Kinematics and Dynamics of Machines

6. Flying Wheels

Introduction

- A Flying wheel is rotating mass which is used to save energy in machines and to regulate machine velocity.
- When the rotational velocity of the machine increases, the flying wheel saves some energy and when the rotational velocity of machine decreases, the flying wheel gives back some energy to the machine.
- Flying wheels are used in electricity generators, mechanical pressing devices, etc.
- Flying wheels can save a big amount of energy in a long period of time and return it in a short time. This enables designers to use smaller engines in many applications.

Coefficient of velocity changes

- Coefficient of velocity changes expresses the ratio of rotational velocity changes to mid-velocity of flying wheel:

$$C = \frac{\omega_1 - \omega_2}{\omega}$$

- The performance of flying wheels is evaluated with coefficient of velocity changes which for example should be something about 0.002 for electricity generators.
- The stresses resulted from centrifugal forces, limit the linear speed of outer ring of a flying wheel to some value about 30 m/s for cast iron or 40 m/s for steel wheels. Thus, coefficient of velocity changes is commonly expressed in terms of linear velocity of outer ring.

Lets consider a flying wheel with gyration radius R and mass m. For this flying wheel, the coefficient of velocity changes can be obtained as follows:

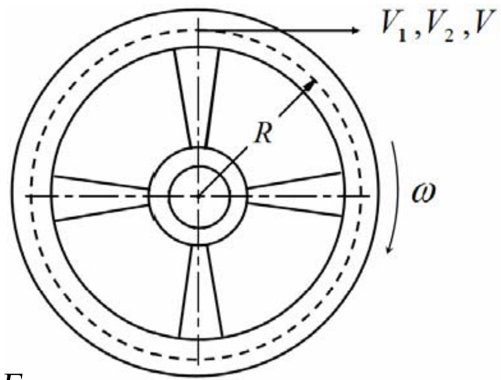
$$C = \frac{\omega_1 - \omega_2}{\omega} = \frac{V_1 - V_2}{V}$$

where

$$V = \frac{V_1 + V_2}{2}$$

Thus, one can get

$$m\,C\,V^2 = \frac{1}{2} m\left(V_1^2 - V_2^2\right) = \Delta E$$

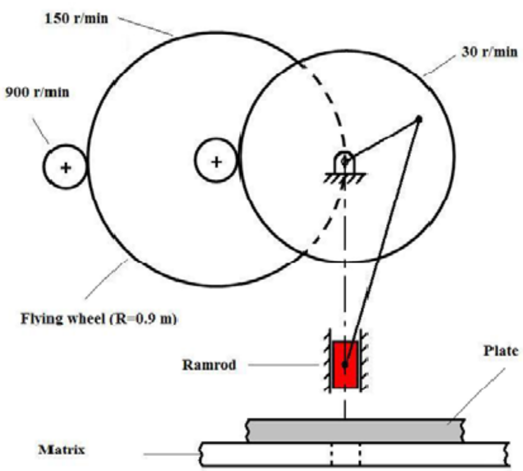


Example: A diagram of a mechanical press is showed in the below figure. The machine is used to cut out 30 holes per minute. Consider that each cutting consumes 1/3 sec. the diameter of each hole is 20 mm and the thickness of the plate is 13 mm. The plate is made of a class of steel with ultimate shearing stress 310 MPa. The electric motor rotates at 900 r/min and a reducer gearbox is used to produce appropriate speed. If the radius of outer ring is R=0.9 m,

a) calculate the energy required to cut out each hole

b) chose a suitable electric motor for the device.

c) Calculate the linear velocity on outer ring

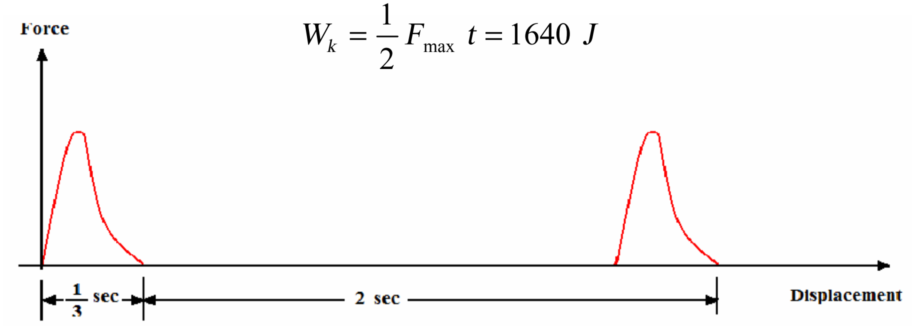


Maximum force required to cut the plate is equal to:

$$F_{\max} = 2\pi\, t\, \tau_u = 253{,}000\ N$$

The below figure illustrates a typical diagram of cutting force versus ramrod displacement. Approximating the force-displacement diagram with a rectangle for the cutting period, the required energy is:

$$W_k = \frac{1}{2} F_{\max}\ t = 1640\ J$$



Therefore, the average power needed to cutting operation is

$$P_{av} = \frac{W_k}{cutting\ \ time} = \frac{1640}{1/3} = 4920\ J, \qquad P_{av} = \frac{P_{\max}}{2}$$

If we use a flying wheel, the required cutting energy can be supplied during a machine cycle which is 2 sec. therefore the maximum power demanded for the electric motor is:

$$P_{\max} = \frac{1640}{2} = 840\ W$$

A part of required energy is supplied by electric motor during the cutting process, which is

$$W_1 = 840 \times \frac{1}{3} = 273\ J$$

The remaining part (1640-273=1367 J) must be provided by the flying wheel. The linear speed of flying wheel on its outer ring mid-radius is

$$V = 2\pi\, R\omega = 7.07\ m/s$$

Assuming the coefficient of velocity changes equal to 0.1, we get

$$m = \frac{E}{C\,V^2} = \frac{1367}{0.1(7.07)^2} = 273\ kg$$

In practice, the outer ring contains 90% of the wheel total mass.

From the basic equations, one can say

$$V_1 - V_2 = C\,V = 0.707\ m/s, \qquad V_1 + V_2 = 2\,V = 14.14\ m/s$$

Thus, the maximum and the minimum linear velocities on outer ring mid radius are

$$V_1 = 7.42\ m/s, \qquad V_2 = 6.72\ m/s$$

which do not exceed the velocity limits.