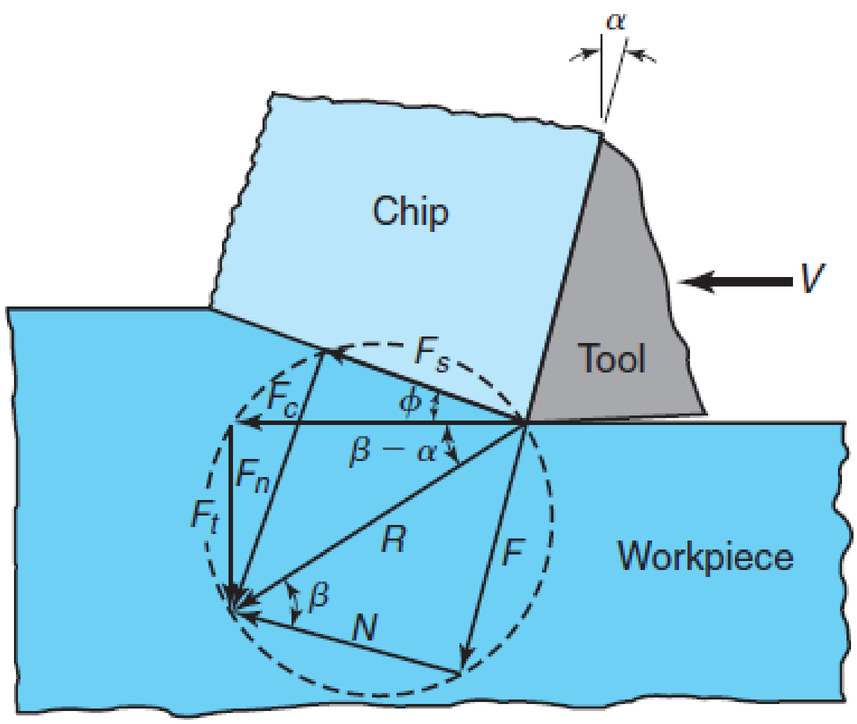
A shaper tool making orthogonal cutting, has a 10 degrees rake angle. The feed rate= 0.2 mm/rev, the depth of cut is 2 mm. The cutting speed is 100 m/min. The main cutting force is 3600 N and the feed (thrust) force is 2400 N. The shear angle is 35 degrees.

i. Draw the Merchant diagram [15 pt]

Note, the word "draw" implies that this must be done to scale (suggestion, use scale of 2 cm: 1,000 N). The lengths of the forces in the diagram should be used to verify the actual values of the forces.



ii. Calculate, [25 pt]

(a) the coefficient of friction.

$$\tan(\beta - \alpha) = \frac{F_t}{F_c} = \frac{2400\ N}{3600\ N} = 0.6667$$
$$\beta - 10° = \tan^{-1} 0.6667 = 33.69$$
$$\beta = 10 + 33.69 = 43.69°$$

$\boldsymbol{\mu} = \tan\beta = \tan 43.69° = \mathbf{0.96}$

(b) the shear stresses on the shear plane

$$\tau_s = \frac{F_s \sin\emptyset}{t_0 w}$$

$$F_s = F_c \cos\emptyset - F_t \sin\emptyset$$

$$= (3600)(\cos 35) - (2400)(\sin 35) = 1572.36\ N$$

$$\boldsymbol{\tau_s} = \frac{F_s \sin\emptyset}{t_0 w} = \frac{(1572.36\ N)(\sin 35)}{(2\ mm)(0.2\ mm)} = \mathbf{2255} \frac{\boldsymbol{N}}{\boldsymbol{mm^2}}$$

Note how we used w to mean and t_0 to mean

(c) the normal stress on the rake face

$$\sigma = \frac{N}{t_c w}$$

We need to find both N and t_c

$$\frac{t_0}{t_c} = \frac{\sin\emptyset}{\cos(\emptyset - \alpha)}$$

$$t_c = \frac{\cos(\emptyset - \alpha)}{\sin\emptyset} t_0 = \frac{\cos(35° - 10°)}{\sin 35°}(2\ mm) = 3.160\ mm$$

Now, consider the R-N-F triangle:

$$N = R\cos\beta = \sqrt{{F_c}^2 + {F_t}^2} * \cos\beta = \sqrt{3600^2 + 2400^2} * \cos 43.69°$$

$$= 4326.66 * 0.7231 = 3128.55\ N$$

$$\boldsymbol{\sigma} = \frac{N}{t_c w} = \frac{3128.55\ N}{(3.160\ mm)(0.2\ mm)} = \mathbf{4950}\ \frac{\boldsymbol{N}}{\boldsymbol{mm^2}}$$

(d) the friction power

$Power\ for\ friction = U_f = FV_c$

We need to find both F and V_c

Consider again the R-N-F triangle:

$F = R\sin\beta = 4326.66 * \sin 43.69° = 4326.66 * 0.6908 = 2988.67\ N$

$$\frac{V}{\cos(\emptyset - \alpha)} = \frac{V_c}{\sin\emptyset}$$

$$V_c = \frac{\sin\emptyset}{\cos(\emptyset - \alpha)}V = \frac{\sin 35°}{\cos(35° - 10°)}(100\ m/min) = 63.29\ m/min$$

$$\boldsymbol{U_f} = FV_c = (2988.67\ N)(63.29\ m/min) = 189{,}145\ N \cdot \frac{m}{min} = \mathbf{3.15\ kW}$$

(e) the shearing power

$Power\ for\ shearing = U_s = F_sV_s$

We have F_s and we need to find V_s:

$$V_s = \frac{\cos\alpha}{\cos(\emptyset - \alpha)}V = \frac{\cos 10°}{\cos(35° - 10°)}(100\ m/min) = 108.66\ m/min$$

$$\boldsymbol{U_s} = F_sV_s = (1572.36\ N)(108.66\ m/min) = 170{,}855\ N \cdot \frac{m}{min}$$

$$= \mathbf{2.85\ kW}$$

(f) the machining power

$$\boldsymbol{Machining\ power} = U_t = F_cV = (3600\ N)\ (100\ m/min)$$

$$= 360{,}000\ N \cdot \frac{m}{min} = \mathbf{6.00\ kW}$$

Check Answer:

$U_t = U_f + U_s = 3.15\ kW + 2.85\ kw = 6.00\ kW$

(g) the specific cutting energy

$$\boldsymbol{u_t} = \frac{U_t}{wt_0V} = \frac{6.00\ kW}{(2\ mm)(0.2\ mm)(100\ m/min)}$$

$$= \frac{6{,}000\ W}{(2\ mm)(0.2\ mm)(100\ m/min)}\left(\frac{1\ m}{1000\ mm}\right)(60\ s/min)$$

$$= \mathbf{9.0\ W \cdot s/mm^3}$$

Note, compare this to the table showing specific energy requirements for different materials.