DEPARTMENT OF MECHANICAL ENGINEERING

ME 643 **Machine Design** **Spring 2016**

Project 1

1. Introduction

The **internal combustion engine** has been a dominant device for converting the chemical energy of a fuel to mechanical work, especially in the transportation sector. In its history of over 100 years, numerous concepts have been proposed and implemented. In most of them, the linear, reciprocating motion of a piston is converted into the rotational motion of a shaft through a suitable **kinematic mechanism**. This mechanism is usually the slider-crank – which you should have examined in detail in your Dynamics course. However, the need to increase the performance of an engine, including its fuel efficiency, and to reduce the overall weight/volume, have brought numerous other concepts to the forefront. Many of these involve the idea an Opposed Piston Engine.

We will be studying the kinematic mechanism of one such concept, which has been implemented in the past: the **Tilling-Stephens TS3** engine that was used in Commer trucks and other commercial vehicles. The formal classification of this engine is “two stroke, folded crankshaft, three cylinder, opposed piston diesel”. Schematics of this engine are given in **Figures 1 and 2**. For the purposes of this project, we will only examine the basic kinematic mechanism of the engine, given in **Figure 3**. The gas pressure in the real engine will be replaced here with a spring.

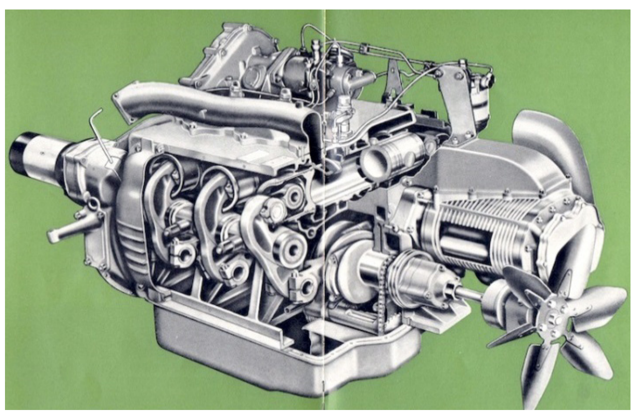

Figure 1: The TS3 opposed piston engine

2. What you will do

The project is structured around 3 deliverables:

a) Kinematic and dynamic analysis of the mechanism

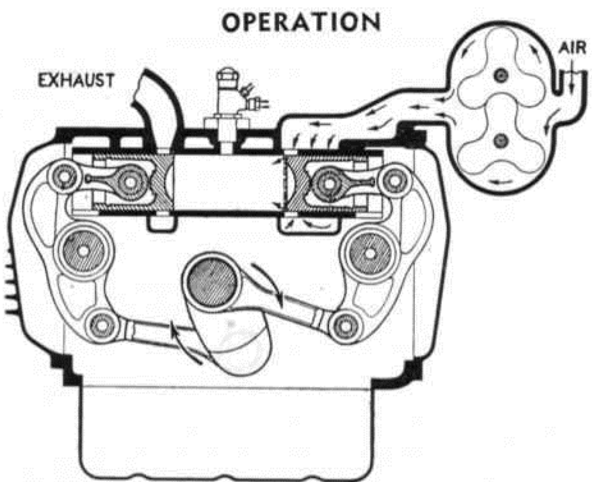

Figure 2: Cross-section of the TS3 engine

Using the geometry given and the angular velocity of the crank, 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 of each member, as well as the forces at the connections between the members. These will be used in the detailed component design that follows.

b) Stress analysis of the components and detailed design

With the FBDs and the member-to-member forces 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 TA. By **Wednesday, March 9** you should email the names of the team leader, his/her e-mail, and the names of team members to both the instructor and TAs.

1st deliverable (due on Friday, April 1 by 5pm):

Turn in a hard copy of your report and email an electronic copy to the instructor and the TAs. Your report should include the following:

a) Your calculations.

b) Graph 1: the trajectories (paths) of points A, B, D and E. You can do this by plotting 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 A and x position of point E, plotted from 0^o to 360^o of the crank angle, θ.

d) Graph 3: the x component of the linear velocities of points A and E, plotted from 0^o to 360^o of the crank angle, θ.

e) Graph 4: the x component of the linear accelerations of points A and E, plotted from 0^o to 360^o of the crank angle, θ and the magnitude of the linear acceleration of the centers of mass of members 1, 2, 3, and 4 plotted from 0^o to 360^o of the crank angle θ.

f) Graph 5: the forces (magnitude) in joints O, A, B, C, D and E plotted from 0^o to 360^o of the crank angle θ.

g) Free Body Diagrams of members 1,2,3,4 and 5 at an arbitrary crank angle θ. The spring constant is 1 lbf/in.

h) Graphs 6-9: 3D plots of the axial force on members 1, 2, 3 and 4. The axis should be "member length"-"crank angle θ" (from 0^o to 360^o)-"axial force". Identify the maximum and minimum force per member at a critical location.

i) Graphs 10-13: 3D plots of the shear force on members 1, 2, 3 and 4. The axis should be "member length"-"crank angle θ" (from 0^o to 360^o)-"shear force". Identify the maximum and minimum force per member at a critical location.

j) Graphs 14-17: 3D plots of the internal bending moment on members 1, 2, 3 and 4. The axis should be "member length"-"crank angle θ" (from 0^o to 360^o)-"internal bending moment". Identify the maximum and minimum moment per member at a critical location.

k) Comments on your results.

The zero stroke position (member 5 all the way to the right), Sxstart = 2.5 inch. Note that at this point the spring is preloaded to 0.5 inch.

ABS P400 properties: Modulus of Elasticity (E) = 230,000 psi, Yield Strength σy = 2,500 psi (17MPa), Ultimate Strength σ_{UTS} = 3000 psi (21MPa), Density 0.0376 lb/in^3 (1040 kg/m^3), S-N curve uploaded on Blackboard.

Make sure that each plot is appropriately titled, the axes appropriately labeled and the different lines appropriately identified. <u>The horizontal axes should be from 0 to 360 degrees 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.

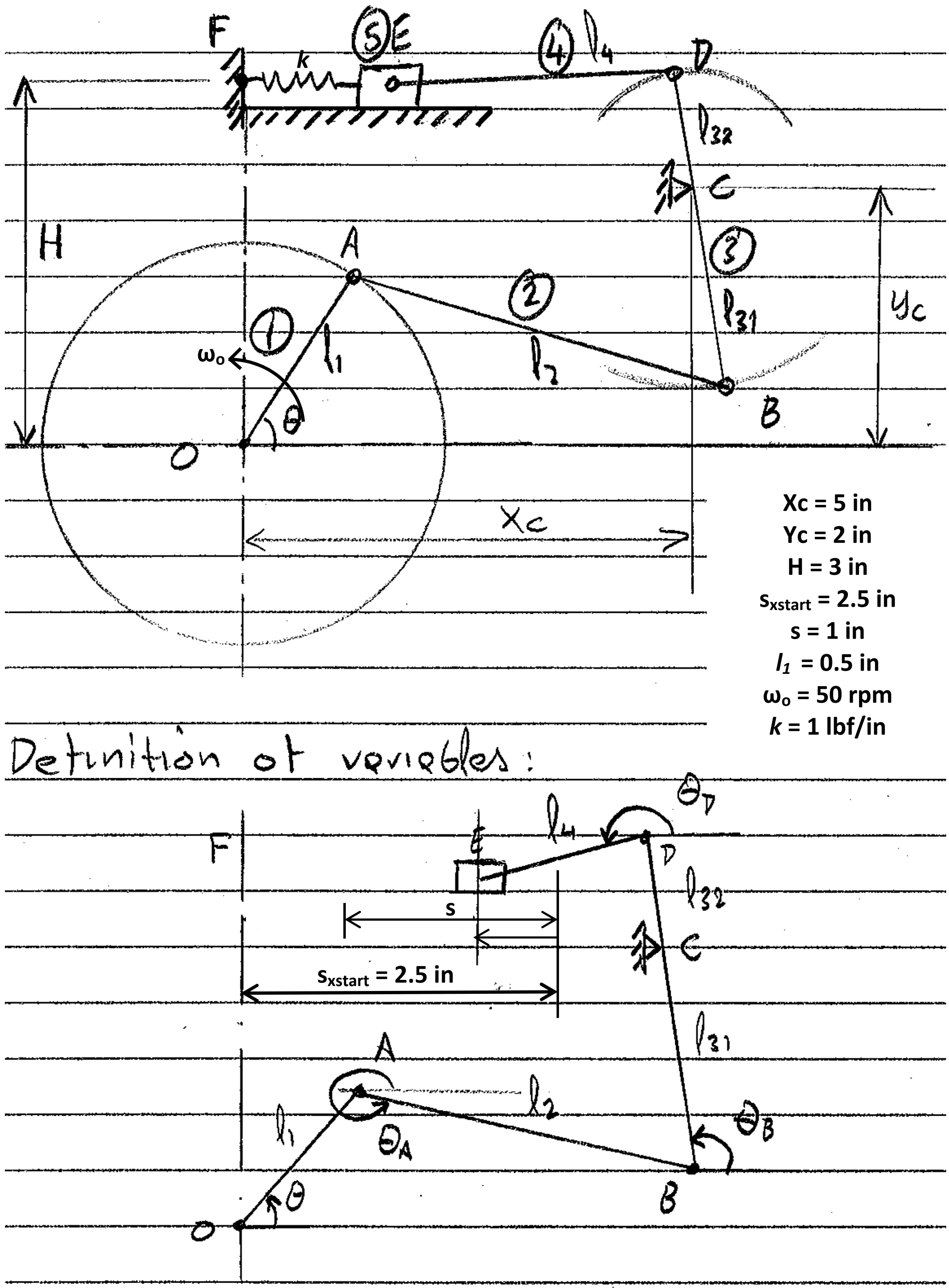

Figure 3: Kinematic mechanism under study and definition of variables