Optimum Design Spring 2016
Homework # 3

Cutter (Bench Shear) Design Notes - Mechanical Advantage Calculation

Background

A hand operated cutter is used to manually cut thin metal or plastic strip. The cutter shown in Figure 1 is a four bar mechanism that provides enough mechanical advantage (MA) to slice through mild steel up to 0.25 in thick.

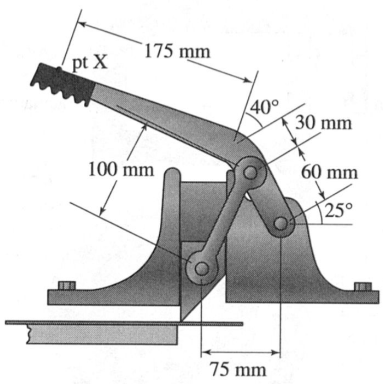

Figure 1: The bench shear to be optimized. Default dimensions are annotated.

Mechanical Advantage Calculation

A designer has many design choices for implementing this cutter, such as link lengths, pivot locations, the cutter's offset, etc. In the design of the bench shear (Figure 2) we would like to choose link lengths and pivot locations that result in the best MA possible, given space constraints.

The objective function we will use to evaluate design alternatives is the MA of the tool, the higher the better. However, the MA of the tool changes throughout its duty cycle, as the the angle of the input link (link 2) changes. For example, a design might only reach a high MA value of 7 at an time instant, but keep the MA low for most of its duty cycle. Another design might have a MA that varies between from 4.9 to 5.0 throughout its duty cycle. The later design would be preferred.

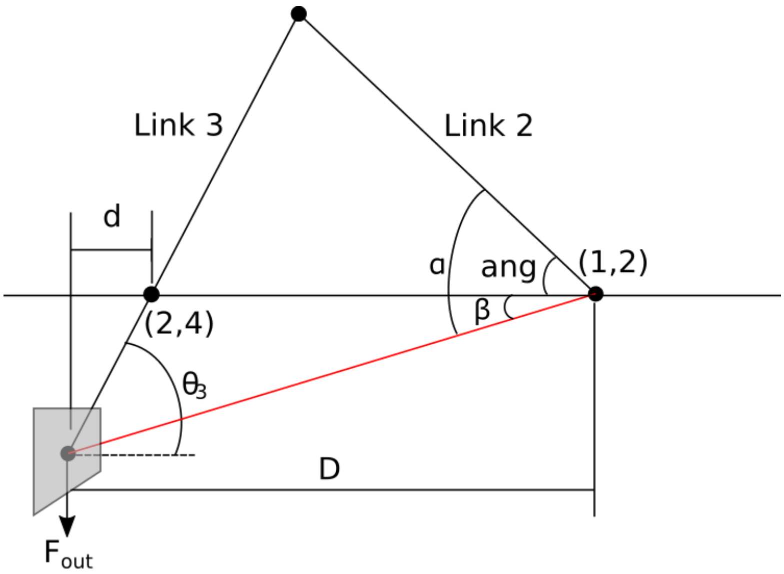

Figure 2: Skeleton diagram for the bench shear

In this homework assignment, we will optimize both the MA and the average MA of the cutter as separated tasks. The MA calculation is provided below.

From the Law of Conservation of Energy

$$Power_{in} = Power_{out} \tag{1}$$

$$F_{in} \cdot r_{in} \cdot \omega_{in} = F_{out} \cdot V_{out} \tag{2}$$

$$MA \equiv \frac{F_{out}}{F_{in}} = \frac{r_{in} \cdot \omega_{in}}{V_{out}} = r_{in} \cdot \frac{\omega_2}{V_o} \tag{3}$$

Method of instant center - Determining ω_2 and V_o

$$\omega_2 \times \overline{(1,2-2,4)} = V_o = \omega_4 \times \overline{(1,4-2,4)} \tag{4}$$

$$V_o = \omega_2 \times \overline{(1,2-2,4)} \tag{5}$$

$$MA = r_{IN} \times \frac{\omega_2}{\omega_2 \times \overline{(1,2-2,4)}} = \frac{r_{in}}{\overline{(1,2-2,4)}} \tag{6}$$

From Figure 2, we see that

$$\overline{(1,2-2,4)} = D - d \tag{7}$$

And

$$tan\theta_3 = \frac{y}{d} \tag{8}$$

Substituting eqn. (7) and eqn. (8) into eqn. (6), we obtain that

$$MA = r_{in} \times \frac{1}{D - \frac{y}{\tan\theta_3}} \tag{9}$$

Next, we determine r_{in} . The handle of the cutter (Figure 1), which is link 2 in Figure 2, is shown below.

$$r_{in} = 90\ cos\ 40^{0} + 175 = 243.94\ mm \tag{10}$$

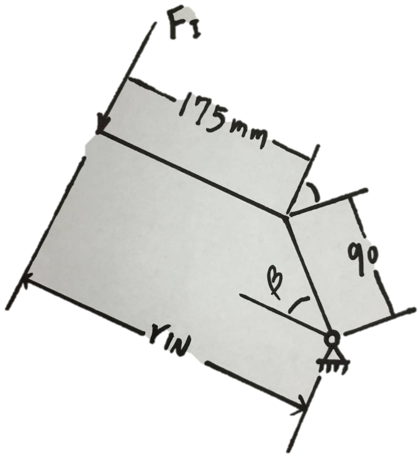

Figure 3: The handle of the cutter with default dimensions

It should be noted that, although Eqn. (10) shows that r_{in} is fixed, the length of link 2 can still vary from 50 to 100 mm depending on which hole position is used (Figure 4).

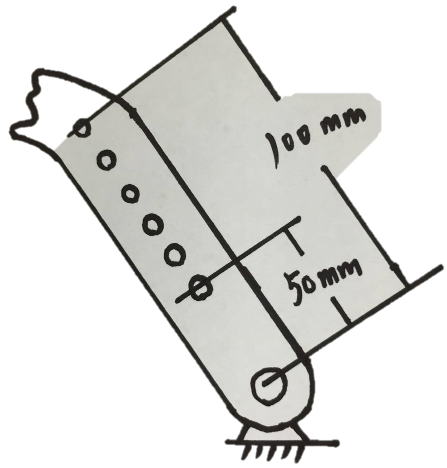

Figure 4: The length of link 2 can be adjusted by drilling a hole at different positions.