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Parametric design and analysis of Machine Elements using Python.

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Abstract: - The idea behind this to minimize the efforts and hard work of Engineers behind their designing process. As they are the ones who are bringing automation all over the globe, and so with the flow we also decided to make the designing process automated, so an Engineer will only give the parameters or conditions like Power, Load, Tensile Stress of material, etc. which he think best for situation and this program will give the safest calculation. We had implemented the 3 machine elements in this project for simplification and easy to understand to everyone.

Keywords: - Designing, Python, AutoCAD

Introduction: - As everything is moving towards Automation, we got idea to automate our design works, our design calculations to solve them with in just matter of time. With the help of Python programming language and some awesome tools we are trying to make the tired and time-consuming work of designing, easy and fast to finish within just some few seconds. We also had added functionality to plot the Shear Force and Bending Moment diagram or to save it as an image as user want which could be used to further analyze.

Our program will not only give the designed calculations but to ensure the design is safe for the given parameters it will also try to check its safety under various loads and if the design is not safe it will again design the elements for given parameters by increasing the FOS 0.5 until user doesn't get the safest design. program user could also realize how to fix some issue and also will be able to experiment the different codes output.

We also had implemented small program to draw the 2D design in AutoCAD by connecting it to through an API (Application Programming Interface) where after designing shaft the AutoCAD will draw the simple 2D drawing of the Shaft with designed parameters thus helping user to analyze it practically as well.

Problem statement: - To develop a software which will recursively design safest dimension for the selected elements for given parameters, load conditions.

Python modules: - Modules are the small program inbuilt in python to enhance the functionality of python programs.

1. Math- To perform mathematical function.
2. Matplotlib- To plot Graphs, SFD, BMD.
3. Tkinter- An API (Application Programming Interface) to create GUI (Graphical User Interface).
4. PyAutoCAD- An API to send commands to AutoCAD from Python.

Methodology: - The main aim is to design the safest dimension for given elements. For it we have to gather all the design formulae and their failure condition of the following 3 elements.

• Cotter Pin

• Kunkle Pin

• Shaft

We had designed all our algorithm on basis of torsional theory and bending theory. We had given how we had arranged the formulae and made our own algorithm so the computer can understand it and we also optimize the code so it would do the work even more quickly with less power and less time consuming. We had to take consider of the failures of elements in different circumstances and we also made an algorithm for same so the program will design the safest possible dimensions.

Design procedure for cotter pin: -

$$p_4 = \frac{\pi}{4}$$

```
Design of rod under tension:
        Diameter of rod (d) = sqrt (P * p4 / Syt)

Design of spigot end tensile:
        d2 = sqrt(P/(p4-0.25) * Syt))
        t = (d2/4)

Design of spigot considering crushing:
        d2 = sqrt (P * 4 / Syc)
        t = d2 / 4

Shearing failure of spigot:
        a = (P/(tau*d2*2))

Crushing of spigot end:
        Syc1 = P / (d2*t)
        If the Syc1 < Syc then design is safe up to this point

Design of spigot collar:
        t1 = (P/(tau*pi*d2))

Design of socket under tension:
        A = P/ Syt
        o = A+(p4*(d2**2) - (d2*t))
        Solving the Quadratic Eqn we get the D
        D1 = solve quadra (p4, -1*t, -o)
        d1 = D1^0.25

Design of socket in crushing failure:
        d4 = P / ((Syc * t) + d2)

Design of socket in shearing failure:
        c = (P/(2*tau*(d4-d2)))

Design of cotter considering shearing failure:
        b = (P/(tau*2*t))
        Length of Pin (L) = (4*d)
        e = (1.2*d)
Bending of cotter:
        z = (t*(b**2))/6
        Moment of inertia (M) = (P / 2) * ((d4/6) + (d2/12))
        sb =  (M/z)
      If sb > Syc then design is unsafe up to this point
```

Design procedure for knuckle pin: -

```
  P = Power to Be Transmitted
  Syt = Shear Strength of Material
  Syc = Compression Strength of Material
  tau = Shear Stress of material

 ## Diameter of rod
 a1 = Syt*π/4 #a1 => area affecting
 Diameter of Rod (d) = sqrt(P/a1)
 ## Diameter of Knuckle Pin
 a2 = 2*π*tau/4 #a2 => area affecting
 Diameter of pin (Dp)= max (sqrt(P/a2), d)

 ## Thickness of Single Eye
 t1 = max(1.25*d , P/(Syc*Dp))

 ## Thickness of Fork
 t = max(0.75*d , P/(Syc*Dp*2))

 ## Diameter
 a5 = P/(tau*t)
 D = max (a5+Dp ,  2*d)


 ## Analysis of Fork end in Tension failure
 a6 = 2*t*(D-Dp)
  Syt1 = P / a6

 ## Analysis of Fork end in shear
 a7 = 2*t*(D-Dp)
 tau1 = P / a7

  If Syt1 < Syt and tau1 < tau then design is safe for the give
parameters
```

Design procedure for shaft: -

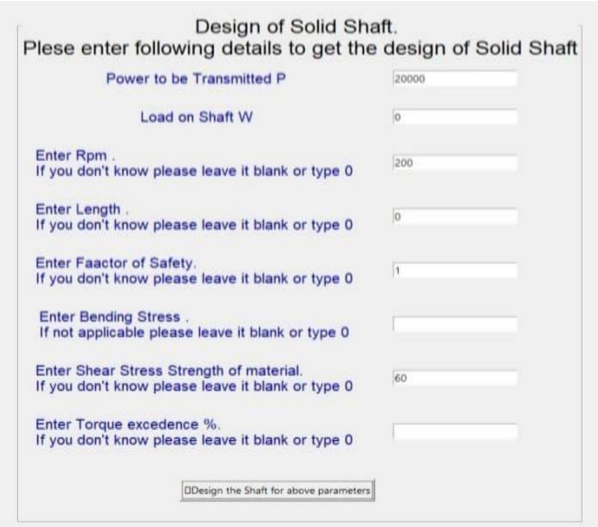
```
For Shaft subjected to twisting Moment
       T     tau     G θ
      --- = --- = -----
       J     d/2      L


      T = Twisting Moment   --- >> unit  N-mm

      Power  =  2 * π * N * T / 60
          where P = Power = Watt
                N = Rpm
                T = N-m

       In case of belt drives the twisting moment (T) is given by

             T = (T1-T2)*R
             where
                  T1 = Tension in tight side  --->> unit Newton
                  T2 = Tension in slack side  --->> unit Newton
                  R = Radius of the Pulley  --->> unit meter

     tau  = Shear stress  ---->> unit N / mm^2

      r = Distance From Neutral Axis to the outer mo Syt fibre.


      J = Polar Moment of Inertia

      For Solid Shaft    J = π/32 * d^4 --->> unit mm^4

      For Hollow Shaft    J = π/32 * ( D^4 - d^4 )


    Thus
         For solid shaft       T = π/16 * tau * d^3
                                   &

         For Hollow Shaft       T = π/16 * tau * D^3 * (1 - k^4)

         where k = d / D (ratio of inner dia to outer dia)

     therefore
         For solid Shaft d = cuberoot((T * 16) / (tau*π))
                                   &
         For Hollow Shaft D = cuberoot((T * 16) / (tau * π * (1 - k^4))
```

```
For Bending Moment

        M     sigma B
       --- = -------
        I        y

        M = Bending Moment        --->> unit N-m

           For Solid Shaft     M = π/32 * sigma B * d^3

           For Hollow Shaft    M = π/32 * sigma B * D^3 (1 - k^4)

           where k = d/D

        I = Moment Of Inertia     --->> unit mm^4

           For Solid Shaft     I = π/64 * d^4

           For Hollow Shaft    I = π/64 * (D^4 - d^4)

       sigma B = Bending stress     --->> unit N/mm^2

           sigma B = (32 * M) / (π * d^3)

           tau = (16 * T) / (π * d^3)

       y = Distance from neutral axis to the outer mo Syt fibre

           y = d/2      --->> unit mm

   If Numerical requires both twisting and bending moment following will be
the procedure

      tau max = 0.5 * sqrt (sigma B^2 + 4 * tau^2

       By Simplifying

           tau max = 16 * sqrt[ M^2 + T^2 ] / ( π * d^3 )
```

```
      The Twisting Moment due to maximum Syt shear Stress on surface of
      Shaft is known as equivalent Twisting moment i.e. Te

        Te = sqrt[ M^2 + T^2 ]

   i.e.  Te = π/16 * tau max * d^3 . . . eqn

      Te = Equivalent Twisting Moment

      Me = Equivalent Bending Moment

      Me = 0.5 * [ M^2 + Te^2]

Calculating by    T       G θ
                 ---  =  -----
                  J        L

    T J= ((Te*16)/(tau*pi) ... eqn
      As We know
        Tmax = π /16  * tau * (D^4 - d^4)/D
        (D^4 - d^4)/D = (Tmax*16) / (π * tau) ... eqn 1
    i.e., T J = (D^4 - d^4)/D

            From this eqn J = (Te * L)/(G * θ)

            J = π /32 *(D^4 - d^4)
thus--->    (D^4 - d^4) = J * 32 / pi ... eqn 2

           Let consider  d1 d2 = J * 32 /pi
           Therefore     d1 d2 = D^4 - d^4
           And           T J = (D^4 - d^4)/D
             i.e.
             d1 d2 / D = T J
             i.e.
             D = d1 d2 / T J

      The max() is a function which takes maximum from given two values
```

These are the formulas we have used in order to create this program. We have tested the program a number of times and encountered few errors in the code. After working on the errors and finding faults we have come up on this final version of the program.

So, the final software looks like this-



We have linked this software with AutoCAD, we also had implemented small program to draw the 2D design in AutoCAD where after designing shaft the AutoCAD will draw the simple 2D drawing of the Shaft with designed parameters thus helping user to analyze it practically as well.

Python and AutoCAD is connected by API (Application Programming Interface) known as PyAutoCAD. PyAutoCAD is aimed to simplify writing ActiveX Automation scripts for AutoCAD with python.

The main purpose to connect python with AutoCAD is to help user to analyze all designs.

Advantages: -This program has better efficiency to calculate the safe dimension fast and better productivity to design the specified elements with calculated dimension.

• Easy to use.

• Easy to implement.

• Save time.

• Quick and correct analysis.

• Wide range of applications.

• Program is portable.

• No need of training.

• No cost or power consuming.

• Easy to detect errors.

Applications: - The main application for this software is

References: -

o www.python.org/docs.com

For solving the and learning about Python errors.

o www.github.com

To manage our Project code o https://pypi.org/project/pyautocad As manual for using PyAutoCAD API

o https://pyautocad.readthedocs.io

For referring to different failures of PyAutoCAD API and designing 2D elements in AutoCAD

o https://www.youtube.com

For referencing the different errors and their solutions occurred while calculating the dimensions.