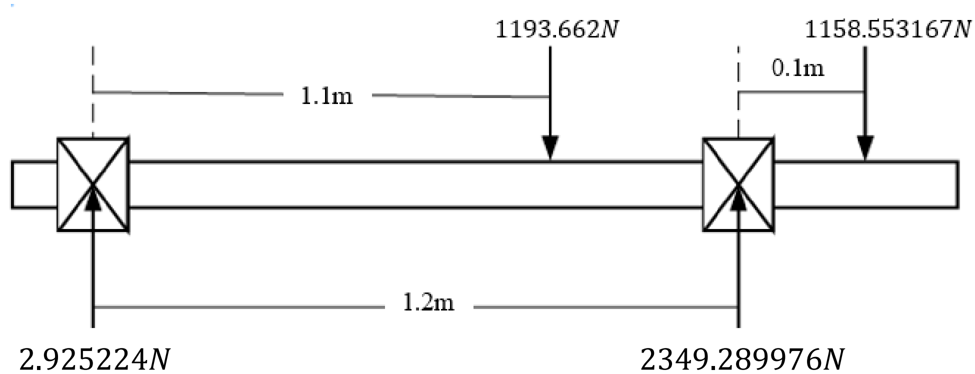
$R_{bv} = -3277.833842N$ And

$$R_{av} = 2046.277N - 3183.0987N - (-3277.833842N\ )$$

$$R_{av} = 2141.012142N$$

After having the horizontal and vertical reactions let us draw the bending moment diagrams using the singularity method.

Horizontal bending moment diagram



The singularity equation for the bending moment diagram of the above shaft is given by,

$M(x) = 2.925224 < x - 0 >^1 - 1193.662 < x - 1.1 >^1 + 2349.28997 < x - 1.2 >^1 - 1158.553167 < x - 1.3 >^1$

Now, let us find the bending moment at each load locations

For $0 < x < 1.1$

$$M(x) = 2.925224(x) = 3.2177464Nm$$

At $x = 0$

$$M(0) = 0$$

At $x = 1.1$

$$M(x) = 2.925224(1.1) = 3.2177464Nm$$

For $1.1 < x < 1.2$

$$M(x) = 2.925224x - 1193.662(x - 1.1)$$

At $x = 1.2$

$$M(x) = 2.925224(1.2) - (1193.662x0.1)$$

$$M(x) = -115.8559312Nm$$

For $1.2 < x < 1.3$

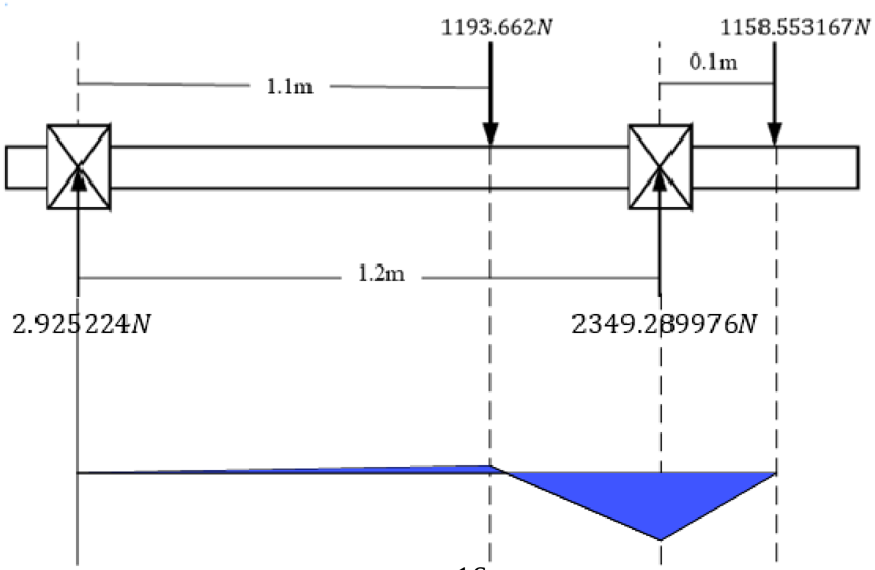
$$M(x) = 2.925224(x) - 1193.662(x - 1.1) + 2349.28997(x - 1.2)$$

At $x = 1.3$

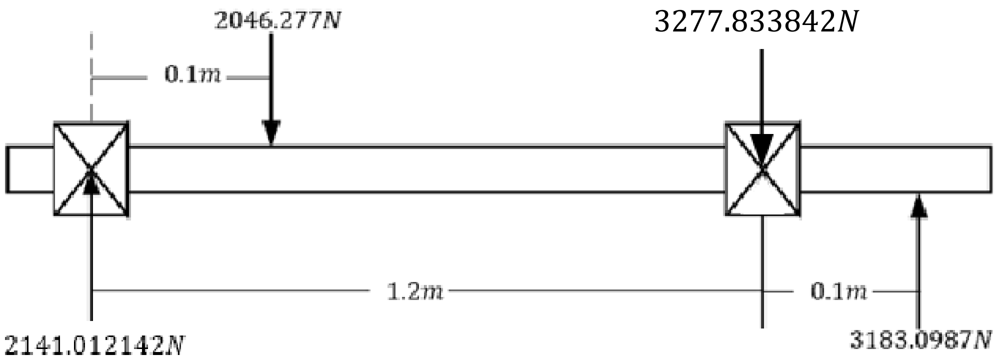
$$M(x) = 2.925224(1.3) - 1193.662(0.2) + 2349.28997(0.1)$$

$$M(x) = 0Nm$$

Having those let us draw the horizontal bending moment diagram for the horizontal loads



Vertical bending moment diagram



The singularity equation for the vertical bending moment diagram of the above shaft is given by,

$$M(x) = 2141.012142 < x - 0 >^{1} - 2046.277 < x - 0.1 >^{1} - 3277.833842 < x - 1.2 >^{1} + 3183.0987 < x - 1.3 >^{1}$$

Now, let us find the bending moment at each load locations

For $0 < x < 0.1$

$$M(x) = 2141.012142(x)$$

At $x = 0$

$$M(0) = 0$$

At $x = 0.1$

$$M(x) = 2141.012142(0.1) = 214.1012142Nm$$

For $0.1 < x < 1.2$

$$M(x) = 2141.012142x - 2046.277(x - 0.1)$$

At $x = 1.2$

$$M(x) = 2141.012142(1.2) - (2046.277x1.1)$$

$$M(x) = 318.3098704Nm$$

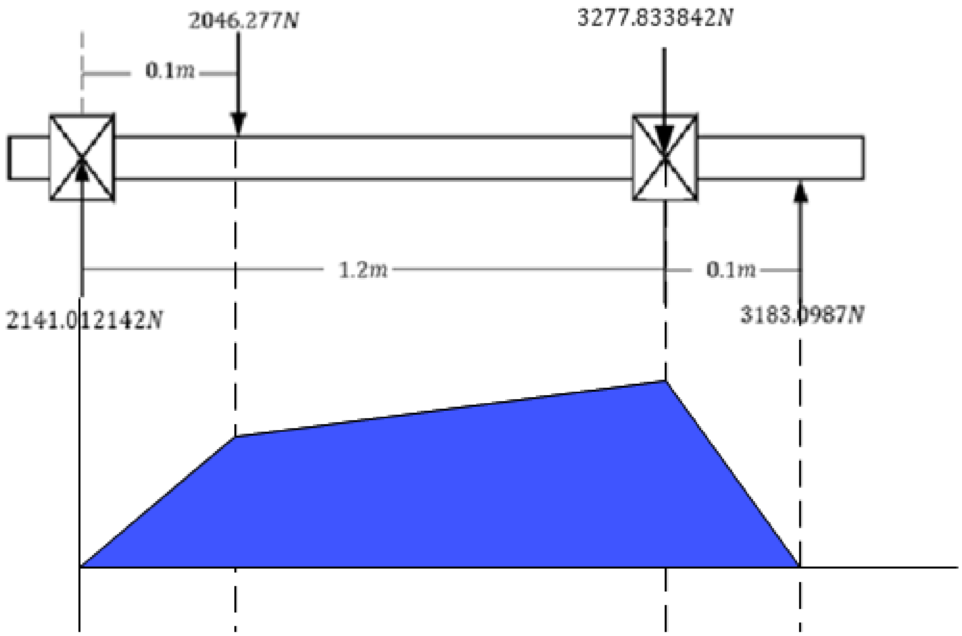
For $1.2 < x < 1.3$

$$M(x) = 2141.012142(x) - 2046.277(x - 0.1) - 3277.833842(x - 1.2)$$

At $x = 1.3$

$$M(x) = 2141.012142(1.3) - 2046.277(1.2) - 3277.833842(0.1)$$

$$M(x) = 0Nm$$



Now let us find the maximum equivalent bending moment

$$T_e = \sqrt{{M_v}^2 + {M_h}^2}$$

As we can see from the two bending moment diagrams the maximum equivalent bending moment is located at x=1.2m.

$$M_e = \sqrt{{M_v}^2 + {M_h}^2}$$

$$M_e = \sqrt{318.3098704^2 + (-115.8559312)^2}$$

$$M_e = 338.7384985\text{Nm}$$

The equivalent twisting moment is given by,

$$T_e = \sqrt{(K_m M_e)^2 + (K_t T)^2}$$

$$T_e = \sqrt{(1.75x338.7384985\text{Nm})^2 + (1.25x477.4648Nm)^2}$$

$$T_e = 841.19560Nm$$

Based on the maximum shear stress theory the equivalent twisting moment is given by,

$$T_e = \frac{\pi}{16}\tau d^3$$

$$d^3 = \frac{16T_e}{\pi\tau}$$

$$d = \sqrt[3]{\frac{16T_e}{\pi\tau}}$$

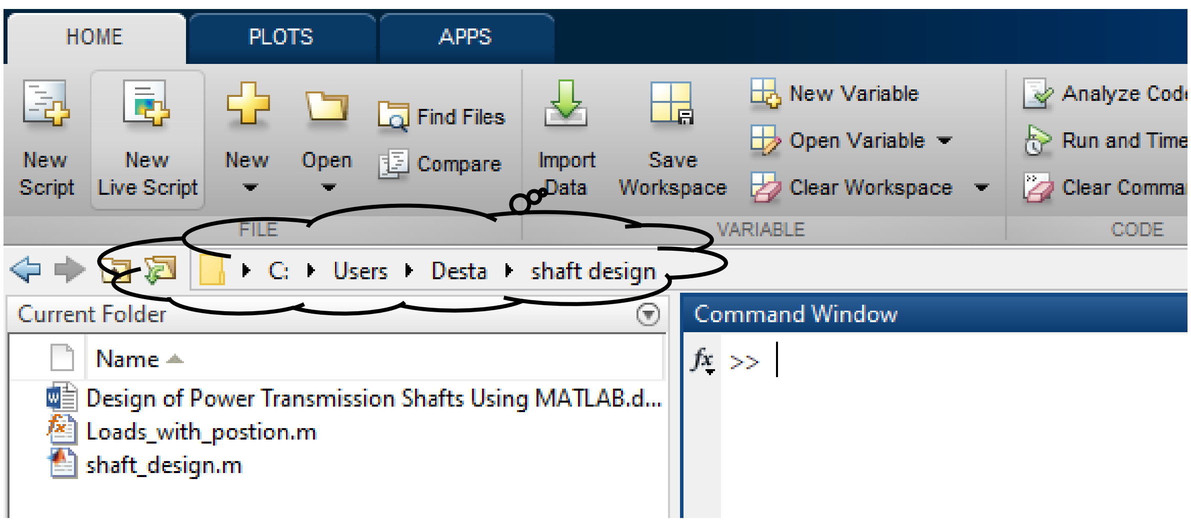
$$d = \sqrt[3]{\frac{16x841.19560Nm}{\pi x65Mpa}}$$

$d = 40.3mm$ For standard size, take 42mm

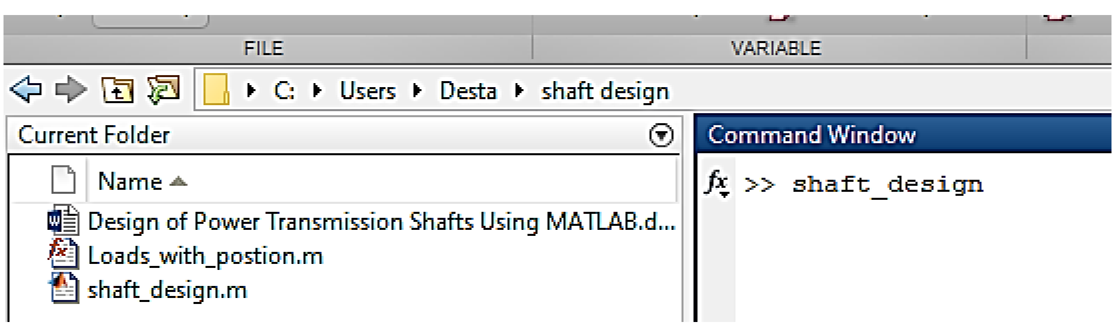
Now let us solve the problem using the MATLAB program.

The MATLAB program contains one m-file called shaft_design, and one function called Loads_with_position.the m-file starts the problem-solving step, and the function file accepts input from the user and do the necessary calculation based on those inputs.

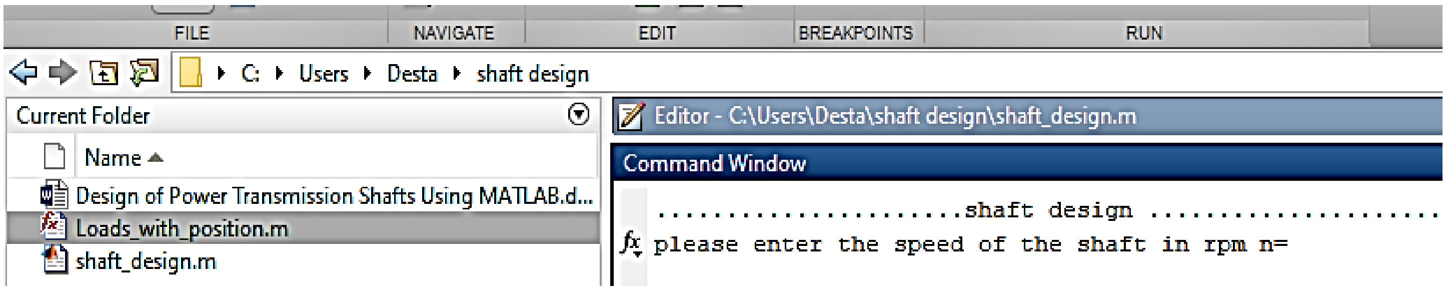
To start using the program first change your MATLAB current directory to the folder that contains the m-file and the function



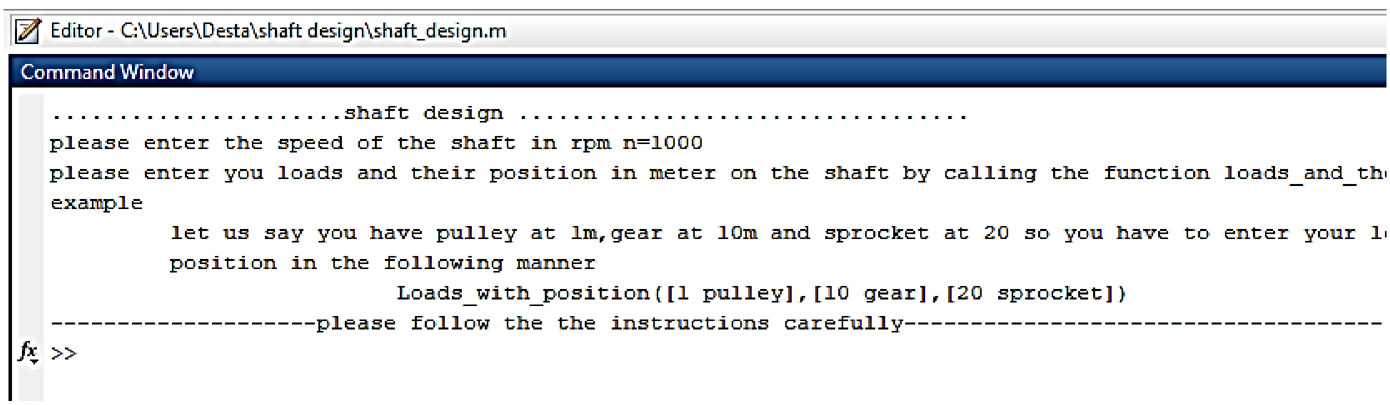
Then run shaft_design from the command window by inserting 'shaft_design' as it is in the matlab command window.



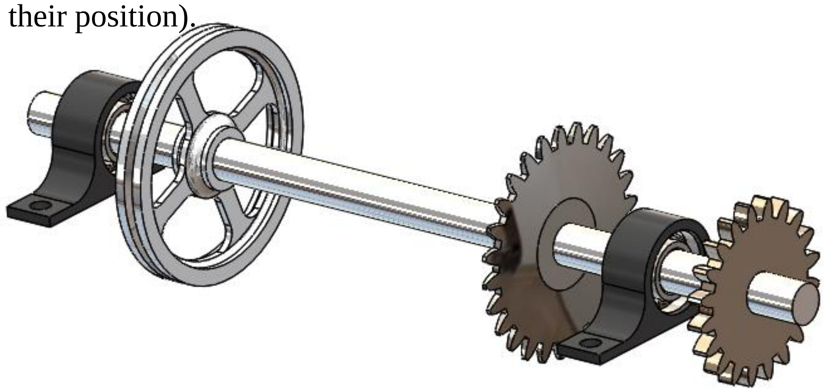
Then when you run, the shaft_design from editor or in the command window by calling the name 'shaft_design' it requests you to enter the speed of the shaft and when you enter a valid speed in rpm, it promotes you to call the function Load_with_position

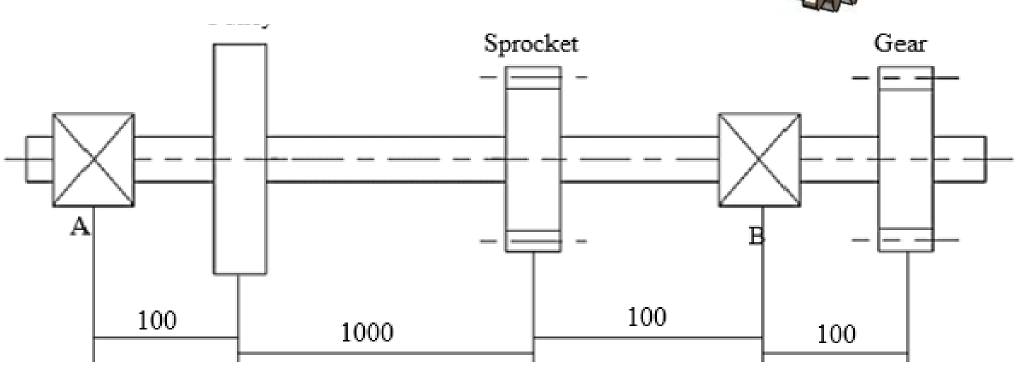


When you enter a valid input the speed of the shaft, it asks you to enter the loads and their position in the shaft in reference to one end of the shaft as shown below.

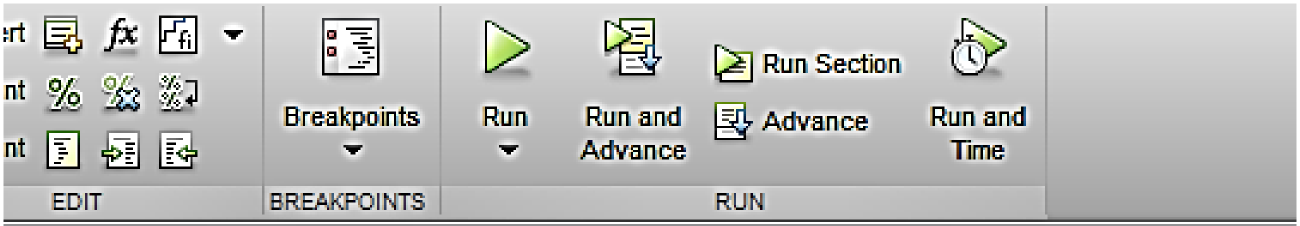


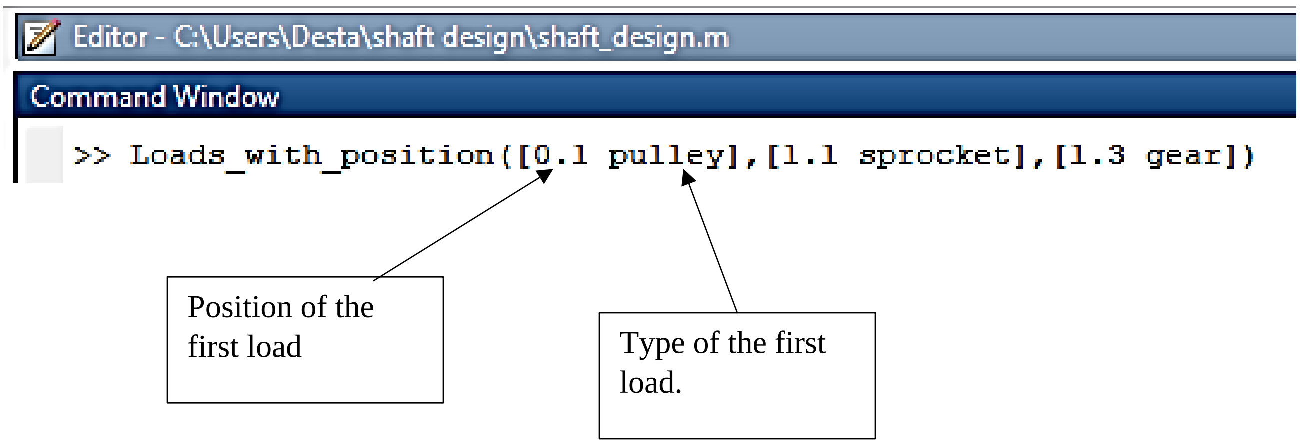
Then to run the function in the command window write the name of the function with its inputs (loads and their position).



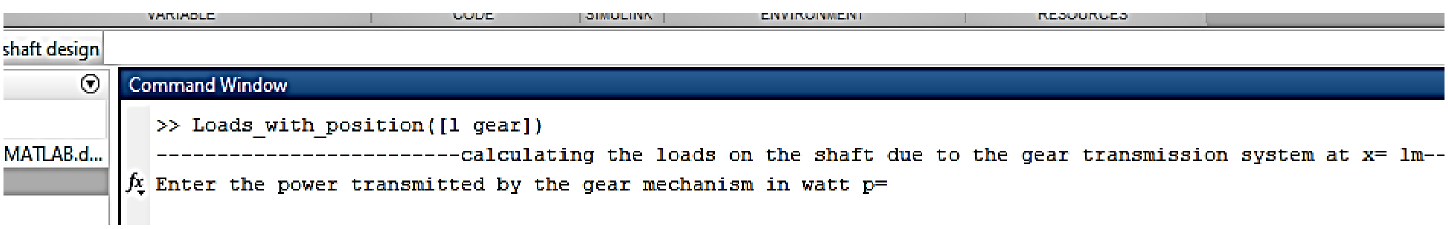


In our question, we have pulley mounted at 0.1m, sprocket mounted at 1.1m and gear at 1.3m so we have to call the function as shown below,

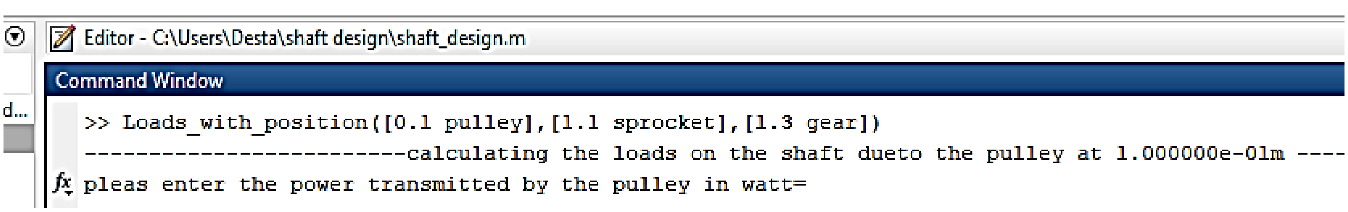




To make it clear let us say we have only one gear mounted on our shaft at 1m so we have to enter the load and its position as shown below.



The maximum loads that the program accepts is four so if we enter the more than four inputs the program askes as to correct the number of inputs. After we enter the loads and their position it starts to calculate the vertical and horizontal loads acting on the shaft due to each loads based on their order by asking the user to enter the necessary inputs for the calculation of the loads.



While entering any value we have to make sure that whether it is valid input for the specific variable. For example if we enter a character for the power, it will ask as to correct our mistake

```
-------------------------calculating the loads on the shaft dueto the pulley at 1.000000e-01m ---
pleas enter the power transmitted by the pulley in watt=hj
Error using input
Undefined function or variable 'hj'.

Error in Loads_with_position (line 16)
            pp(k)=input('pleas enter the power transmitted by the pulley in watt=');

fx pleas enter the power transmitted by the pulley in watt=
```

In addition, if we enter a zero value for the power while designing a power transmission shaft the program tells us how to correct the error.

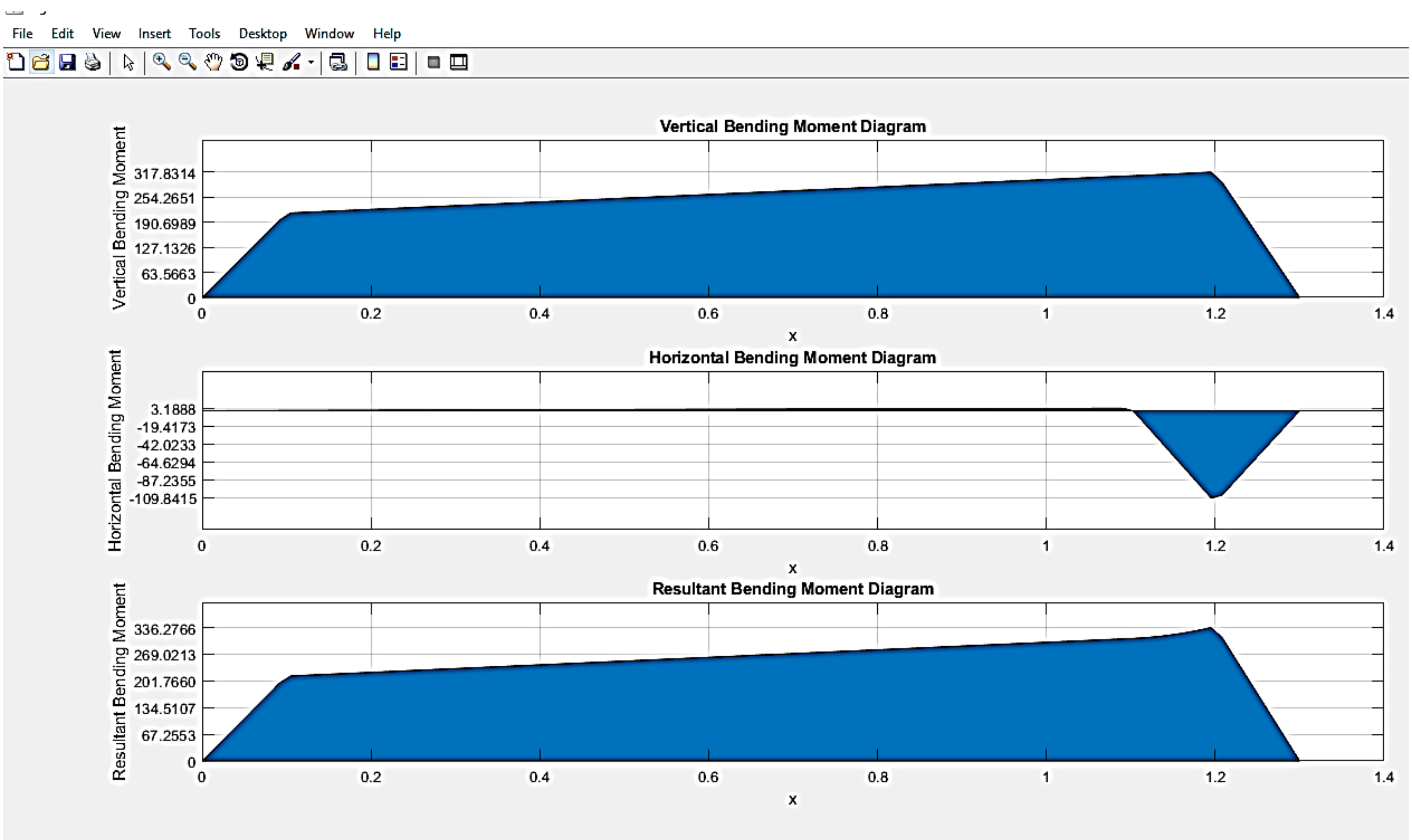
```
pleas enter the power transmitted by the pulley in watt=0
Error invalid input for power
fx enter valid non zero non-negative power transmitted by the pulley in watt,p=
```

After entering every necessary inputs, it calculates the horizontal and vertical loads acting in the shaft.as shown below.

```
>> Loads_with_position([0.1 pulley],[1.1 sprocket],[1.3 gear])
-------------------------calculating the loads on the shaft dueto the pulley at 1.000000e-01m -------------------------
pleas enter the power transmitted by the pulley in watt=25000
pleas enter the diameter of the pulley in meter,D=0.7
please enter the ratio of the belt tension of the pulley(T1/T2)=2
please enter the mass of the pulley in Kg if it is neglegible enter 0 m=0
The torque transmitted by the gear is 2.387324e+02Nm
The tension at the tension side of the pulley is T1=1.364185e+03N
The tension at the slack side of the belt T2=6.820926e+02N
please enter the angle of the tension side of the belt with respect to positive x-axis in degree=-90
please enter the angle of the slack side of the belt with respect to positive x-axis in degree=-90
The vertical load applied at the location of the pulley (at x=1.000000e-01m) by the belt transmission is Fv=2.046278e+03N In
-------------------------calculating loads at the shaft due to the chain mechanism mounted at x=1.100000e+00m-----
please enter the power transmitted by the sprocket in watt,p=25000
please enter the diameter of the sprocket in meter,D=0.4
please enter the mass of the sprocket in Kg if it is neglegible enter 0 m=0
please enter the angle of the tension side of the chain wrt posetive x-axis in degree,angle=0
the horizontal load applied on the shaft by this chain mechanism is 1.193662e+03N in the positive x- direction
The vertical load applied on the shaft by this chain mechanism is 0N
-------------------------calculating the loads on the shaft due to the gear transmission system at x= 1.300000e+00m--
Enter the power transmitted by the gear mechanism in watt p=50000
pleas enter the pitch diameter of the gear in meter=0.3
please enter the mass of the gear in Kg if it is neglegible enter 0 m=0
please enter the angle that tangential load makes with x-axis=90
The torque transmitted by the gear mechanism is 4.774648e+02Nm
please enter the pressure angle of the gear if no enter 0=20
The vertical force acting in the shat by the gear mechanism is Fv=3.183099e+03N
The horizontal force acting on the shaft by the gear mechanism is Fh=1.158553e+03N
```

After calculating the horizontal and vertical loads acting on the shaft due to the different types of loads, the program asks us to enter the location of the two bearings and the length of the shaft.by using the provided inputs, the program calculates the reaction at each bearings and the bending moment diagram as shown below.

```
please enter the location of the first bearing in the shaft in m,a=0
please enter the location of the second bearing in the shaft in m,b=1.2
The reaction at the first bearing in the horizontal direction is R1=2.925736e+00N
The reaction at the second bearing in the horizontal direction is R2=2.349290e+03N
The reaction at the first bearing in the vertical direction is R1=2.141013e+03N
The reaction at the second bearing in the vertical direction  is R2=-3.277834e+03N
please enter the length of the shaft in m L=1.3
The maximum resultant bending moment is 3.362766e+02Nm located at 1.194949e+00m
```



As we can see the bending moment diagrams, they are the same with what we have get from the manual calculation

After this the program asks us to enter the combined fatigue and shock factors as shown below

```
Enter the fatigue and shock factor for bending Kb, enter kb=1 if it is ideal or not given,Kb=1.75
Enter the fatigue and shock factor for bending, enter kt=1 if it is ideal or not given,Kt=1.25
please enter ductile if the shaft is ductile and enter brittle if the shaft is brittle=
```

Next to this, the program asks us to decide whether the shaft is made up of ductile or brittle material. If the material is ductile it uses to the maximum shear force theory and if the material is brittle the program uses the maximum normal stress theory. Here we have to enter ‘ductile’ if the material is ductile and ‘brittle’ if the material is brittle.

```
please enter ductile if the shaft is ductile and enter brittle if the shaft is brittle=ductile
----------------------------Calculating the diameter of ductile shaft using the Maximum shear stress theory or Guest's
The equivalent twisting moment is 8.381652e+02Nm
please enter the permissible shear stress of the material used for the shaft in Mpa=
```

Then to calculate the diameter the program asks us to decide whether the shaft if solid or hollow. If the shaft is solid we have to enter ‘solid’ and if the shaft is hollow we have enter ‘hollow’.

```
please enter ductile if the shaft is ductile and enter brittle if the shaft is brittle=ductile
-----------------------------Calculating the diameter of ductile shaft using the Maximum shear stress theory
The equivalent twisting moment is 8.381652e+02Nm
please enter the permissible shear stress of the material used for the shaft in Mpa=65
please enter solid if the shaft is solid and enter hollow if the shaft is hollow=solid
-------The diameter of the shaft needed to carry the loads safley is --------
                              D=4.034553e+01mm
>>
```

As we can see for the result it is the same as the diameter we have found manually. And if we want to design another shaft with similar speed we can continue to call the function without running the ‘shaft_design.m’ and if we want to design shaft with different speed with the last one we have to run the shaft_design.m again.

-------------------END----------------

Thank you

Appendix

A. Shaft _design

```
clc;
clear;
format shortG;
global n;
pulley=1;gear=2;sprocket=3;
disp('......................shaft design ...................................')
n=input('please enter the speed of the shaft in rpm n=');
while n<0
    disp('error this program is developed for rotating shaft')
    n=input('enter valid non-zero non-negative speed of the shaft in rpm n=')
end
while isnumeric(n)==0
    disp('Error speed cannot be character so please enter a numeric value')
    n=input('enter valid non-zero non-negative speed of the shaft in rpm n=')
end
while size(n)==[0 0]
    disp('Error speed cannot be empty');
    n=input('enter valid non-zero non-negative speed of the shaft in rpm n=')
end
disp('please enter you loads and their position in meter on the shaft by
calling the function loads_and_theire_postion(varargin)')
disp('example')
disp('         let us say you have pulley at 1m,gear at 10m and sprocket at
20 so you have to enter your loads and theire ')
disp('         position in the following manner ')
disp('                           Loads_with_position([1 pulley],[10 gear],[20
sprocket])')
disp('--------------------please follow the the instructions carefully-------
-----------------------------')
```

B.Load_with_position

```
function Loads_with_postion(varargin)
global n;
format shortG
for k = 1:length(varargin)
x(k) = varargin{k}(1); % Cell array indexing
L(k) = varargin{k}(2);
j=nargin;
J=j-4;
while J>0
   error('This program is designed for design of shafts with maximum of 4
loads please revise your input loads');
end
   if(x(k)~=0)
switch L(k)
        case 1
            fprintf('-------------------------calculating the loads on the
shaft dueto the pulley at %dm -------------------------\n',x(k)')
            pp(k)=input('pleas enter the power transmitted by the pulley in
watt=');
            while size(pp(k))==[0 0]
                disp('Error you cannot leave the power empty')
                pp(k)=input('enter valid non zero non-negative power
transmitted by the pulley in watt,p=')
            end
            while isnumeric(pp(k))==0
                disp('Error invalid input for the power of the pulley');
                pp(k)=input('enter valid non-zero non-negative power
transmitted by the pulley in watt,p=');
            end
            while pp(k)<=0
                disp('Error invalid input for power ')
                pp(k)=input('enter valid non zero non-negative power
transmitted by the pulley in watt,p=');
            end
            T(k)=(60*pp(k))/(2*pi*n);
            Dp(k)=input('pleas enter the diameter of the pulley in
meter,D=');
            while size(Dp(k))~=[1 1]
                 disp('Error you cannot leave the diameter empty');
                 Dp(k)=input('enter valid non-zero non-negative diameter of
the pulley in m,D=');
            end
             while isnumeric(Dp(k))==0
                 disp('Error invalid input for diameter');
                 Dp(k)=input('Enter a valid non-zero non-negative diameter of
the pulley in m,D=');
             end
            while  Dp(k)<=0
                disp('Error invalid dimension for the diameter of the
pulley')
                 Dp(k)=input('enter valid non-zero non-negative diameter of
the pulley in m,D=');
            end
            a(k)=input('please enter the ratio of the belt tension of the
pulley(T1/T2)='); % T2 is the tension at the slack side
            while  a(k)<=0
                disp('Error tension ratio cannot be zero or negative')
```

```
                a(k)=input('Enter valid non-zero non-negative tension
ratiio,a=');
            end
            while size(a(k))==[0 0]
                disp('Error you cannot leave the tension ratio empty');
                a(k)=input('Enter valid non-zero non-negative tension
ratiio,a=');
            end
            while isnumeric(a(k))==0
                disp('Error invalid input for tension ratio');
                a(k)=input('Enter valid non-zero non-negative tension
ratio,a=');
            end
            mp(k)=input('please enter the mass of the pulley in Kg if it is
neglegible enter 0 m=');
            while  mp(k)<0
                disp('Error mass cannot be negative')
                 mp(k)=input('enter valid non-negative value for the mass of
the pulley in Kg,m=');
            end
            while size(mp(k))==[0 0]
                disp('Error you cannot leave the mass empty');
                mp(k)=input('Enter valid non-negative value for the mass of
the pulley in Kg,D=');
            end
            while isnumeric(mp(k))==0
                disp('Error invalid input for diameter of the pulley');
                mp(k)=input('Enter valid non-negative value for the mass of
the pulley in Kg,m=');
            end
            wp(k)=mp(k)*9.81;
            T2(k)=(2*T(k))/((a(k)-1)*Dp(k));
            T1(k)=a(k)*T2(k);
            fprintf('The torque transmitted by the gear is %dNm \n',T(k));
            fprintf('The tension at the tension side of the pulley is
T1=%dN\n',T1(k));
            fprintf('The tension at the slack side of the belt
T2=%dN\n',T2(k));
            angle1(k)=input('please enter the angle of the tension side of
the belt with respect to positive x-axis in degree=');
            while size(angle1(k))==[0 0]
                disp('Error you cannot leave the angle of the tension side
empty');
                angle1(k)=input('Enter valid angle of the tension side of the
belt with respect to positive x-axis in degree=');
            end
            while isnumeric(angle1(k))==0
                disp('Error invalid input for angle');
                angle1(k)=input('Enter valid angle of the tension side of the
belt with respect to positive x-axis in degree=');
            end
            T1v(k)=T1(k)*(sind(angle1(k)));
            T1h(k)=T1(k)*(cosd(angle1(k)));
            angle2(k)=input('please enter the angle of the slack side of the
belt with respect to positive x-axis in degree=');
            while size(angle2(k))==[0 0]
                disp('Error you cannot leave it empty');
```

```
                angle1(k)=input('Enter valid angle of the slack side of the 
belt with respect to positive x-axis in degree=');
            end
            while isnumeric(angle2(k))==0
                disp('Error invalid input for angle');
                angle2(k)=input('Enter valid angle of the slack side of the 
belt with respect to positive x-axis in degree=');
            end
            T2v(k)=T2(k)*(sind(angle2(k)));
            T2h(k)=-T2(k)*(cosd(angle2(k)));
            Tv(k)=T1v(k)+T2v(k)-wp(k);
            Th(k)=T1h(k)+T2h(k);
            if (Tv(k)>0)
                Fv(k)=Tv(k);
                fprintf('The vertical load applied at the location of the 
pulley (at x=%dm) by the belt transmission is Fv=%dN In the upward 
direction\n',x(k),Tv(k));
            elseif (Tv(k)<0)
                Fv(k)=Tv(k);
                absTv(k)=-1*Tv(k);
                fprintf('The vertical load applied at the location of the 
pulley (at x=%dm) by the belt transmission is Fv=%dN In the downward 
direction\n',x(k),absTv(k));
            else Fv(k)=0;
                fprintf('The vertical load applied at the location of the 
pulley (at x=%dm) by the belt transmission is Fv=%dN\n',x(k),Fv(k));
            end
            if (Th(k)>0)
                Fh(k)=Th(k);
                fprintf('The horizontal load applied at the location of the 
pulley(at x=%dm) by the belt transmission is Fh=%dNm In the positive x-
direction\n',x(k),Th);
            elseif (Th(k)<0)
                absTh(k)=-1*Th(k);
                Fh(k)=abs(Th(k));
                fprintf('The horizontal load applied at the location of the 
pulley(at x=%dm) by the belt transmission is Fh=%dNm In the negative x-
direction direction\n',x(k),absTh(k));
            else Fh(k)=0;
                fprintf('The horizontal load applied at the location of the 
pulley(at x=%dm) by the belt transmission is Fh=%dNm\n',x(k),Fh(k));
            end
        case 2
           fprintf('-------------------------calculating the loads on the 
shaft due to the gear transmission system at x= %dm-------------------------
\n',x(k));
           pg(k)=input('Enter the power transmitted by the gear mechanism in 
watt p=');
           while isnumeric(pg(k)==0)
                disp('Error invalid input for diameter of the gear');
                pg(k)=input('Enter valid non zero non-negative power 
transmitted by the gear in watt,p=');
            end
           while pg(k)<=0
                disp('Error invalid input power ')
                pg(k)=input('Enter valid non zero non-negative power 
transmitted by the gear in watt,p=');
```

```
             end
            while size(pg(k))~=[1 1]
                disp('Error you cannot leave the it empty');
                pg(k)=input('enter valid non zero non-negative power
transmitted by the gear in watt,p=');
            end
            T(k)=(60*pg(k))/(2*pi*n);
            Dg(k)=input('pleas enter the pitch diameter of the gear in
meter=');
            while  Dg(k)<=0
                disp('Error, invalid dimension for the diameter of the gear')
                 Dg(k)=input('Enter valid non-zero non-negative diameter of
the gear in m,D=');
            end
            while size(Dg(k))==[0 0]
                disp('Error, you cannot leave the diameter empty');
                Dg(k)=input('Enter valid non-zero non-negative diameter of
the gear in m,D=');
            end
            while isnumeric(Dg(k))==0
                disp('Error, invalid input for diameter of the gear');
                Dg(k)=input('Enter valid non-zero non-negative diameter of
the gear in m,D=');
            end
            mg(k)=input('please enter the mass of the gear in Kg if it is
neglegible enter 0 m=');
            while  mg(k)<0
                disp('Error, mass cannot be negative')
                 mg(k)=input('enter valid non-negative value for the mass of
the gear in Kg,m=');
            end
            while size(mg(k))==[0 0]
                disp('Error you cannot leave the mass empty');
                mg(k)=input('Enter valid non-negative value for the mass of
the gear in Kg,D=');
            end
            while isnumeric(mg(k))==0
                disp('Error invalid input for diameter of the gear');
                mg(k)=input('Enter valid non-negative value for the mass of
the gear in Kg,m=');
            end
            angle4(k)=input('please enter the angle that tangential load
makes with x-axis=');
            while size(angle4(k))==[0 0]
                disp('Error you cannot leave the angle empty');
                angle4(k)=input('please enter the angle that tangential load
makes with x-axis=');
            end
            while isnumeric(angle4(k))==0
                disp('Error invalid input for angle');
                angle4(k)=input('please enter the angle that tangential load
makes with x-axis=');
            end
            wg(k)=mg(k)*9.81;
            Ft(k)=(((2*T(k))/Dg(k)));
            fprintf('The torque transmitted by the gear mechanism is %dNm
\n',T(k));
```

```
angle3(k)=input('please enter the pressure angle of the gear if no enter
0=');
            while size(angle3(k))==[0 0]
                disp('Error you cannot leave the pressure angle empty');
                angle3(k)=input('please enter the pressure angle of the
gear=');
            end
            while isnumeric(angle3(k))==0
                disp('Error invalid input for angle');
                angle3(k)=input('please enter the pressure angle of the
gear=');
            end
            Fr(k)=Ft(k)*tand(angle3(k));
            Fh(k)=(((Ft(k)*cosd(angle4(k))+(Fr(k)*sind(angle4(k))))));
            Fv(k)=(((Ft(k)*sind(angle4(k))+(Fr(k)*cosd(angle4(k))))))-wg(k);
            fprintf('The vertical force acting in the shat by the gear
mechanism is Fv=%dN \n',Fv(k));
            fprintf('The horizontal force acting on the shaft by the gear
mechanism is Fh=%dN\n',Fh(k));
        case 3
           fprintf('------------------------calculating loads at the shaft
due to the chain mechanism mounted at x=%dm------------------------\n',x(k))
           ps(k)=input('please enter the power transmitted by the sprocket in
watt,p=');
             while ps(k)<=0
                disp('Error invalid power ')
                ps(k)=input('Enter valid non-zero non-negative power
transmitted by the sprocket in watt,p=');
             end
            while size(ps(k))==[0 0]
                disp('Error you cannot leave the power empty');
                ps(k)=input('Enter valid non-zero non-negative power
transmitted by the sprocket in watt,p=');
            end
            while isnumeric(ps(k))==0
                disp('Error invalid input for power transmitted by the
sprocket');
                ps(k)=input('Enter valid non-zero non-negative power
transmitted by the sprocket in watt,p=');
            end
            T(k)=(ps(k)*60)/(2*pi*n);
            Ds(k)=input('please enter the diameter of the sprocket in
meter,D=');
             while  Ds(k)<=0
                disp('Error invalid dimension for the diameter of the
sprocket')
                 Ds(k)=input('Enter, valid non-zero non-negative diameter of
the sprocket in m,D=');
             end
             while size(Ds(k))==[0 0]
                 disp('Error, you cannot leave the diameter empty');
                 Ds(k)=input('Enter valid non-zero non-negative diameter of
the sprocket in m,D=');
             end
             while isnumeric(Ds(k))==0
                 disp('Error invalid input for diameter');
```

```
Ds(k)=input('Enter valid non-zero non-negative diameter of the sprocket in m,D=');
             end
            ms(k)=input('please enter the mass of the sprocket in Kg if it is neglegible enter 0 m=');
            while  ms(k)<0
                disp('Error mass cannot be negative')
                 ms(k)=input('Enter valid non-negative value for the mass of the sprocket in Kg,m=');
            end
             while size(ms(k))==[0 0]
                 disp('Error you cannot leave the mass empty');
                 ms(k)=input('Enter valid non-negative value for the mass of the sprocket in Kg,m=');
             end
             while isnumeric(ms(k))==0
                 disp('Error invalid input for diameter of the sprocket');
                 ms(k)=input('enter valid non-negative value for the mass of the sprocket in Kg,m=');
             end
            ws(k)=ms(k)*9.81;
            Fc(k)=(2*T(k))/Ds(k);
            angle4(k)=input('please enter the angle of the tension side of the chain wrt posetive x-axis in degree,angle=');
            Fch(k)=Fc(k)*cosd(angle4(k));
            Fcv(k)=(Fc(k)*sind(angle4(k)))- ws(k);
            if (Fch(k)>0)
                Fh(k)=Fch(k);
                fprintf('the horizontal load applied on the shaft by this chain mechanism is %dN in the positive x- direction \n',Fch(k));
            elseif(Fch(k)<0)
                absFch(k)=Fch(k)*-1;
                Fh(k)=Fch(k);
                fprintf('The horizontal load applied on the shaft by this chain mechanism is %dN in the negative x-direction\n',absFch(k));
            else Fh(k)=0;
                fprintf('The horizontal load applied on the shaft by this chain mechanism is %dN\n',Fh(k));
            end
            if (Fcv(k)>0)
                Fv(k)=Fcv(k);
                fprintf('The vertical load applied on the shaft by this chain mechanism is %dN in the upward direction \n',Fcv(k));
            elseif(Fcv(k)<0)
                Fv(k)=Fcv(k);
                absFcv(k)=Fcv(k)*-1;
                fprintf('The vertical load applied on the shaft by this chain mechanism is %dN in the downward direction \n',absFcv(k));
            else Fv(k)=0;
                fprintf('The vertical load applied on the shaft by this chain mechanism is %dN\n',Fv(k));
            end
end
end
end
FH=Fh;
FV=Fv;
```

```
switch j
        case 1
            x(2)=0;x(2)=0;Fh(3)=0;x(3)=0;Fh(4)=0;x(4)=0;
        case 2
            Fh(3)=0;x(3)=0;Fh(4)=0;x(4)=0;
        case 3
            Fh(4)=0;x(4)=0;
    end
    a=input('please enter the location of the first bearing in the shaft in
m,a=');
    while size(a)==[0 0]
        disp('Error, you cannot leave it empty');
        a=input('Enter valid non-negative value for the location of the first
bearing in m,a=');
    end
    while isnumeric(a)==0
        disp('Error invalid input for diameter of the sprocket');
        a=input('Enter valid non-negative value for the location of the first
bearing in m,a=');
    end
    while a<0
        disp('Error position cannot be negative');
        a=input('please enter non-negative value for the position of the
first bearing in the shaft in m,a=');
    end
    b=input('please enter the location of the second bearing in the shaft in
m,b=');
    while b<0
        disp('error position cannot be negative');
        b=input('please enter non-negative value for the position of the
second bearing in the shaft in m,b=');
    end
    while size(b)==[0 0]
        disp('Error, you cannot leave it empty');
        b=input('Enter valid non-negative value for the location of the
second bearing in m,b=');
    end
    while isnumeric(b)==0
        disp('Error invalid input for diameter of the sprocket');
        b=input('Enter valid non-negative value for the location of the
second bearing in m,b=');
    end
    R2h=(((Fh(1)*(a-(x(1))))+(Fh(2)*(a-(x(2))))+(Fh(3)*(a-(x(3))))+(Fh(4)*(a-
(x(4)))))/(a-b));
    R1h=Fh(1)+Fh(2)+Fh(3)+Fh(4)-R2h;
    fprintf('The reaction at the first bearing in the horizontal direction is
R1=%dN\n',R1h);
    fprintf('The reaction at the second bearing in the horizontal direction
is R2=%dN\n',R2h);
  switch j
        case 1
            x(2)=0;x(2)=0;Fv(3)=0;x(3)=0;Fv(4)=0;x(4)=0;
        case 2
            Fv(3)=0;x(3)=0;Fv(4)=0;x(4)=0;
        case 3
            Fv(4)=0;x(4)=0;
  end
```

```
    R2v=-(((Fv(1)*(a-(x(1))))+(Fv(2)*(a-(x(2))))+(Fv(3)*(a-
(x(3))))+(Fv(4)*(a-(x(4)))))/(a-b));
    R1v=-Fv(1)-Fv(2)-Fv(3)-Fv(4)-R2v;
    fprintf('The reaction at the first bearing in the vertical direction is
R1=%dN\n',R1v);
    fprintf('The reaction at the second bearing in the vertical direction  is
R2=%dN\n',R2v);
  Q=input('please enter the length of the shaft in m L=');
while Q<=0
    disp('error length cannot be zero or negative')
    Q=input('please enter non-zero, non-negative length of the shaft in m,
L=');
end
while size(Q)==[0 0]
    disp('Error, you cannot leave it empty');
    Q=input('Enter valid non-negative value for the length of the shaft in m,
L=');
end
    while isnumeric(Q)==0
        disp('Error invalid input for the length of the shaft');
        Q=input('Enter valid non-negative value for the length of the shaft
in m, L=');
    end
u=linspace(0,Q);
Vh=R1h*(u>a)+R2h*(u>b)+Fh(1)*(u>x(1))-Fh(2)*(u>x(2))-Fh(3)*(u>x(3))-
Fh(4)*(u>x(4));
Mh=(R1h*(u-a).*(u>a))+(R2h*(u-b).*(u>b))-(Fh(1)*(u-x(1)).*(u>x(1)))-
(Fh(2)*(u-x(2)).*(u>x(2)))-(Fh(3)*(u-x(3)).*(u>x(3)))-(Fh(4)*(u-
x(4)).*(u>x(4)));
Vv=R1v*(u>a)+R2v*(u>b)+Fv(1)*(u>x(1))+Fv(2)*(u>x(2))+Fv(3)*(u>x(3))+Fv(4)*(u>
x(4));
Mv=(R1v*(u-a).*(u>a))+(R2v*(u-b).*(u>b))+(Fv(1)*(u-
x(1)).*(u>x(1)))+(Fv(2)*(u-x(2)).*(u>x(2)))+(Fv(3)*(u-
x(3)).*(u>x(3)))+(Fv(4)*(u-x(4)).*(u>x(4)));
M=sqrt(((Mv.^2))+((Mh.^2)));
Z=max(M);
subplot(3,1,1)
area(u,Mv),xlabel('x'),ylabel('Vertical Bending Moment'),title('Vertical
Bending Moment Diagram')
set(gca,'YTick',[(min(Mv)):(((max(Mv))-min(Mv))/5):(max(Mv))]);
grid on;
subplot(3,1,2)
area(u,Mh),xlabel('x'),ylabel('Horizontal Bending Moment'),title('Horizontal
Bending Moment Diagram')
grid on
set(gca,'YTick',[(min(Mh)):(((max(Mh))-min(Mh))/5):(max(Mh))]);
grid on;
subplot(3,1,3)
area(u,M),xlabel('x'),ylabel('Resultant Bending Moment'),title('Resultant
Bending Moment Diagram')
grid on
set(gca,'YTick',[(min(M)):(((max(M))-min(M))/5):(max(M))]);
grid on;
[difference,Mmax_loaction]=min(abs(M-max(M)));
X=u(Mmax_loaction);
fprintf('The maximum resultant bending moment is %dNm located at %dm\n',Z,X);
if X<=x(1)
```

```
    T=T(1);
elseif X<=x(2)
    T=T(2);
elseif X<=x(3)
    T=T(3);
else T=T(4);
end
Kb=input('Enter the fatigue and shock factor for bending Kb, enter kb=1 if it is ideal or not given,Kb=');
while Kb<=0
    disp('Error, invalid input for Kb');
    Kb=input('please enter non-zero non-negative Kb');
end
while size(Kb)==[0 0]
        disp('Error, you cannot leave it empty');
        Kb=input('Enter valid non-negative non-zero value for the fatigue and shock factor for bending Kb,Kb=');
end
    while isnumeric(Kb)==0
        disp('Error invalid input for fatigue and shock factor bending Kb');
        Kb=input('Enter valid non-negative non-zero value for the fatigue and shock factor for bending Kb=');
    end
Kt=input('Enter the fatigue and shock factor for bending, enter kt=1 if it is ideal or not given,Kt=');
while Kt<=0
    disp('Error,invalid input for Kt');
    Kt=input('please enter non-zero non-negative Kt');
end
while size(Kt)==[0 0]
        disp('Error, you cannot leave it empty');
        Kt=input('Enter valid non-negative non-zero value for the fatigue and shock factorfor twisting Kt,Kt=');
end
while isnumeric(Kt)==0
    disp('Error invalid input for fatigue and shocke fcator twisting Kt');
    Kt=input('Enter valid non-negative non-zero value for the fatigue and shock factor for twisting Kt=');
end
Te=sqrt((((Kb*Z)^2)+(Kt*T)^2));
Me=((1/2)*((Kb*Z)+Te));
ductile=6;
brittle=7;
Material_Type=input('please enter ductile if the shaft is ductile and enter brittle if the shaft is brittle=');
switch Material_Type
    case 6
        disp('-----------------------------Calculating the diameter of ductile shaft using the Maximum shear stress theory or Guest’s theory---------------------')
fprintf('The equivalent twisting moment is %dNm\n',Te);
t=input('please enter the permissible shear stress of the material used for the shaft in Mpa=');
while t<=0
    disp('Error,invalid input for t');
    t=input('please enter non-zero non-negative permissible stress =');
end
```

```
while size(t)==[0 0]
        disp('Error, you cannot leave it empty');
        t=input('Enter valid non-negative non-zero value for the permissible
stress =');
end
while isnumeric(t)==0
    disp('Error invalid input for the permissible stress of the shaft');
    t=input('Enter valid non-negative non-zero value for the permissible
stress of the shaft=');
end
    case 7
       disp('-----------------------------Calculating the diameter of brittle
shaft using the Maximum normal stress theory or Rankine’s theory-------------
-------')
       fprintf('The equivalent bending moment is %dNm\n',Me);
       bs=input('please enter the permissible bending stress of the material
used for the shaft in Mpa=');
       while bs<=0
           disp('Error,invalid input for t');
           bs=input('please enter non-zero non-negative permissible stress
=');
       end
       while size(bs)==[0 0]
           disp('Error, you cannot leave it empty');
           bs=input('Enter valid non-negative non-zero value for the
permissible stress =');
       end
       while isnumeric(bs)==0
           disp('Error invalid input for the permissible stress of the
shaft');
           bs=input('Enter valid non-negative non-zero value for the
permissible stress of the shaft=');
       end
end
solid=4;
hollow=5;
shaft_type=input('please enter solid if the shaft is solid and enter hollow
if the shaft is hollow=');% if it is solid enter solid and if it is hollow
enter hollow
while shaft_type<=0
    disp('Error,invalid input for the shaft_type');
    shaft_type=input('please enter non-zero non-negative permissible stress
=');
end
while size(shaft_type)==[0 0]
        disp('Error, you cannot leave it empty');
        shaft_type=input('please enter solid if the shaft is solid and enter
hollow if the shaft is hollow=');
end
while isnumeric(shaft_type)==0
    disp('Error invalid input for the shaft type');
    shaft_type=input('please enter solid if the shaft is solid and enter
hollow if the shaft is hollow=');
end
switch shaft_type
    case 4
        if Material_Type==6
```

```
d=(10*((16*Te)/(t*pi))^(1/3));
        elseif Material_Type==7
            d=(10*((16*Me)/(bs*pi))^(1/3));
        end
          disp('-------The diameter of the shaft needed to carry the loads
safley is --------')
          fprintf('                              D=%dmm
\n',d);
    case 5
        q=input('please enter the ratio of the inner diameter to the outer
diameter=');
        while q<=0
            disp('Error,invalid input for the ratio of the inner diameter to
the outer diameter');
            q=input('please enter non-zero non-negative ratio of the inner
diameter to the outer diameter =');
        end
        while size(q)~=[1 1]
            disp('Error, you cannot leave it empty');
            q=input('Enter valid non-negative non-zero value for the ratio of
the inner diameter to the outer diameter=');
        end
        while isnumeric(q)==0
            disp('Error invalid input for the ratio of the inner diameter to
the outer diameter');
            q=input('Enter valid non-negative non-zero value for the ratio of
the inner diameter to the outer diameter=');
        end
        if Material_Type==6
            do=(10*((16*Te)/((t*pi*(1-(q^4)))))^(1/3));
        elseif Material_Type==7
            do=(10*((16*Me)/((bs*pi*(1-(q^4)))))^(1/3));
        end
        di=q*do;
        disp('-------The outer diameter of the hollow shaft needed is -------
-')
        fprintf('                              Do=%dmm
\n',do);
        disp('-------The internal diameter of the hollow shaft needed is ----
----')
        fprintf('                              Di=%dmm
\n',di);
end
end
```