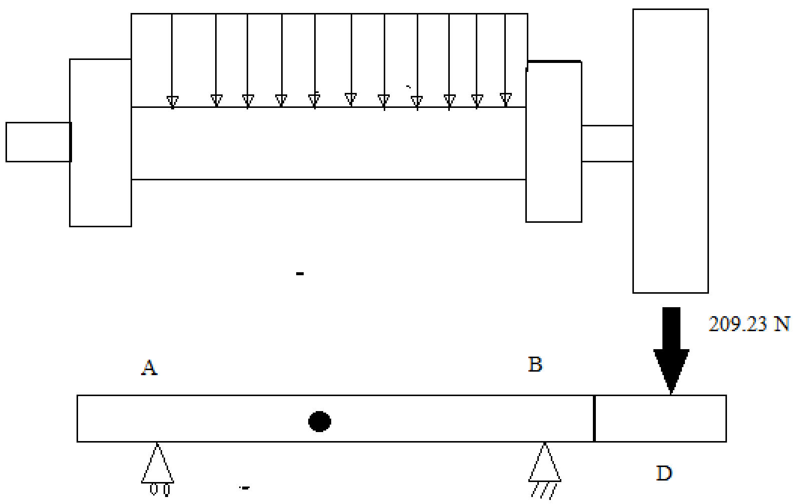
3.6 Calculations

3.6.1 Calculating Torque, shear force and diameter of the shaft

The free body diagram of the shaft of shredder is shown below.



The shear forces and shaft diameter are calculated as follows;

$$A = \frac{B\ \times H}{2}$$

$$A = \frac{9.993\ \times 7.32}{2}$$

$$A = 36.6 \text{ mm } 2$$

Shear force to shred plastic (Fsh):

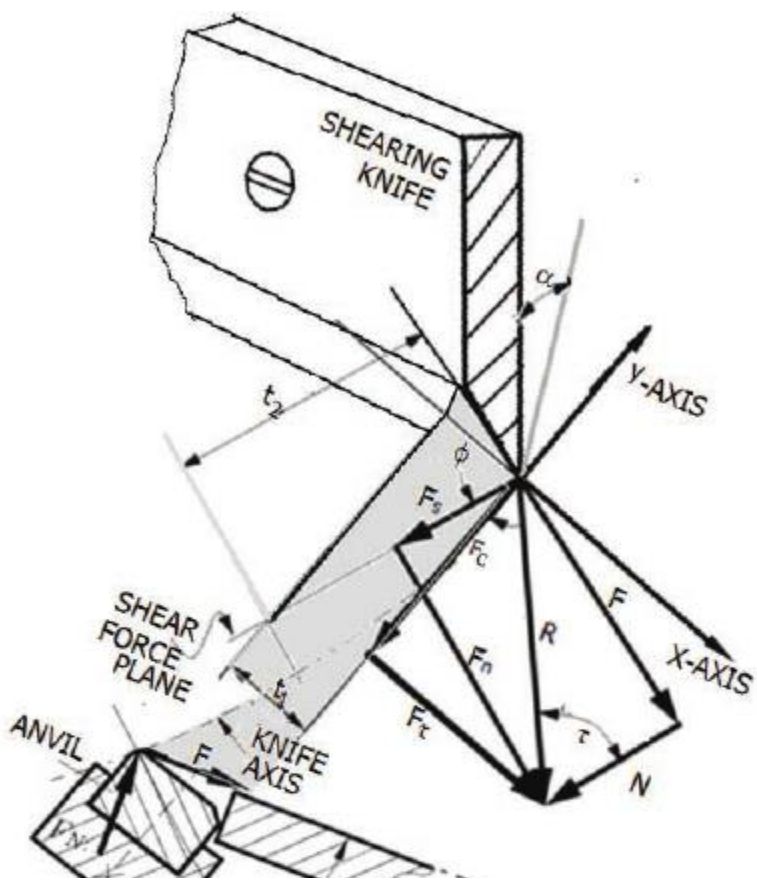


Figure 1Figure 11: Knife cutting forces and chipping diagram (Bello & Onilude, 2011)

Sut (PET plastic) = 55 MPa (Mathweb, n.d.)

$Sus = 0.577 \times Sut$

$Sus = 0.577 \times 55$

Sus = 31.73 MPa

Assume F.O.S = 2

$\zeta = \frac{Fsh}{SA} = \frac{Sus}{F.O.S}$

$\frac{Fsh}{36.6} = \frac{31.73}{2}$

$Fsh = 580.66\ N$

Cutting Force (Fc)

Sy = 80 Mpa (Warlimont H. , Martienssen, 2005)

$\delta = \frac{Fc}{Ac} = \frac{Sy}{F.O.S}$

$\frac{Fc}{36.6} = \frac{80}{2}$

$Fc = 1464\ N$

Torque:

$Tsh = Fsh \times radius$

$Tsh = 580.66 \times 80.09 \times 10 - 3$

$Tsh = 46.5\ N.m$

Total Torque

$Ttotal = Tsh \times 2$

$Ttotal = 93.01\ N.m$

Power at shaft

$Power = Tsh \times Wsh$

$Assume\ Nsh = 200\ r.p.m\ (human\ work)$

$$Wsh = \frac{2 \times \pi \times 200}{60}$$

$Wsh = 20.94\ rad/s$

Maximum Torque

$Tmax = 400 \times 0.14$

$Tmax = 56\ N.m$

$\Sigma Fy = 0$

$Ra + Rb = (2.658 \times 6 \times 9.81) + (0.098 \times 5 \times 9.81) + (1.1 \times 4 \times 9.81)$

$Ra + Rb = 209.23\ N$

$\Sigma Ma = 0.0$

$209.23 \times 326.5 - Rb \times 200.17 = 0$

$Rb = 341.28\ N$

$Ra = -132.05\ N$

Moment at point C

$Mc = 132.05 \times 200.17 = 26.43\ N.m$

Moment at point B

$Mb = 341.28 \times 76.5 = 26.11\ N.m$

Since thermoplastics are elastic thus cutting is preferred over shearing.

$$d^3 = \frac{1}{\pi}\sqrt{(K \times Mb)^2 + (K \times Mc)^2}$$

Kt = 2.0

Kb = 2.0

$d = 35\ mm$

$take\ d = 40\ mm$

Ccording to the objective applied force should be equal to 400 N (maximum force exerted by a human.

To convert torque, the force in multiplied with lever's length which is 0.4 m

400 x 0.14 = 56 N m

Converting Nm into pound force m

56 N.m = 12.5893 lb force m