AE 340 Laboratory 8, Hay and Forage (Not all topic yet covered in Lectures)

Question 11.1 A certain knife has a rake angle of 85˚ and a clearance angle of 2˚. Calculate (a) the bevel angle and (b) the chip angle of the knife.

Question 11.3 In Figure 11.8, the oblique angle of the sickle section is 30˚ when the forward velocity of the mower is zero, so that the velocity of the knife relative to the plants coincides with the velocity of the knife relative to the mower.
a) When the forward speed is 2.2 m/s, what knife velocity yields an oblique angle of zero?

Question 11.4 Refer to Figure 11.8. Consider a smooth sickle section with an oblique angle of 30˚, a coefficient of friction of 0.306, and a forward speed of the mower is zero (so that the velocity of the knife relative to the plants coincides with the velocity of the knife relative to the mower.
(a) Will the plant material slide along the edge when the knife moves toward the countershear?
(b) What is the minimum coefficient of edge friction that will prevent sliding?

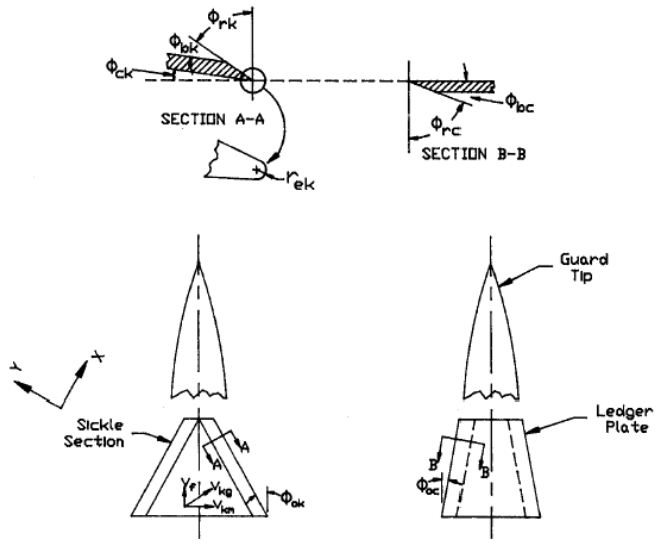

Figure 11.8 – Illustration of geometry of a knife and countershear.

Question 11.6 Assume an alfalfa plant with a stem diameter of 3 mm, stem modulus of elasticity of 1,800 N/mm2, and ultimate tensile strength of 35 N/mm^2 is being cut at a height of 60 mm above the ground, i.e., the plant roots fix the stem to the ground and the knife loads the stem as a cantilever beam. (a) How large must the knife force be to load the plant fibers to their ultimate stress? (b) How far would the stem deflect when the plant fibers reached their ultimate stress?

Question 11.8 Use Equations 11.10 and 11.11 to generate a curve of knife force versus knife displacement (ranging from 0 to 9 mm) during the cutting of forage. The knife width is 10 mm, the bevel angle is 20˚, the radius of the knife edge is 0.15 mm, and initial penetration occurs when the knife edge pressure on the forage reaches 20 N/mm2. The uncompressed depth of the forage is 9 mm, the bulk modulus is 10 N/mm2, and the coefficient of friction between forage and knife is 0.3. Assume the exponent $\lambda = 2$ in Equation 11.10.

Question 11.10 A forage harvester with 8 knives on the cutterhead rotates at 900 rpm. The depth of forage at initial contact of the knife is 150 mm and the maximum cutting force is 8 kN. Estimate the power required for cutting (Equation 11.12).

Question 11.12(modified) Use Equation 11.16 to study the effect of stem diameter on the theoretical minimum velocity required for impact cutting. Assume the radius of gyration of the cut portion of the plant equals the height of the center of gravity of the cut plant to simplify the equation. Use Equation 11.6 to calculate the bending resistance of the solid (not hollow) stem, assuming that the roots fix the stem as a cantilever beam which is struck by the knife at a distance 100 mm above the soil and the ultimate bending strength of the stem is 50 N/mm^2. Use Equations 11.10 and 11.11 to estimate the knife force. Let the knife width, the uncompressed depth of material, and the total knife displacement all be equal to the stem diameter; assume the exponent $\lambda = 2$, forage bulk modulus is 10 N/mm^2, the coefficient of forage on the knife is 0.25, and the bevel angle of the knife edge is 20˚. Also, assume that the edge radius of the knife is 0.1 mm (a sharp knife) and the pressure ahead of the knife edge is 30 N/mm^2 to initiate cutting. Finally, note that the mass, m_p, will vary with stem diameter, i.e., more massive plants must have larger stems to support gravitational and wind loads on the plant.
Assume that $m_p = (5.10^{-6})d^4$, where d is the stem diameter in millimeters and m_p is the plant mass in kilograms. Calculate the required knife velocity versus stem diameter for diameters from 1, 5 and 20 mm.

Question 11.26 (modified) A flail mower has a total of four rows of flails but, because of offsetting the flails as in Figure 11.21b, there are effectively only two rows from the standpoint of stubble uniformity. The rotor radius is 250 mm.
(a) Calculate the ratio of stubble height difference over rotor radius (zd/rf) versus velocity ratio (vf/vp) for the following velocity ratios 0.025, 0.05, 0.1.
(b) Calculate similar values for a six-row rotor with offset flails.
What is the maximum stubble height difference for the
(c) four-row rotor and
(d) six-row rotor?

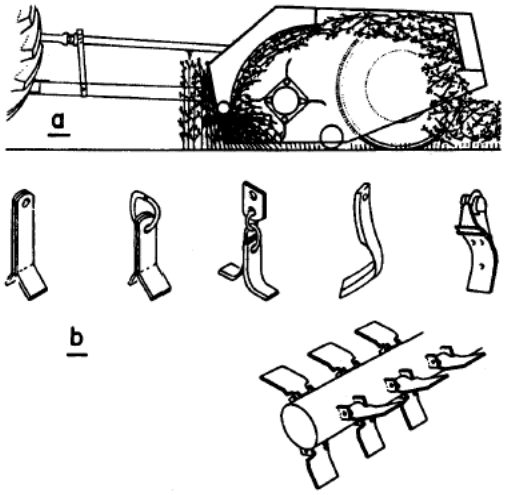

Figure 11.21 – A flail mower, showing (a) side view and (b) flail detail (reprinted from Persson, 1987).

Question 11.32 Consider a disk-type rotary mower that has six disks, each cutting a 0.4 m width; the mower is traveling at 15 km/h. Stating other assumptions:
(a) Estimate the PTO power requirement if the blades are sharp.
(b) Estimate the PTO power requirements for the same mower after the blades become worn.

From: Srivastava, Ajit K., Carroll E. Goering, Roger P. Rohrbach, and Dennis R. Buckmaster. 2006. (rev.) Hay and forage harvesting. Chapter 11 in Engineering Principles of Agricultural Machines, 2nd ed., 325-402. St. Joseph, Michigan: ASABE.

Question 11.34 A forage harvester has a cylindrical cutterhead 600 mm in width and 700 mm in diameter. It has 8 knives and rotates at 900 rpm. It is to harvest corn at a feed rate of 65 Mg/h while producing an average length of cut of 5 mm. The specific cutting energy can be held to 14 J m/kg when the knives are sharp. The forage is in contact with the housing for 2.36 radians of arc and the coefficient of friction between the corn and the steel housing is 0.49. Crop density between the feed rolls is 300 kg/m3. Calculate

(a) the required peripheral speed of the feed rolls,
(b) the maximum height of the throat area,
and the PTO power requirements for
(c) chopping,
(d) friction,
(e) impelling (assume the impeller peripheral velocity equals that of the chopper),
(f) moving air, and
(g) the total power requirement.
(h) For comparison, calculate the total PTO power requirement using Equation 11.42.