COMPARISON OF DYNAMIC PROPERTIES OF DUAL MASS FLYWHEEL

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Summary

The stringent worldwide CO_2 limit values are the primary requirement for future mobility. So the environmentally vehicle's drivetrain is element of energy efficiency worldwide mobility. Hence, the development of efficient drivetrain is the top priority. We can also follow the optimization of existing system and introduction of completely new system. According to the various experts, these new trends have expressive effect on torsional vibration in drivetrain. For this reason, many elements such as the clutch disc equipped with a torsional vibration dampers and dual mass flywheels are posed higher and higher requirements for minimizing vibration, and that, in the case of research of mentioned elements are required the application of methods of design diagnostics. In order to accomplish the growing requirements we need to know the basic dynamic properties, torsional stiffness and damping. Therefore, we decided to study of these properties of a dual mass flywheel in our laboratory. Mentioned properties were evaluated from measurements on the experimental stand for measuring by forced vibration and they were monitored at various conditions.

Keywords: design diagnostics, dual mass flywheel, forced vibration, hysteresis loop, dynamic stiffness.

PORÓWNANIE WŁAŚCIWOŚCI DYNAMICZNYCH DWUMASOWEGO KOŁA ZAMACHOWEGO

Streszczenie

Jednym z wymagań stawianych przyszłym rozwiązania w dziedzinie mobilności jest spełnienie zaostrzonych światowych norm emisji CO_2. Przyjazny środowisku układ przeniesienia napędu w pojeździe jest jednym z elementów sprawności energetycznej mobilności rozważanej w skali światowej. Możemy rozpatrywać optymalizację systemów istniejących i wprowadzenie całkowicie nowego systemu. Wg różnych ekspertów nowe trendy w dziedzinie konstruowania mają znaczący wpływ na drgania skrętne układu przeniesienia napędu. Z tego powodu wielu elementom takim jak tarcza sprzęgła wyposażona w tłumiki drgań skrętnych i dwumasowe koła zamachowe stawiane są coraz wyższe wymagania związane z minimalizacją drgań, to z kolei w przypadku badań wymienionych elementów wymaga zastosowania metod diagnostyki konstrukcyjnej. W celu spełnienia rosnących wymagań należy znać podstawowe właściwości dynamiczne, sztywność skrętną i tłumienie. Dlatego też zdecydowaliśmy się na badania dwumasowego koła zamachowego w naszym laboratorium. Właściwości, których jest wyżej mowa zostały ocenione na podstawie pomiarów na stanowisku laboratoryjnym przy wymuszonych drganiach i w różnych warunkach pracy.

Słowa kluczowe: diagnostyka konstrukcyjna, koła dwumasowe, zmuszony drgań, pętla histerezy, sztywność dynamiczna.

1. DETERMINATION OF PROPERTIES OF DYNAMIC COMPONENTS

Vehicle drive system can be presented as a torsional vibrating mechanical system. In terms of dynamics of engines, there is a possibility to compensate the mentioned system with rotating elements and discs joined together by dynamic components such as various flexible components or flexible couplings. In case of vehicle drive system, flexible components are represented by a damped clutch disc as well as a dual mass flywheel. Both the development of torsional vibrating mechanical system and the dynamical component require defining their properties before their application. One of the possibilities to acquire the properties of dynamic components and their system behavior are experiments. Experimental devices with static and dynamic loading are used for the analysis of dynamic components. They work on the principles of kinematic or dynamic exciting of loading torsional vibrations.

Create modern technical solutions required the application of diagnostic methods in each stage of their development. For this reason, we can distinguish the diagnostics at the stage of evaluation, design, control, operational, technological and other. Therefore in our department, we have constructed several devices for the research of properties of dynamic components. In this paper will be presented topic related with design diagnostics oriented to minimalization of vibration by using the dual mass flywheel with the original structure.

1.1. Measurement methods

Methods for measuring are divided into two types: static and dynamic. In case of static measurement, the properties of fixed dynamical element are determined. Gradually, the element is loaded by increasing and decreasing torque and the value of mutual twist angle for appertaining torque is measured at the same time. It is necessary to observe the same torque change in unvaried time. Following a practical experience, at least four loading cycles are recommended because of the similarity of value measured in the third and fourth cycle. According to measurements, it is possible to define static characteristics of dynamic component, namely the torque - twist angle dependency. Resulting from the mentioned dependency, the value of static torsional stiffness and maximum torque of the component without damage is defined. In our laboratory, we have realized and consequently evaluated several static measurements of a dual mass flywheel as a dynamic component. The use of the method of static measurement is not suitable for defining dynamic stiffness and damping of dynamic components. For these purposes, the dynamical methods for measuring were required.

1.2. Dynamic measurement methods

Dynamic measurements enable to determine dynamic properties of dynamic components, both torsional stiffness and damping. During the process of dynamic measuring, the component does not need to rotate; it can only be loaded by a dynamic torque. The measurement results of such conditions are approaching to values in working conditions.

The simplest method of how to define the dynamic properties is a method of free vibration. For its realization a device for measurement of static properties is sufficient. During measurement, a dynamic component is loaded by the torque less than maximum torque and it is released suddenly. The component starts to vibrate by free loaded vibrations recorded in the measuring equipment. Output from free vibration depends on the characteristics of the dynamic component and friction which damp the vibration. The simplest case in the measurement evaluation is to assume a linear characteristic together with a damping proportional to a deviation speed. Depending on the type of dynamic components, this approach is not always possible. However, a non-linear characteristic of a dynamic component, an influence of non-linear damping but also influence of dry friction need to be taken into account. After the evaluation, it is convenient to provide a loop check by calculating vibrations and a comparing measured and calculated data. Regarding the influence of dry friction and proportion of damping and a speed deviation, the free vibration experiment with a dual mass flywheel was realized in our laboratory. Measured data were compared with the values obtained by calculation. Free vibration experiment can be considered as a control or subsidiary experiment.

2. FORCED VIBRATIONS MEASUREMENT

Experimental measuring equipment has to correspond to the conditions which are expected in the mechanical system. In our case, it is loading of a dynamic component by a variable torque so that it is possible to define its dynamical torsional stiffness and damping in conditions similar to loading in the real mechanical system. In our conditions, we work with a mechanism where the component does not rotate but it is forced to vibrate by variable torque. Therefore, the above mentioned measuring method is called a method of forced vibrations and it is applicable for complex determination of dynamic properties of dynamic components.

When measuring with forced vibrations, a mechanism with kinematic exciting is commonly used. It is able to twist a dynamic component by predetermined deviation, which is given by kinematic four-jointed kinematic mechanism. In the mentioned mechanism, it is possible to change a value of amplitude of oscillation from 2 to 8 degrees, gradually one by one, as well as change preload of dynamic component and to initiate a fluent change in exciter frequency. All these conditions have an influence on dynamic properties of test component and they are shown in experiment evaluation. In a given mechanism we can provide an experiment with or without the use of dynamic properties of a given system. Following this fact, the measurement is distinguished into two types: measuring with brake mass in output on one hand and measuring with free oscillating mass in output on the other.

2.1. Measurement with a brake mass in output

A kinematic scheme of measuring equipment for measuring by using the method of a brake mass is shown in Fig. 1.

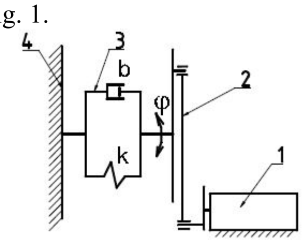

Fig. 1 Kinematic scheme of measuring with brake mass

Following a scheme; the first part of measuring set is an electromotor (1) which is controlled by frequency exciter. Subsequently the electromotor propels through a four-jointed mechanism (2) a measured dynamic component (3) which is held to brake (4).

By using the mentioned measuring set, a change of the component torque and a twist of dynamic component is recorded. The real value of torque can be measured only in connection point with brake.

By the depiction of the measured value, a hysteresis loop is acquired (seen in Fig. 2). In the graph of the hysteresis loop, values for the calculation of dynamic torsional stiffness k_{dyn} and the relative damping ψ are clearly shown. The relative dumping ψ can be presented as a ratio of damped energy A_t represented by an area of the hysteresis loop and accumulated energy depicted in the graph as a crosshatched area:

$$\psi = \frac{A_t}{A_a} \tag{1}$$

As seen, the relative damping depends on exciting frequency ω; therefore it is always necessary to mark the frequency by which the relative damping was measured. In the graph of the hysteresis loop (as seen in Fig. 2), the dynamic torsional stiffness is following:

$$k_{dyn} = tg\,\alpha = \frac{M_{(\varphi\max)}}{\varphi_A} \tag{2}$$

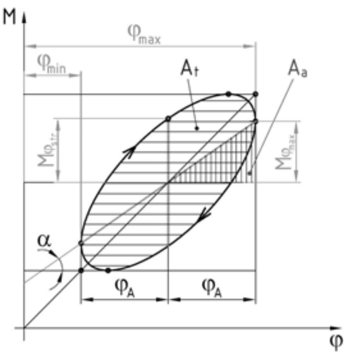

Fig. 2 Example of evaluation of the hysteresis loop

3. RESULTS FROM MEASUREMENT

The measuring equipment for the experiment with forced vibration we have provided in our laboratory is presented in Fig. 3. Particular instruments of the equipment are the following; electromotor (seen as 1), four-joined kinematic mechanism (2), dual mass flywheel (3), joining element for a change of preload (4), torque meter (5), brake (6) and measuring device (7).
Measurements were realized with harmonic oscillation with amplitude of oscillation of 2 degrees, while we were changing a preload value and exciting frequency by frequency convertor connected to electromotor. During the experiment, a change of deviations of exciting to this appertaining torque for all the defined loaded variants was recorded. After measuring, the hysteresis loop was plotted. Consequently, it provided a value for dynamic torsional stiffness as well as the relative damping mentioned in the previous chapter.

In Fig. 4, the hysteresis loop is plotted, appertaining for given preload, a static twist angle of 35 degree and oscillation frequency of 8 Hz.

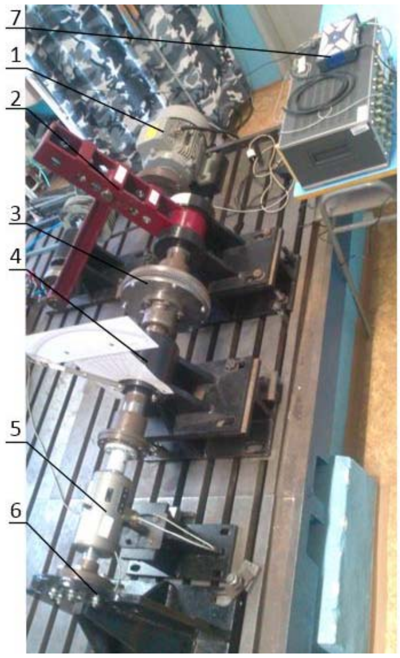

Fig. 3 Measuring set for the experiment with forced vibration

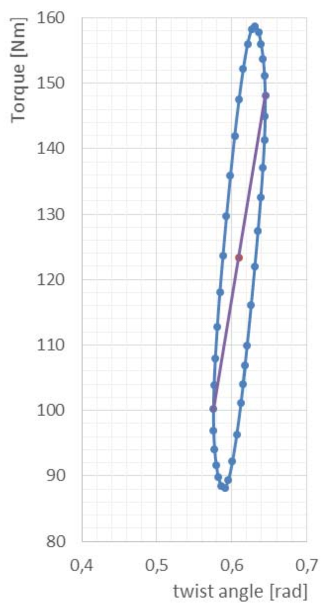

Fig. 4 The hysteresis loop

From a set of measurements, dependence of dynamic torsional stiffness k_{dyn} and the relative damping ψ on a preload and oscillation frequency was presented. Fig. 5 shows the dependence of dynamic stiffness for various values of preload and two different frequencies. As it can be seen, dynamic stiffness is slightly increasing with an increase of preload but also with an increase of frequency. As it is presented in Fig. 6, aside of the decrease of relative damping depending on the increase of frequency, there is also damping dependent on alternating preload.

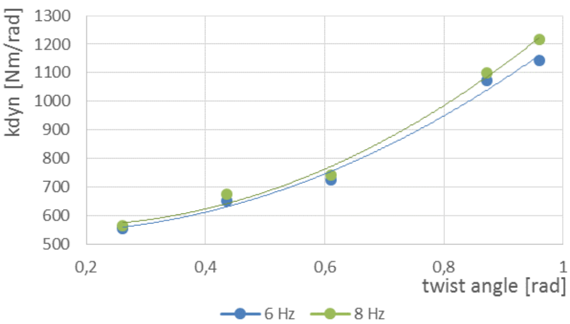

Fig. 5 Dependence of dynamic stiffness on a preload and on two oscillation frequencies

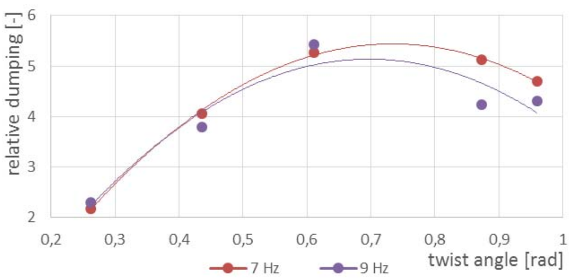

Fig. 6 Dependence of the relative damping on the preload and oscillation frequency

4. SUMMARY

Acquired characteristics of dynamic stiffness k_{dyn} and the relative damping ψ present a change of a dual mass flywheel behavior in a twist angle from value 0,7 rad. The reason of mentioned flywheel behavior rests in its construction influenced by its two-stage static characteristic of torsional stiffness as well as phenomenon known as dry friction. Following measured data are used as a basis for next definition and verification of a rheology model of dual mass flywheel and consequently its application in dynamic calculation.

The application of a dual mass flywheels as well as other dynamic components is widely used in vehicle drive. Therefore it is necessary to know properties and behaviour of mentioned dynamic components in a system. As late as the properties are known, we can prepare a set of measuring instruments but also to accomplish a dynamic calculation. Use of measurement method of forced vibration presents a fast but undoubtedly exact method for dynamic components determination. However, a definite and specific method of experiment have to be observe in order to acquire a correct and usable results.

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