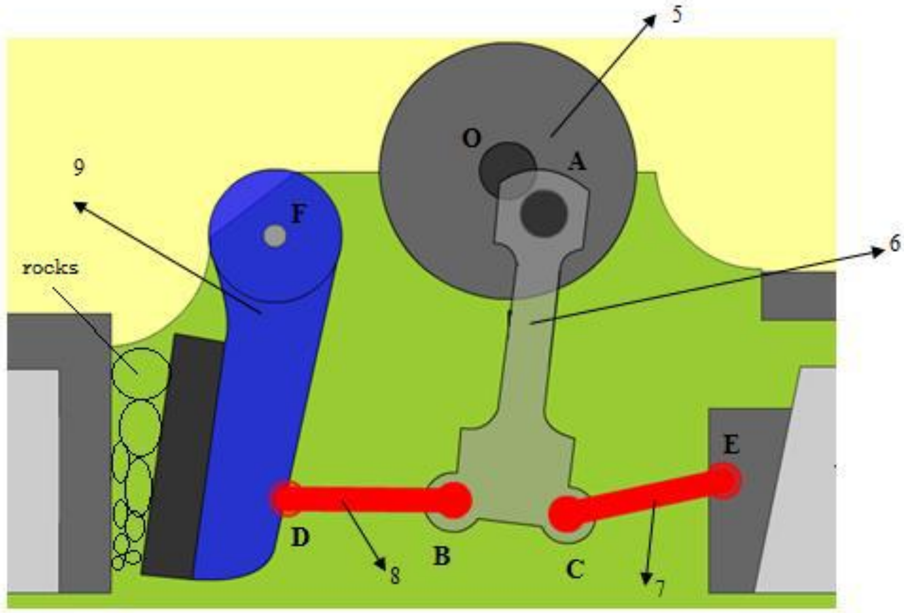
ME 307 MACHINE ELEMENTS I
FALL 2016/17- TERM PROJECT
Design of a Stone Crusher Machine

Due Date: December 19, 2016 16:30 / to L-A10

In this project, you are required to design some specific parts of a "stone crusher" machine as seen on the figure. The machine performs crushing by means of a four-bar and a five- bar mechanisms. Around the extended position (when link BD and link CE become straight) of the mechanisms, the rocks are crushed by the output-link (crusher) till the parts are small enough to pass through the "sieve".

The electric motor (1) on the ground drives the pulley (2) via the belt (3) as shown in Figure 2. The pulley mounted on the shaft (4) rotates at a constant angular velocity transmits the motion to the crank (5). The shaft (4) rotates on large journal bearings that can be considered as revolute joints. The crank (5) is attached to the connecting rod (6) by the pin A. Similarly, connecting rod (6) is joined to the Link BD and CE by the pin B and C, respectively. Crusher is hinged to the machine frame by pin F and to the link DB by pin D.

Detail drawings of the shaft (4), pin B are given in Figure 3 and Figure 4, respectively. Bracket (10) is part welded to the crusher (9) as shown in Figure 5. Also, position variables of the mechanism are shown in Figure 7. Also, the angle between the surface of the crusher (9) and the line connecting D and F points is given in Figure 8.



Crusher Machine Figure 1. Stone (http://www.mekanizmalar.com/stone_crusher.html)

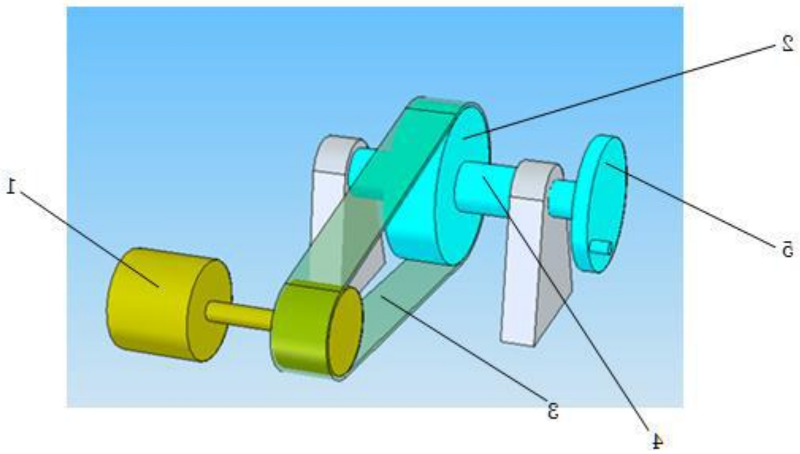


Figure 2. Drive belt system.

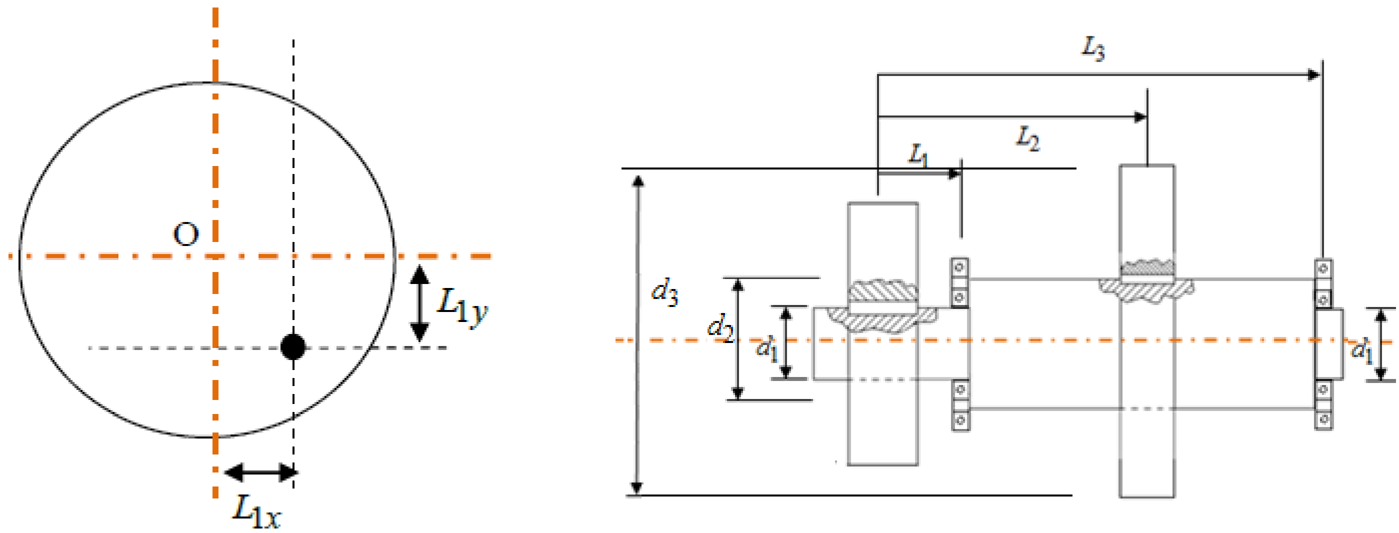


Figure 3. Front view of the crank (5) at the maximum torque case and the Shaft (4).

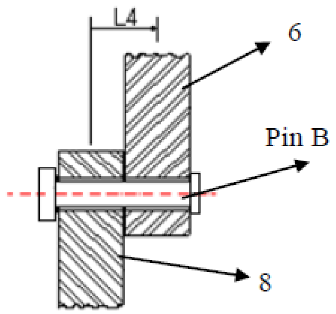


Figure 4. Pin B

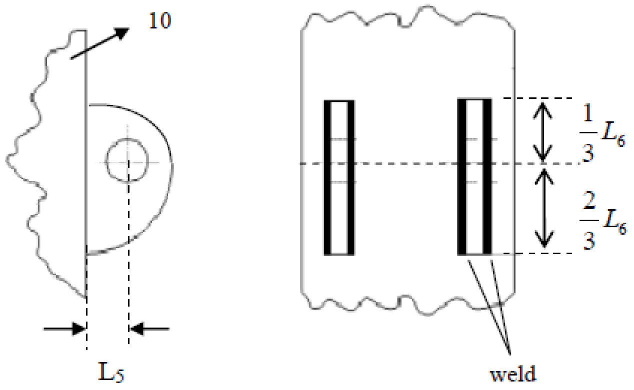


Figure 5. Sketch for the weld and bracket

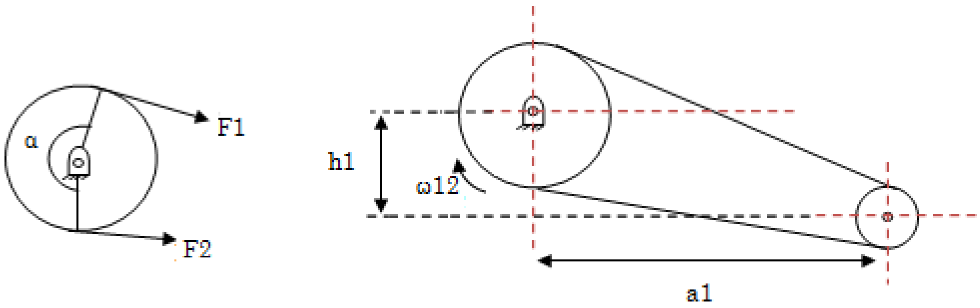


Figure 6. Sketch for the pulley and the electric motor

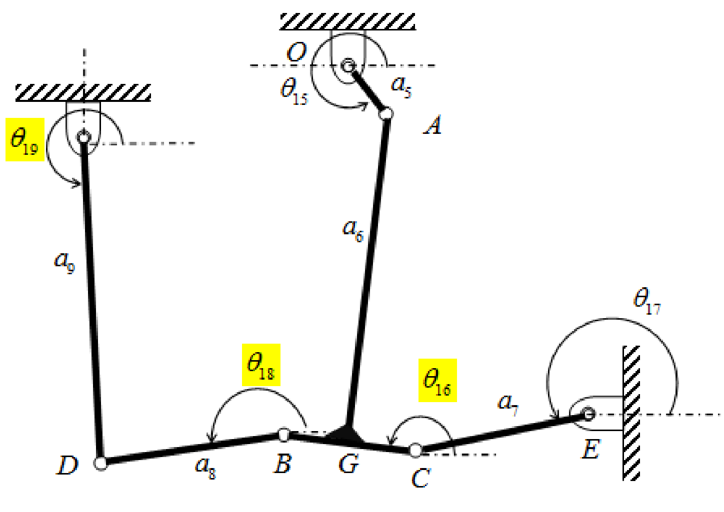


Figure 7. Position of the links at the critical loading.

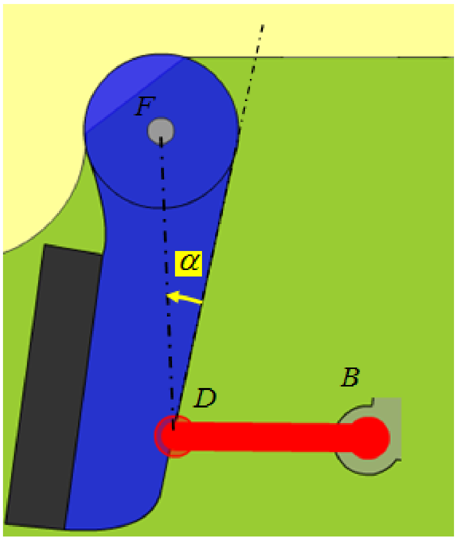


Figure 8. The angle between the surface of the crusher (9) and the line connecting D and F points

In the project do the followings in the given order. **(Reports with wrong data sets will be graded as zero).**

A. Draw the free body diagrams of the following parts (neglect inertias)

1. The Pulley (2)
2. The Shaft (4)
3. The Crank (5)
4. The Connecting Rod (6)
5. Link CE (7)
6. Link BD (8)
7. Pin B
8. The Crusher (9)

B. Shaft Design

The belt forces can be calculated from the equation
$\frac{F_1}{F_2} = e^{f\alpha}$, where f is the coefficient of friction and α is the angle of wrap, shown in Figure 6.

1. Draw the shear force and the bending moment diagrams of the shaft.
2. Design the shaft for fatigue loading. Use distortion energy theory and Soderberg criteria in the design. Note that the shaft is machined. The pulley and the cranks are fixed to the shaft with sled runner type of keys.

   Hint: Note that the magnitude of reaction forces acting on the shaft is a function of the crank angle. You may design the shaft as if the loadings on the shaft changes between 0 and the value corresponding to the maximum torque case (Figure 1). In reality, for the critical locations, you need to plot the bending moment with respect to the crank angle and angular position of the shaft and determine the critical point (crank angle and angular position) from the 3D plot. At the maximum torque position: $\theta_{15}=300^0$, $\theta_{16}= 170^0$, $\theta_{17}=190^0$ $\theta_{19}=275^0$ and $\theta_{18}= 190^0$
   For the maximum torque position, **the moment of the total rock force about point F is 100 kNm.**

C. Rod Design (BD)

The cross section of the connecting link is hollow-square and the ratio of a side on the outer perimeter to the thickness is given in the data sets. Design the connecting rod by considering buckling and maximum normal stress theory.

D. Pin Design (Pin B)

1. Determine the diameter of the pin B and specify an appropriate fit for the pin. Design the pin for static case. Use maximum shear stress theory.

E. Find the size of the welds between the crusher and the bracket considering fatigue loading.

F. Make an engineering drawing of the following parts

1. The Shaft
2. Pin B
3. Details of the weld section

The technical drawings should

- be prepared using CAD tools and be scaled.
- contain the tolerances in the pin design.

While preparing the report, follow the rules given in the course website.

Surname, Name :

Table 1- Data Sets

Materials (Steel HR)	Set 1	Set 2	Set 3	Set 4	Set 5
Material of the shaft	1040	1040	1040	1040	1040
Material of the links	1035	1035	1035	1035	1035
Material of the pin B	1050	1050	1050	1050	1050
Material of the brackets	1035	1035	1035	1035	1035
Geometric Parameters	Set 1	Set 2	Set 3	Set 4	Set 5
a_1 (mm)	1000	1050	1100	1075	1025
h_1 (mm)	500	475	490	450	525
d_3 (mm)	800	810	820	790	800
a_5 (mm)	150	150	150	150	150
a_6 (mm)	1500	1500	1500	1500	1500
a_7 (mm)	500	500	500	500	500
a_8 (mm)	500	500	500	500	500
a_9 (mm)	1000	1000	1000	1000	1000
$\lvert BG \rvert$ (mm)	200	200	200	200	200
$\lvert GC \rvert$ (mm)	200	200	200	200	200
L_1 (mm)	240	250	240	230	240
L_2 (mm)	550	560	550	540	550
L_3(mm)	860	870	860	850	860
L_4 (mm)	55	60	50	55	50
L_5 (mm)	40	40	40	40	40
L_6(mm)	200	190	180	210	200
L_{1x} (mm)	75	75	75	75	75
L_{1y} (mm)	$75\sqrt{3}$	$75\sqrt{3}$	$75\sqrt{3}$	$75\sqrt{3}$	$75\sqrt{3}$
r / d of fillets on the shaft	0.15	0.15	0.15	0.15	0.15
d_2 / d_1	1.1	1.1	1.1	1.1	1.1
α (degree)	15	15	15	15	15
Design Specifications	Set 1	Set 2	Set 3	Set 4	Set 5
Speed ratio of the pulley and the electric motor	16	16	16	16	16
Factor of safety	2	2	2	2	2
Reliability	0.95	0.95	0.95	0.95	0.95
Ambient temperature (°C)	25	25	25	25	25
Coefficient of friction between the belt and the pulley	0.30	0.30	0.30	0.30	0.30
Side to thickness ratio in the rocker (Link BD)	4	4	4	4	4