**DEPARTMENT OF MECHANICAL ENGINEERING**

**ME 643** **Machine Design** **Spring 2017**

## 1. Introduction

The purpose of this project is to design a “quick-return mechanism” (QRM), starting from the equations of Mechanics and ending into a functioning prototype. QRMs are very popular with a specific type of metal-cutting machine tool termed “shaper” (Fig. 1). These machines are the equivalent of a tractor plowing a field: they would linearly displace a cutting tool relative to a metal block, thus removing material from the surface in the form of chips. At the end of each stroke the tool retracts, the metal block advances laterally to expose new material to be cut and the cycle repeats. Since no profit is gained while the tool is being retracted, the time of that motion should be minimized. On the other hand, a certain speed needs to be kept while the tool is advancing and cutting metal (otherwise the surface finish is bad and the tool life uneconomical). The simplest way to achieve different velocities in forward and reverse while being powered by a standard, “constant” rpm electric motor is to use the QRM.


Figure 1. A metal shaper.

## 2. What you will do

The project is structured around 3 deliverables.

**a) Kinematic and dynamic analysis of the mechanism**:
Using the geometry given in Fig. 2 calculate the positions, velocities and accelerations of each member of the mechanism. After the kinematic analysis, perform a dynamic analysis; determine the free body diagrams (FBDs) of each member; determine the internal forces

and moments; and the forces at the connections between the members (see below for more details on what to deliver). These will be used in the detailed component design that follows in b).

**b) Stress analysis of the components and detailed design**:
With the loads fully determined, you can design the members and the connectors of the mechanism in detail. All components will be made out of P 400 ABS plastic, which is the material you will use in the Rapid Prototyping in c). More information on this will become available later.

**c) Manufacturing, assembly, and testing of the mechanism**:
With the component design fully completed, you can make the parts you designed in the RP machine in S211, assemble them, and then test-run the mechanism. You will be provided with the frame, motor, piston and spring. More information on that will be forthcoming later in the semester.

## 3. Deliverables

You will form and work in groups of 5 students. Your grade will be partly common with the other team members and partly individual. The members of a team need to identify a leader, who will be the contact point with the instructor and the TAs. By **Wednesday, March 8th** you should email the names of the team leader and the names of team members to both the instructor and TAs.

**1st deliverable (due Wednesday, March 29th by 5pm)**:
Turn in a hard copy of your report and email an electronic one to the instructor and the TAs. Append your code at the end of the file. The name of the file should be TeamLeaderName_1stdeliverable. docx/pdf.

Your report should include the following:
a) Your calculations.
b) Graph 1: the trajectories (paths) of points A, B and C (the x-position vs. the y-position for each of these points). Plot all points in the same graph.
c) Graph 2: the x-position of point C plotted from $0^o$ to $360^o$ of the crank angle. Note, $0^o$ is an arbitrary position that you will adopt.
d) Graph 3: the x-component of the linear velocity of point C plotted from $0^o$ to $360^o$ of the crank angle.
e) Graph 4: the magnitude of the linear acceleration of the centers of mass of members 2 ($A_oA$), 4 (BC), 5 ($B_oB$), and 6 (C) plotted from $0^o$ to $360^o$ of the crank angle.
f) Graph 5: the forces (magnitude) in joints $A_o$, A, $B_o$, B, and C plotted from $0^o$ to $360^o$ of the crank angle.
g) The FBDs of 2, 3 (joint between 2 and 4), 4, 5 and 6 (all separately) at an arbitrary crank angle.

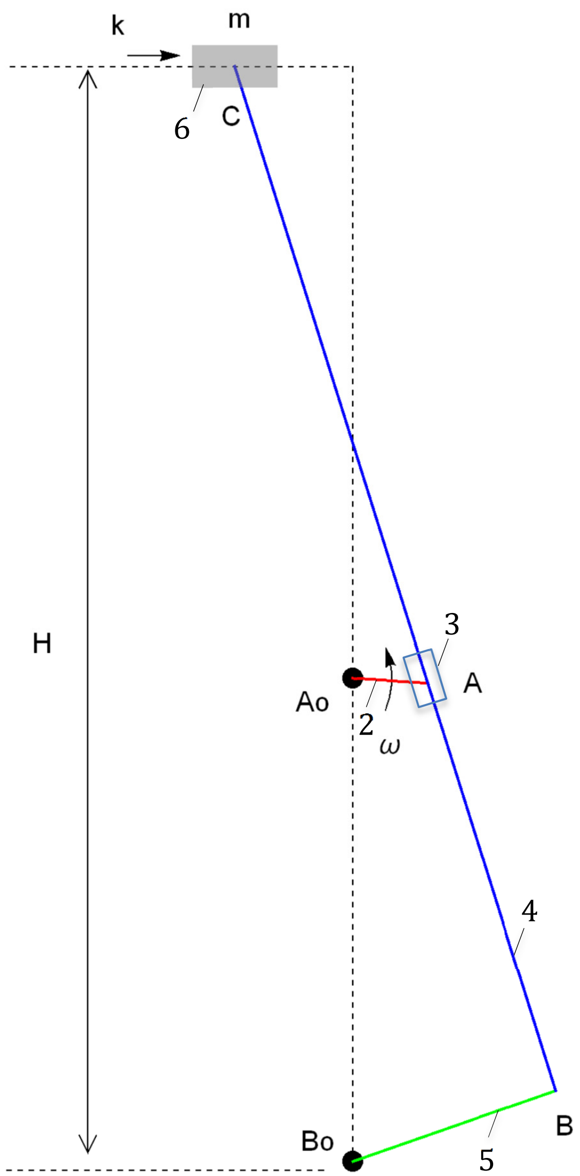
h) Graphs 6-8: 3D plots of the axial force on members 2, 4 and 5. The axis should be "member length"-"crank angle [from 0 to 2π or from $0^o$ to $360^o$]"-"axial force". Identify the location of maximum and minimum of the quantity per member. Note that the location is the same material point undergoing the identified minimum and maximum in every crank angle revolution.

i) Graphs 9-11: 3D plots of the shear force on members 2, 4 and 5. The axis should be "member length"-"crank angle [from 0 to 2π or from $0^o$ to $360^o$]"-"shear force". Identify the location of maximum and minimum of the quantity per member. Note that the location is the same material point undergoing the identified minimum and maximum in every crank angle revolution.

j) Graphs 12-14: 3D plots of the internal bending moment on members 2,4 and 5. The axis should be "member length"-"crank angle [from 0 to 2π or from $0^o$ to $360^o$]"-"internal bending moment". Identify the location of maximum and minimum of the quantity per member. Note that the location is the same material point undergoing the identified minimum and maximum in every crank angle revolution.

Make sure that each plot is appropriately titled, the axes appropriately labeled and the different lines appropriately identified. <u>One axes should be from 0 to 2π (or from 0° to 360°) exactly (e.g., not 0° to 400° etc)</u>. If you have no access to a color printer, use different types of lines to help distinguish between the different curves.

ABS P400 properties: Modulus of Elasticity $E$ = 1586 MPa, Yield Strength $\sigma_y$ = 17MPa, Ultimate Strength $\sigma_{UTS}$ = 21 MPa, Density 1040 kg/m$^3$, S-N curve will be uploaded on myCourses.




$A_0A = 7$ mm
$B_0B = 20$ mm
$BC = 100$ mm
$A_0B_0 = 45$ mm
$H = 102$ mm

$\omega = 1$ rpm
$m = 0.45$ kg
$k = 175$ N/m
$\rho = 1070$ kg/m$^3$

Spring is to the left from point C. Note, it is always compressed during the operation of the mechanism. The spring force acts horizontally to the right, and it depends on the spring constant, $k$, and the distance from C to the point in line with $A_0$ and $B_0$ (vertical dashed line, $r_y$) or when $r_x = 0$. The spring is unstressed when C is directly above $A_0$ and $B_0$ or when $r_x = 0$.

Figure 2. Mechanism and definition of variables.