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Mini review

What is the Flywheel for

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Opinion

In industry and transport technology, the flywheel in most cases is a rotating body with significant main moment of inertia [kgm^2] compared to the other parts of the mechanical system.Its first analogue has been known since ancient times as pottery's wheel, wherethe sculptor of clay drives his work table directly with foot or by means of elementary crank mechanism Figure1. During the first industrial revolution about two hundred years ago, after the appearance of the steam engine, the flywheel was a vital element of it. Its initial purposewas to overcome the so-called dead positions, and subsequently it carried out the energy transfer within a period of the stationary (steady state) motion to ensure a certain degree of non-uniformity of the angular velocity of the main shaft of the machine.

Due to relatively low speeds of that time, the dimensions of the flywheels are significant, Figure 1. With increasing operating speeds, its dimensions are reduced remarkably. At present, in explicit form, as a separate machine element it exists in construction of almost every energy or technological machine–Internal Combustion Engines (ICE), piston pumps, compressors, presses, dies, pins, etc. In the sixties of the last century, the idea of using the kinetic energy when stopping the vehicle by accumulating it in a high-speed flywheel, called "super-flywheel" arose. One of the apologists for this idea is Prof. D. F. Rabenhorst from the "John Hopkins" University, USA, who created a research laboratory whose main activity is the research application of super-flywheels in vehicles technology and industry.[1–2] The conditional speed limit between classic and high-speed flywheels is 1000 [1/s] (10000 [tr/min])[3]. The first are usually monolithic, made of cast iron or steel, and practice has proven their safety from the ouint5 of view of risk assessment. The stresses generated by the centrifugal inertial field are far from the permissible ones for the respective material. Their predominant form is usually a disk, most often in combination with a clutch, recently they are rarely seen a ring with spokes and a[4]hub In industry and transport technology, the flywheel in most cases is a rotating body with significant main moment of inertia [kgm^2] compared to the other parts of the mechanical system. During the first industrial revolution about two hundred years ago, after the appearance of the steam engine, the flywheel was a vital element of it. Its initial purpose was to overcome the so-called dead positions, and subsequently it carried out the energy transfer within a period of the stationary (steady state) motion to ensure a certain degree of non-uniformity of the angular velocity of the main shaft of the machine.

Due to relatively low speeds of that time, the dimensions of the flywheels are significant, Figure 2. With increasing operating speeds, its dimensions are reduced remarkably. At present, in explicit form, as a separate machine element it exists in construction of almost every energy or technological machine – Internal Combustion Engines (ICE), piston pumps, compressors, presses, dies, pins, etc. Modern super-flywheels have the shape of a disk made of coiled threads or ribbons or a combination of these. The materials from which they are made are mainly composites of the type of C-phazer HT with an allowable tensile stress of 2370 [MN/ m^2], or C-phazer IMER–3450 [MN/m^2], or mostly a bundle of carbon threads in a polymer or graphite C–C matrix, with even higher additional stresses. It is relatively easy to prove that the ideal flywheel for energy storage should be light and made of material with great strength.[3–4] If we consider a thin toroidal thread, rotating with an angular velocity ω around its main axis of inertia, a one-dimensional stressed state (tensile) can be assumed with great confidence, which has the form:

$$\sigma_{\hat{\imath}\,\ddot{\imath}} = \rho \mathrm{v}^2, \tag{1}$$

where ρ [kg/m^3] is the density of the material, v [m/s] – peripheral linear velocity.

The main characteristic of the flywheels are:

specific energy capacity K_e of the thread represents the ratio of the accumulated energy to its mass, i.e.:

$$K_e = \frac{E}{m} = \frac{1}{2}\mathrm{v}^2 \text{ or } K_e = \frac{1}{2}\frac{\sigma_{\hat{\imath}\,\ddot{\imath}}}{\rho}, \tag{2}$$

which confirms the above statement, or in the case of a real flywheel K_e is directly proportional to $\sigma_{\hat{\imath}\,\ddot{\imath}}$ [N/m^2]and inversely proportional to ρ [kg/m^3] of the material

$$K_e \Rightarrow \frac{\sigma_{\hat{\imath}\,\ddot{\imath}}}{\rho}. \tag{3}$$

- energy density coefficient

$$K_p = \frac{E}{V}\left[\frac{\text{kJ}}{\text{m}^3}\right], \tag{4}$$

where E is the largest possible value of accumulated energy [kJ], V – flywheel volume [m^3];

– - the form factor K shows how efficiently the material is used, and for a flywheel with the equal speed shapethis coefficient is assumed to be unity [4];

– - speed coefficient

$$\xi = \frac{\omega}{\omega_0} , \quad (5)$$

where ω is the allowable angular speed of the flywheel, and the same speed of the toroidal thread for the same material, ω_0 – the same speed of the toroidal thread for the same material;

- coefficient of specific power

$$K_m = \frac{P}{m}\left[\frac{\mathrm{W}}{\mathrm{kg}}\right], \quad (6)$$

In industry and transport technology, the flywheel in most cases is a rotating body with significant main moment of inertia [kgm^2] compared to the other parts of the mechanical system.

Figure 1. Pottery wheel

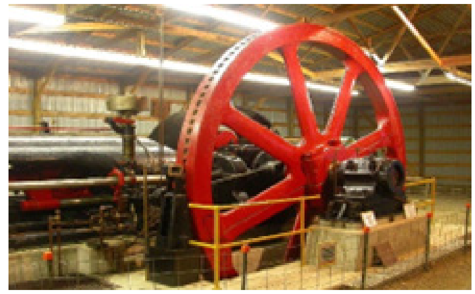

Figure 2. The flywheel of steam engine

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