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THE REDUCTION OF VIBRATIONS IN A CAR – THE PRINCIPLE OF PNEUMATIC DUAL MASS FLYWHEEL

Summary. The dual-mass flywheel replaces the classic flywheel in such way that it is divided into two masses (the primary mass and the secondary mass), which are jointed together by means of a flexible interconnection. This kind of the flywheel solution enables to change resonance areas of the engine with regard to the engine dynamic behaviour what leads to a reduction of vibrations consequently. However, there is also a disadvantage of the dual-mass flywheels. The disadvantage is its short-time durability. There was projected a new type of the dual-mass flywheel in the framework of our workplace in order to eliminate disadvantages of the present dual-mass flywheels, i.e. we projected the pneumatic dual-mass flywheel, taking into consideration our experiences obtained during investigation of vibrations.

Keywords: combustion engine, vibrations, pneumatic dual-mass flywheel.

WYELIMINOWANIE WIBRACJI SAMOCHODU – PODSTAWA PNEUMATYCZNEGO DWUMASOWEGO KOŁA ZAMACHOWEGO

Streszczenie. Dwumasowe koło zamachowe zastępuje klasyczne koło zamachowe w ten sposób, że jest podzielone na dwie masy (pierwotną i wtórną), które są ze sobą połączone w elastyczny sposób. Z punktu widzenia dynamiki taka konstrukcja koła zamachowego zapewnia zmianę rezonujących stref silnika, czego wynikiem będzie zmniejszenie wibracji. Dużą wadą dwumasowych kół zamachowych jest ich krótka trwałość. Na podstawie uzyskanych w naszej pracowni doświadczeń dotyczących wibracji w celu wyeliminowania wad obecnych kół dwumasowych zaprojektowaliśmy nowy typ dwumasowego koła zamachowego, którym jest pneumatyczne dwumasowe koło zamachowe.

Słowa kluczowe: silnik spalinowy, wibracje, pneumatyczne dwumasowe koło zamachowe.

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1. INTRODUCTION

Undoubtedly, reduction of vibrations of the car drive is a very actual topic. It is necessary to pay attention to vibrations from excitation components, that ensure from increasing of emissions in combustion engine. Vibrations like these have not had any impact on the car drive by now.

Mostly, it is result of accidental harmonic components, whose impact becomes more significant due to unstable running of combustion engine and interception of ignition of pistons. Concerning all these facts, as already mentioned above, they have a negative impact on running of the car drive. Resonance becomes evident by changing of vibration amplitudes and by increasing of level of noise as well.

In our dynamical analysis, the car drive, consisting of 3 main parts, specifically a combustion engine, a gear box and a car axle, can be replaced with a three-mass system Fig. 1.

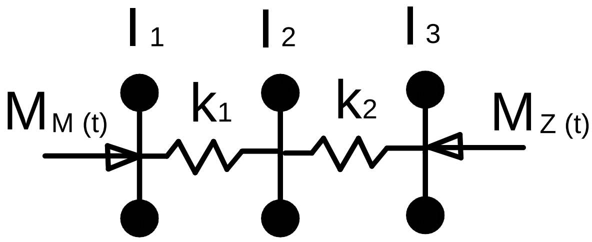

Fig. 1. Schematic model of torsionally oscillating mechanical system without damping
Rys. 1. Schematyczny model mechanicznego układu drgającego bez tłumienia

where:
φ_1, φ_2, – angle of twist,
I_1, I_2, I_3 – moment of inertia,
k_1, k_2 – torsional stiffness,
$M_M(t)$ – loading torque of combuston engine,
$M_Z(t)$ – loading torque of drive wheel.

In this case of solving three-mass system, we obtain two natural frequencies of the car drive formula (1).

$$\Omega_{12}{}^2 = \frac{k_1.\left(\frac{1}{I_1}+\frac{1}{I_2}\right)+k_2.\left(\frac{1}{I_2}+\frac{1}{I_3}\right)}{2} \pm \sqrt{\left(\frac{k_1.\left(\frac{1}{I_1}+\frac{1}{I_2}\right)+k_2.\left(\frac{1}{I_2}+\frac{1}{I_3}\right)}{2}\right)^2 - k_1.k_2.\frac{I_1+I_2+I_3}{I_1.I_2.I_3}} \qquad (1)$$

For even more detailed figure of arosen resonance of mechanical system, it is effectively to use a Campbell diagram Fig. 2. [1]

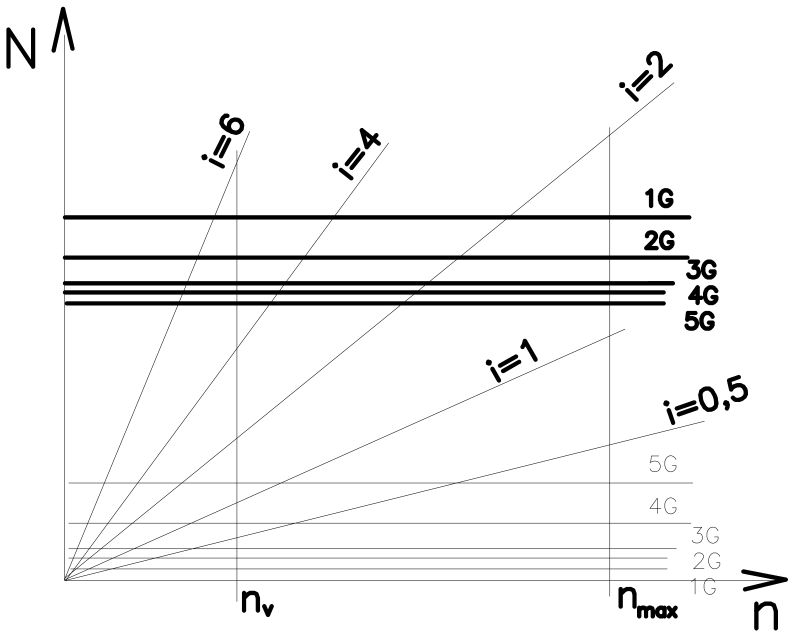

Fig. 2. Campbell diagram
Rys. 2. Wykres Campbella

Operating range of the mechanical system is shown by revolutions n_v and $n_{max.}$ Thin lines marked from i=0,5 to i=6 represent harmonic components of torque**.** Thin lines marked from 1G to 5G represent speed gear for the first natural frequencies. Thick lines marked from 1G to 5G represent speed gear for the second natural frequencies. It is thus apparent, Fig. 2 shows two resonance areas. Resonance of the first natural frequencies of oscillation occurs under the working area of the combustion engine. A second resonance area of second natural frequencies of oscillation occurs directly at the working area of the combustion engine.

Particularly the second resonance area is more dangerous as the first one because of the frequent increase of level of vibrations and noisiness. Nowadays, it is possible to eliminate these negative impacts by use of the pneumatic dual-mass flywheel in the car drive.

The company LuK produces a new solution of the dual-mass flywheel, Fig. 3. The main purpose of the dual-mass flywheel is a reduction of torsional vibration amplitudes. Such reduction can be reached using separation of the flywheel on two individual masses that are jointed each other by means of a flexible connection. Application of the dual-mass flywheels in the diesel engines has also disadvantages with regard to the durability of them. The durability of the flywheel depends on the loading regime predominately. The flexible connection between the both masses is realized with a metal spring, which is stressed due to repeated dynamic impacts during starting-up of coupling, which is connected with one of both masses. The starting phase is characterised by a low speed and high loading. Such kind of fatigue of the connecting spring causes a higher noisiness and higher level of vibrations.

Fig. 3. Dual-mass flywheel LuK
Rys. 3. Dwumasowe koło zamachowe LuK

Again, the following Campbell diagram shows, Fig. 4 a dynamical impact of the dual-mass flywheel as well as its alternation of resonance area of second natural frequencies. That area, mentioned above, occurs under the working area of the main harmonic component.

The aim of this article is to highlight the accidental harmonic components whose occurrence is caused by unstable ignition of pistons and turning off the pistons, in order to decrease consumption of car.

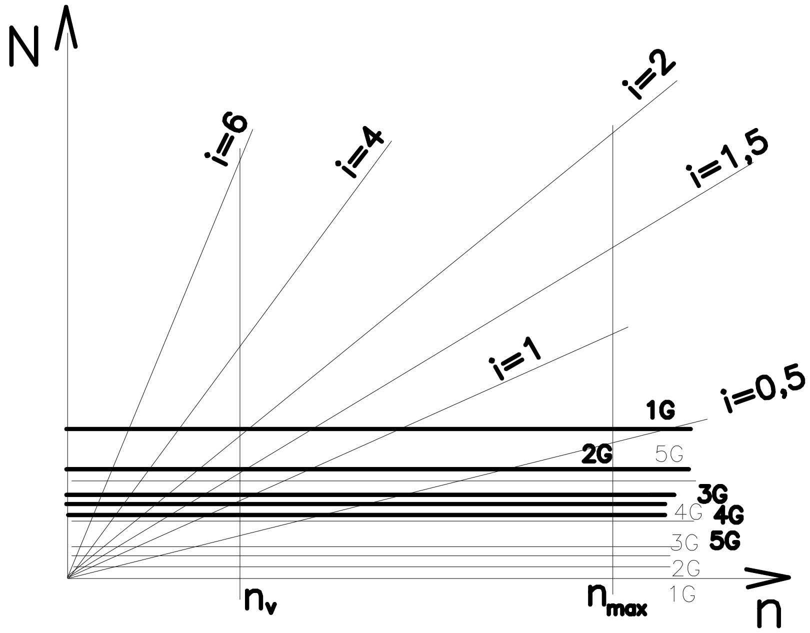

Fig. 4. Campbell diagram with Dual-mass flywheel
Rys. 4. Wykres Campbella dla dwumasowego koła zamachowego

2. THE TUNING OF THE CAR DRIVE WITH PNEUMATIC DUAL-MASS FLYWHEEL

Our research team obtained a great amount of experiences in the development area of machineries and systems projected at our workplaces for reduction of torsional vibrations.

Therefore we developed also a new pneumatic dual-mass flywheel, Fig. 5, which consists of the primary mass (1) and the secondary mass (2). The secondary mass is pressured with the pneumatic flexible chambers that are shaped like half-moons and are filled with the air (3). The primary mass is joined to the carrier (4), which is equipped with the compression pistons (5). The pistons are linked with the pneumatic flexible chambers. The chambers are compressed towards the pistons when they are loaded. The pneumatic dual-mass flywheel is attached to the pneumatic accumulator situated out of the combustion engine. The main task of the pneumatic accumulator is keeping of a constant air pressure in the pneumatic flexible chambers.

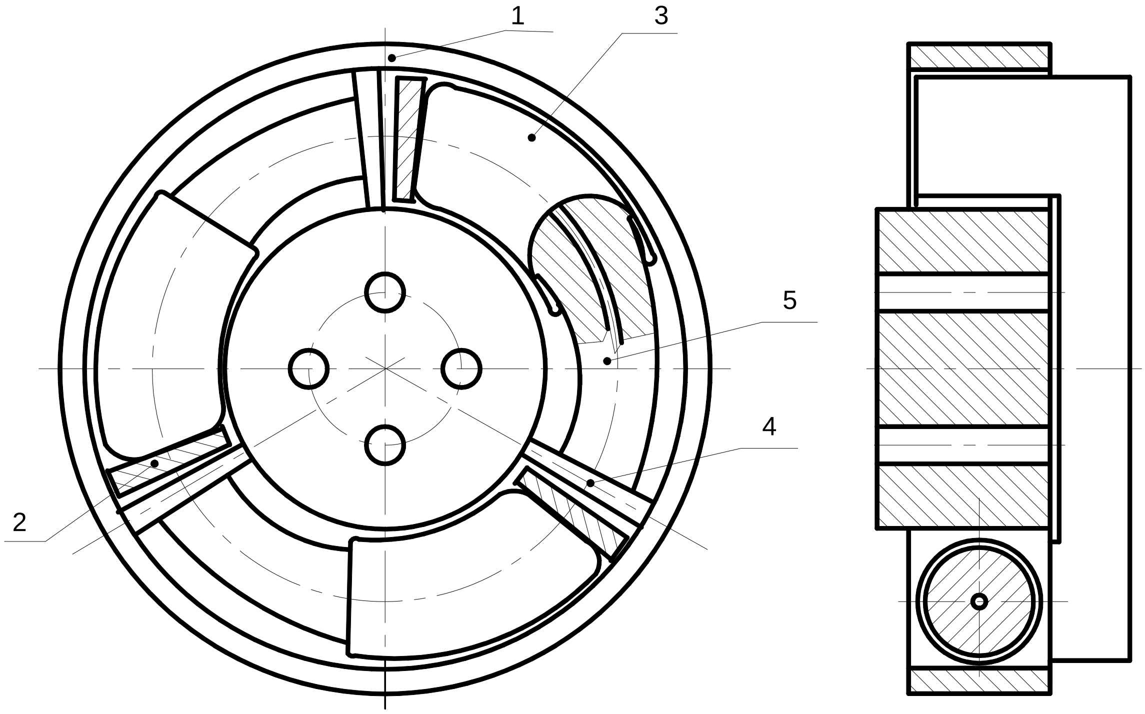

Fig. 5. Pneumatic dual-mass flywheel
Rys. 5. Pneumatyczne dwumasowe koło zamachowe

There were defined the basic loading characteristics according to the performed theoretical analysis, Fig. 5 and it was specified the static torsional stiffness of the designed pneumatic dual-mass flywheel, Fig. 4. The air pressure in the pneumatic dual-mass flywheel can be changed from the 100 kPa up to 800 kPa. The behaviours signed with the letters from *a* to *h* in the Fig. 6 are the loading characteristics and in the Fig. 7 are presented the courses of static torsional stiffness of the pneumatic dual-mass flywheel operating at the pressure levels from the 100 kPa up to 800 kPa.

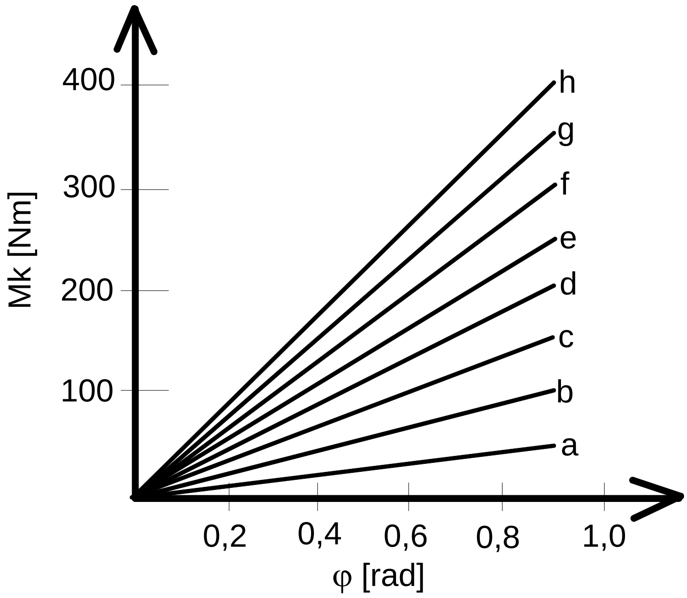

Fig. 6. Loading characteristics of the pneumatic dual-mass flywheel
Rys. 6. Charakterystyki obciążeniowe pneumatycznego dwumasowego koła zamachowego

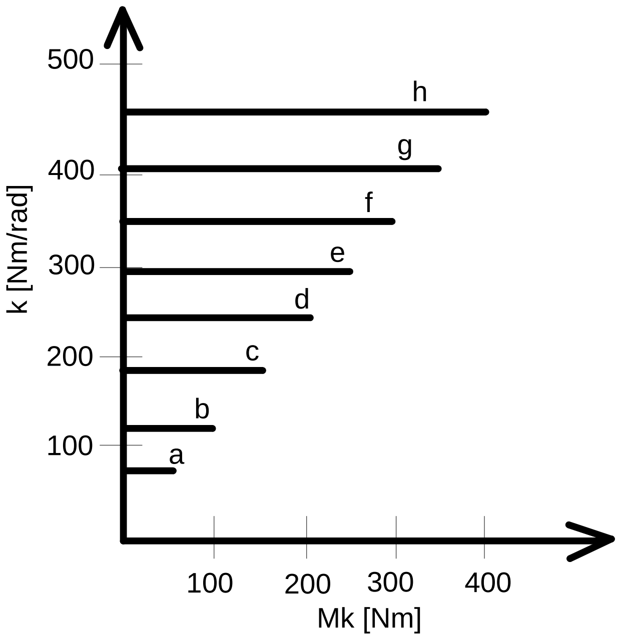

Fig. 7. Characteristics of torsional stiffness of the pneumatic dual-mass flywheel
Rys. 7. Przebiegi statycznej sztywności skrętnej pneumatycznego dwumasowego koła zamachowego

Application of the suggested pneumatic dual-mass flywheel ensures elimination of impacts of accidental harmonic components. Repeatedly, the impact of the mentioned solution for the resonance area of the car drive can be presented by Campbell diagram Fig. 8. Fig. 8 shows a Campbell diagram of a second natural frequencies.

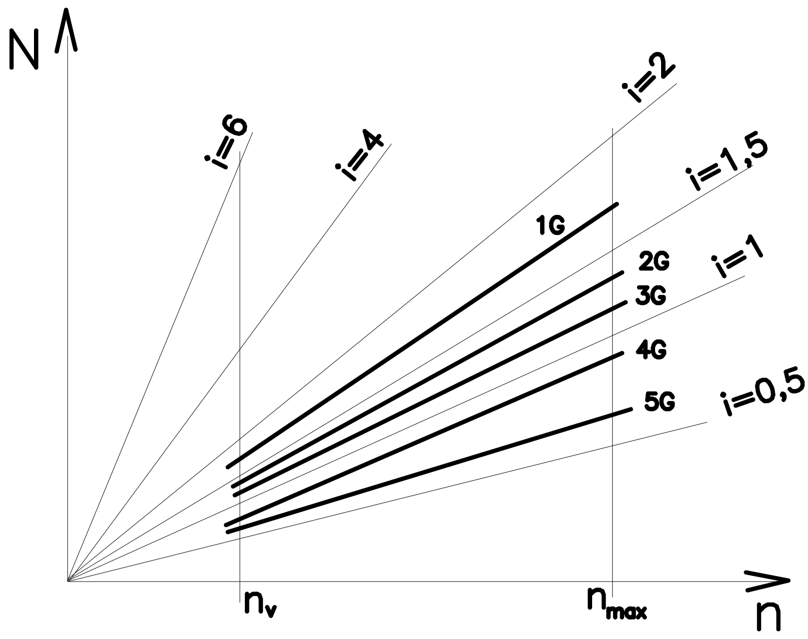

Fig. 8. Campbell diagram with pneumatic dual-mass flywheel
Rys. 8. Wykres Campbella dla pneumatycznego dwumasowego koła zamachowego

3. SUMMARY

The pneumatic dual-mass flywheel was projected on the basis of experiences gained at our department in the area of the torsional oscillation tuners.

By changing of the stiffness of the pneumatic dual-mass flywheel it is possible to ensure the change of natural frequency of the car drive during the running of the engine. By this change, we should achieve no resonance area from an accidental harmonic components in working area of the car drive, Fig. 8. This condition could be realized by stepless change of air pressure in the pneumatic dual-mass flywheel, which can change torsional stiffness and thus the change of the own frequency of the car drive.

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