RESEARCH IN THE FIELD OF PHOTOELASTICITY IN THE DIAGNOSIS OF SELECTED PARTS OF TORSIONAL VIBRATION DAMPERS

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Summary

The article presents the results of experimental research selected parts of the rubber small-dimension torsional vibration damper. The study aimed to determine the dynamic loads and stress pattern in the area of the damper hub mounting   to a crankshaft of a multicylinder engine. For this purpose a photoelasticity is used, what allows to distribution of effort of both real parts of machine and models based on their , made, among others, RP rapid prototyping techniques (called. Rapid Prototyping) and RT techniques (called. Rapid Tooling), in particular by casting in silicone molds (VC. Vacuum Casting).

The paper presents the exact process of create models of torsional vibration damper VC techniques based on real element and the process of coating photoelasticity layer to the model, what is necessary to carry the analysis out by photoelasticity method on the reflected light. The results of analysis, determining the hazardous area in terms of stress distribution. In this study is presented own experiences and verify the suitability of the method and material used for research photoelastic ity torsional vibration damper.

Keywords: torsional vibration damper, photoelasticity research, stress pattern

BADANIA ELASTOOPTYCZNE W DIAGNOZOWANIU WYBRANYCH CZĘŚCI TŁUMIKÓW DRGAŃ SKRĘTNYCH

Streszczenie

W artykule przedstawiono wyniki badań eksperymentalnych wybranej części małogabarytowego gumowego tłumika drgań skrętnych. Przeprowadzone badania miały na celu określenie obciążeń dynamicznych na rozkład naprężeń w obszarze mocowania piasty tłumika do wału korbowego wielocylindrowego silnika. Do tego celu wykorzystano elastooptykę, która umożliwia uzyskanie rozkładu wytężenia zarówno na rzeczywistych elementach maszyn, jak i stworzonych na ich podstawie modelach, wykonanych m.in. technikami szybkiego prototypowania RP (*ang. Rapid Prototyping*) oraz technikami RT (*ang. Rapid Tooling*), a w szczególności metodą odlewania w formach silikonowych VC (*ang. Vacuum Casting*).

W artykule przestawiono dokładny proces wykonania modeli tłumika drgań skrętnych technikami VC na podstawie elementu rzeczywistego, jak i proces pokrycia modelu powłoką elastooptyczną, niezbędną do przeprowadzenia analizy metodą elastooptyczną na światło odbite. Zaprezentowano wyniki przeprowadzonej analizy, określając strefy niebezpieczne pod względem rozkładu naprężeń. Przedstawiono własne doświadczenia oraz weryfikację przydatności metody oraz zastosowanego materiału do badań elastooptycznych tłumika drgań skrętnych.

Słowa kluczowe: tłumik drgań skrętnych, badania elastooptyczne, rozkład naprężeń

1. INTRODUCTION

The method allowing for verification of stress pattern in spatial structures include among others, photoelasticity [1,2,5,6].

It enables analysis of distribution of effort of both real objects and their models when direct evaluation of the results is impossible. Such objects can be examined both when are mounted in a real system, where they are loaded arising from their nature of work and loaded into a specially prepared position [3,4].

Photoelasticity research results can be assessed in two ways:

a) as a quantitative tests as the basis for determining the state of stress,

b) as a qualitative research, showing the locations of sensitive zones and horizontal of effort gradients.

The results may also form the basis for the adjustment of numerical analysis, and consequently acceptance of the numerical model as adequate to the considered problems.

There are two commonly used testing methods photoelasticity, for example, method of transmitted light and reflected light method. Both methods are applicable to the flat state of stress. In special cases where it is necessary to determine the spatial distribution of stresses in the elements of the machine, the method of freezing stresses is used.

Photoelasticity is based on the phenomenon of forced birefringence, which occurs in some transparent materials under the action of loads. ray falling on the surface of the material loaded photoelasticity splits into two rays refracted differently which, after leaving the material are offset from each other in phase due to the occurrence of the speed difference of both the rays in the birefringent center. This relative offset is proportional to the difference of principal stresses. The size of the resulting effect photoelasticity is a function of the principal stress. Isochromatic lines illustrate the distribution effort on the surface of tested element. They are places of permanent differences geometric points of principal stresses.
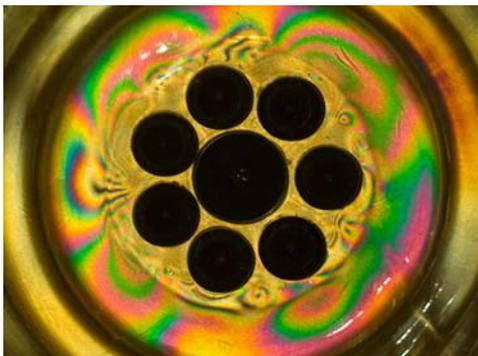

Fig. 1. Distribution of isochromatic
on the surface of a damper hub model

For testing was used the method of reflected light in which the polarized light passes through the optically active layer, which is affixed to the laden model, and is reflected from the reflector of the adhesive layer, and then passes through the coating and is dispersed into two constitutive ray whose mutual out of phase is proportional to the difference of principal stresses model.

For analysis, the company Vishay polariscope reflected light was used (Fig. 2). It consists of a white light source, suitable filters polarizer, analyzer together with quarter-wave plates and recorder.
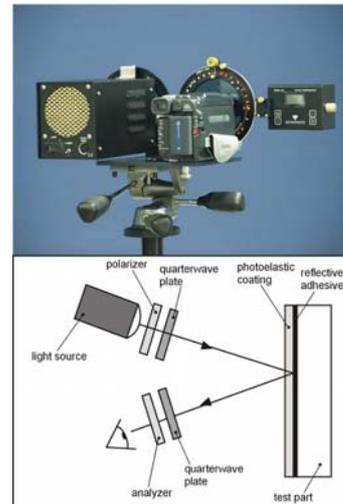

Fig. 2. Vishay polariscope on
reflected light and the scheme of
model by using polariscope

In this method, it is necessary to impose the resin with suitable photoelasticity properties on the optically active layer of model test. Technique of applying such layers depends on the shape and size of the model test. This is connected with the need to conduct a thorough analysis, the result of which is to determine the proper methodology of applying the coating providing to obtain results as close as possible to real conditions.

2. IMPLEMENTATION OF MODEL BY USING THE REFLECTED LIGHT AS A PHOTOELASTICITY TEST METHOD

Photoelasticity research were conducted by using the actual torsional vibration damper and the model formed of resin Epidian 51. Model of the resin was performed by using method of vacuum casting VC (Vacuum Casting).

VC vacuum casting method (Vacuum Casting)

Method VC is one of the RT techniques (Rapid Tooling) for rapid prototyping include parts of machine. This method involves making silicone molds based on the models mostly created by using RP techniques, or actual machine elements. Experimental research often result in model damage and then the direct use of prototypes made by using RP methods as well as the real machine elements becomes too expensive.

The method of VC is carried out in a reusable, silicone casting molds, whereby use of this method is the only way to obtain a larger number of less expensive models, thus enabling to perform multiple experimental studies.

Execution of silicone molds comprises the following steps:
- preparation flask having an appropriate volume,

- preparation of models pouring cup and air vent lumen,
- execution of sets of model through a combination of models pouring cup and air vent lumen with output model,
- placing the model set in the molding flask,
- preparation liquid mass silicone to a form,
- fill the flask with a set of silicone mass model,
- degassing forms in a vacuum chamber,
- heating the silicone molds,
- separation flask from the silicone mold block.

The first step is to analyze the shape and size of the prototype model, in order to select properly matched flask. Size boxes should guarantee   a stable fixing assembly of the model and to minimize volume of used silicone. The advantage of silicone molds is their flexibility, making the process of separating form from final model is easier and allows them to reuse. Nevertheless, it should be provided for both parting lines   by analyzing the shape of model , so that it is not damaged, and distribution of pouring cup and air vent lumen forming with the model so-called model kit. Example of flask fitted with a set of based model is shown in Figure 3.

Fig. 3. Flask together with a set of
torsional vibration damper model

The next step is to prepare the silicone mass. Forms were made by using a set of liquid silicone plus hardener TV MM240 A + B in a ratio of 10: 1. After thorough mixing of the components silicon degassed in an apparatus for vacuum casting Vacuum UHG 400 in a vacuum atmosphere of 2 to 50 hPa. Then the flask is filled with silicone mass and degassed again. Example silicone mold after the completion of its curing process is shown in Figure 4.

When the silicone is already hard, next step is division of silicone mold along planes to ensure separation of the mold without damage. Example of mold separation elements is shown in Figure 5a. After removing and cleaning, separated parts of model set , they can be re-folded and sealed to the outer surface of fast drying silicone. Such prepared form , should be then fill with an epoxy resin ,for example, Epidian 51 (Fig. 5b).

Fig. 4. The silicone mold of torsional
vibration damper after completion of
the curing process

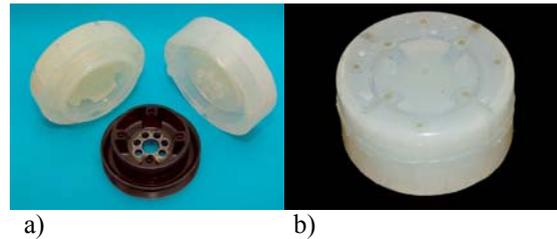a)   b)

Fig. 5. The silicone mold of torsional
vibration damper: a - the internal and
external after separation, b - filled
with an epoxy resin

The forms can be separated again only after the complete   polymerization   of   the   resin.   The separation process forms of hub of torsional vibration damper model is shown in Figure 6.

Fig. 6. Process of separation of
torsional vibration damper model
form

Model pulled out of the mold should be clean up and remove the sprues and venting canals should be remove. Finished models made of Epidian 5 epoxy resin is shown in Figure 7.
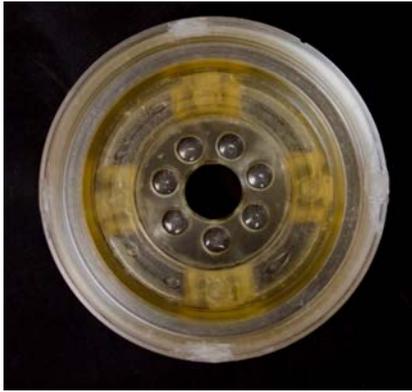
Fig. 7. Ready-made model of
torsional vibration damper made
from Epidian 5 epoxy resin

Thus prepared, the model can only cover the optically active layer.

Preparation of the optically active layer

An important issue in the process of generate a model for testing the proper preparation and application of the optically active layer. The analysis were used made from resin coatings of an optically active type PL-1 (curing agent PCH-1) from Vishay. It is a resin intended to contain a non-deformed (maximum elongation of not more than 5%, the Young's modulus E = 2900 MPa, Poisson's ratio v = 0.36).

Preparation and application of coatings is a complex process which requires a lot of experience. The first step is to analyze the model, which will be coatings imposed. t is crucial to both the shape of the model, as well as its size. From these elements depends on the fact of how many parts will consist of photoelasticity coating and how they will run the dividing lines between them. It is important to determine the photoelasticity coating thickness. If coating is too thick it may cause stiffening of the model and make it more difficult to observe photoelasticity effect as well as thin coating, because the effect is attenuated with decreasing film thickness. In addition, there is a risk of damaging the model during pull too thin coating.To prepare optically active layers used in special Vishay teflon plate (Fig. 8). Plate is covered with a mix of PL-1 resin and hardener PLH-1.
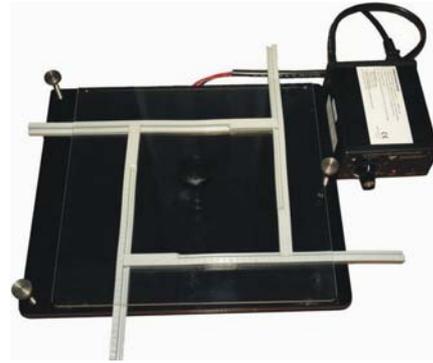

Fig. 8. Teflon plate for producing an
optically active layer

The coating is ready for application after reaching the partial polymerization. Then it is flexible enough that it can be formed on the surfaces of the model, even for very complicated shapes (Fig. 9). After coating, should be leave on the model for 24 hours until a state of complete polymerization.

Fig. 9. Process of applying an
optically active layer of real torsional
vibration damper made of resin and
the casting method

After complete polymerization, the coating may be remove and subjected to finishing (Fig. 10).

Fig. 10. Finishing the optically active
layers

Ready optically active layers is shown in Figure 11.

Fig. 11. Finished optically active
layers

Clean and properly prepared layers should then stick to the surface of the adhesive reflective model of the PC-1 of aluminum dust, which ensures the coating optically reflective layer, enabling the reflection of incident polarized light (Fig. 12).

Fig. 12. Optically active layers
adhered on the model of the torsion
vibration damper in justified cases

After the glue dries, finishing is made (Fig. 13).

Fig. 13. Drilling of holes in the
optically active layers

The model such prepared is left until the glue binding to afford a permanent connection of the model optically active layers. Built Models hub dumper pasted with an optically active layer are shown in Figure 14.

Fig. 14. Drilling of holes in the
optically active layers

3. RESULTS

For the photoelasticity research that allowing to determine the stress distribution of hub damper and mounted it on a test bench in a manner corresponding to real mounting on the crankshaft of the engine. To read isochromatic distribution on the surface of the torsion damper hub Vishay polariscope was used (Fig. 15).

Fig. 15. The test bench along with
Vishay polariscope used to analyze
the stress distribution in torsional
vibration damper

The analysis of the distribution of effort of fixing area from the screw and the crankshaft depending on the torque which are tightened with bolts and a torque applied to the hub damper.

The study was performed on both the model and the real model made from an epoxy resin, which allows application of a much smaller loads, the values determined in accordance with the principles of the similarity of the model [4]. Exemplary distributions isochromatic in the area of the hub mounting the damper shown in Figure 16.
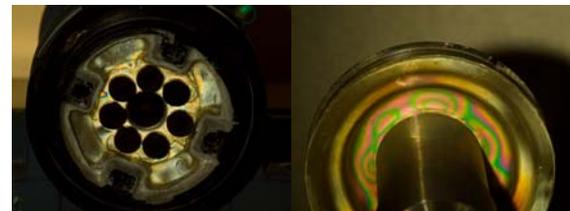
a)   b)

Fig. 16. Distribution of the effort of
the registered as isochromatic on the
surface of the damper: a - from the
clamping screws, b - from the side of
the crankshaft

In parallel with photoelasticity research , the numerical analysis was performed by using MES (finite element method). Examples of distribution of effort in the area of the dumper hub mounting

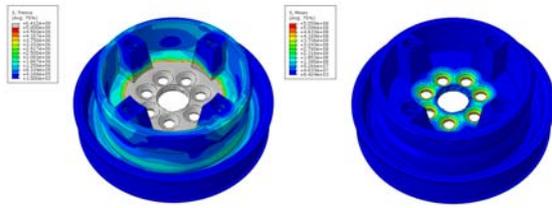obtained by FEM numerical analysis shown in Figure 17.

Fig. 17. Distribution effort of in the
area of a damper   hub mounting
obtained by MES

The similarity of the results obtained by photoelasticity and numerical methods allows to verify the numerical model and evaluate the correctness of its implementation on both the geometry, carried discretization model and adopted boundary conditions.

4. CONCLUSION

The method of light reflected proved to be a satisfactory tool to verify the results obtained by MES. Thanks to it became possible to observe the distribution effort on the surface of the test model and the evaluation of the adopted numerical model.

The convergence of results from both methods demonstrates proper performance of the numerical model in the range:
• mapping the real load of selected cases,
• model discrete division into final elements ,
• determine the boundary conditions that have a decisive influence on obtaining correct results in numerical method.

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