SILICONE-TYPE TORSIONAL VIBRATION DAMPERS*

By

S. Betlej

The objectives of our examinations were to evolve up-to-date systems for the damping of torsional vibrations and to analyse the correlated movement of single-connected chains of a finite number of freedom degrees; and of vibration damping systems which can be represented by a system of non-linear differential equations — with a special view to the determination of the distribution of steady-state forced amplitude.

In recent years increasingly stringent criteria were set for torsional vibration dampers which have induced researchers and designers to evolve simpler, safer and smaller dampers to replace the more conventional oil-, friction-, or rubber vibration dampers. As a result of researches carried out in several countries, there is a distinct tendency towards using dampers with silicone oil as the viscous damping medium.

Silicone-oil vibration dampers were first designed and put to use in Britain. Their operation relied on synthetic silicone oil, a new oil product developed in recent decades.

A suitable oil having become available, attention turned towards the problems of design and construction.

With the exception of the temperature factor, the viscosity properties of silicone oil were regarded to be essentially identical with those of the known kinds of mineral oils. Accordingly, in dimensioning silicone-oil vibration dampers, the designers relied on the available data, viz. on the theory of linear vibration. i

Silicone-oil torsconal vibration dampers have become widespread; on the basis of experienee gained by their use, however, it was found that the conventional principl s and methods of dimensioning could not be applied with them. They proved hardly more than a rough approximation. During operational tests it was found, furthermore, that after a few hundred hours of running, the viscosity of the silicone oil suddenly decreases by orders of magnitude, affecting the service life of the damper.

* Co-report read at the Engineering Committee of the Hungarian Academy of Sciences.

Practice and experience have posed the following fundamental problems:

1. To render silicone oils suitable for practical application, the stability of their viscosity at a given temperature had to be considerably improved.

2. To elucidate the correlations of viscosity properties which have a bearing on vibration damping, the viscosity properties of silicone oils had to be thoroughly studied.

3. In possession and in consideration of the characteristic and essential theoretical correlations, a dimensioning process, acceptable for the engineering practice, had to be elaborated.

Chemists soon solved the problems of stability of viscosity characteristics. They succeeded in evolving, among other things, closed-chain methyl oils with chemical stability values which at a given temperature met all practical criteria and restored the confidence in silicone oils as a medium for vibration dampers.

NESTORIDES, the British researcher, was the first to study the viscosity of silicone oils used for the above purpose. He found that the kinematic viscosity of silicone oils varies widely in function of velocity gradient and illustrated this correlation graphically. On the basis of his measurements he proposed a correction formula to increase the accuracy of the linear dimensioning of vibration dampers.

NESTORIDES' experiment — notwithstanding its great significance in development — did not solve the essential problem.

Later OSUKA, Japanese research worker, by examinations, stated and verified that the calculation method based on the theory of linear vibrations was unreliable. His experiments in the laboratory, yielded valuable data for the trend and extent of corrections, of parameters of determining the damping of vibration by traditional calculation procedures.

ALEXEIEV, Soviet researcher, also dealt with this problem. Relying on NESTORIDES' experimental findings he proposed a formula which ensures a fair approximation of the correlation between kinematic viscosity and the velocity gradient.

Several authors dealt with silicone oil vibration dampers without, however, disclosing any new knowledge of the problem.

ALEXEIEV, on the basis of his formula and the non-linear vibration theory, evolved a calculation method for the case in which the silicone oil vibration damper is linked to a multimass system by means of a slim flexible shaft. In spite of its approximative character, his method is too complex to be applicable in the engineering practice. Since, in addition, the experimental data on which his formula is based was obtained with silicone oils having insufficient viscosity stability, their validity for the more recent types of silicone oils needs a revision.

In the first stage of our experiments towards the development of silicone oil torsional vibration dampers, it was tried to find a solution to the mentioned problems by elucidating the viscosity behaviour of stable silicone oils in function of temperature and velocity gradient and by elaborating a reliable dimensioning process, applicable in the engineering practice.

Through instrumental examinations on domestic and foreign silicone oils of different stability, viscosity, the relationship between kinematic viscosity and the velocity gradient, and temperature were established. The correlations, which were found to be fundamentally non-linear, were also expressed in mathematical formulas.

In considering the non-linearity of kinematic viscosity, the damping factor of the vibration damper was derived and by its use the regularities of the co-action of silicone oil dampers linked to vibrating systems of one mass and of a number of masses, respectively, concentrating on the amplitudes of the steady state vibrations were examined in two variants.

Into the differential equations for co-action the harmonic excitation of a single angular frequency was included in the first variant and two harmonic excitations of dissimilar angular frequencies in the second. The latter variant enabled us to throw light on the intereffect of the excitation harmonics.

In the first approximation the Galjorkin process was used in the resolution of the non-linear differential equation system, then the more simple Fourier series expansion. Finally, by the application of the energetic method and the consideration of the non-linearity of kinematic viscosity, we succeeded in evolving a simplified dimensioning process for silicone oil vibration dampers linked with 1-mass equivalent vibration system.

The experimental dampers were dimensioned according to the so obtained calculation method, tested on a special laboratory equipment and on actual motors, showing a fair agreement between calculation and measurement results.

In the second stage of the research work, on the basis of the above outlined findings, it was tried to evolve a new and more efficient silicone oil vibration damper, applying the principle of dynamics. This silicone oil vibration damper, as to its principle, differs from the above described one in that it has a silicone rubber flexible coupling inserted between the vibration-ring floating in silicone oil and the damping body. The elements are actuated by pressure. The facility to apply the dynamics principle in practice was afforded by the suitable special properties of silicone rubbers.

The use of silicone rubbers in vibration dampers was preceded by thoroughgoing physical-mechanical examinations as to their properties. These examinations concerned the static and dynamic elasticity of eight different domestic and foreign-made silicone rubbers and yielded valuable information for the dimensioning of similar flexible connections. Processing the test findings, the torsional stiffness of the flexible joint assembled of an n number of elements was theoretically determined in function of the relative angle of torsion. It should be noted that, unlike normal rubbers, this correlation is fundamentally non-linear.

Making use of the analytical correlations of the flexibility properties of silicone rubbers, the peculiarities of the co-action of multimass vibrating systems and silicone-type vibration dampers attached to them in two variants, were investigated with a special view to the amplitude distribution of steady-state movement. The system of differential equations describing the co-action shows a non-linearity which can be characterized by two different functions. In the first variant one harmonic excitation was considered and in the second two, with dissimilar angular frequencies, in the system of equations. In the first approximation the solution sought for was along the well proved Fourier series expansion.

In the first variant a closed solution was arrived at. Although in the second variant this was impossible to achieve, we succeeded in evolving an iteration method converging to the exact solution.

The experiments performed with silicone vibration dampers both in the laboratory and in the plant proved that calculations exactly agreed with the measurement results to 7—12 per cent. The deviations may be due to the fact that in the calculations no consideration was taken of the inherent internal damping of the elements of the silicone rubber flexible coupling.

Calculations on a digital computer relating to both damping systems (silicone oil and silicone rubber) have shown that by the insertion of the said flexible coupling piece, an at least 40 per cent more efficient vibration damper can be applied. For the sake of orientation we wish to state that the industrial application at the Csepel Automobile Factory of the silicone oil vibration damper is in preparation. Its dimensioning, along one of the above outlined methods was carried out at the Institute for Vehicle Development. For the design of the silicone damper, patent rights for Hungary and Britain were granted to me.

In the course of the physical-mechanical examination of silicone rubbers we succeeded, among other things, in establishing the numerical value of the relative internal damping factor. This factor is rather high, therefore, the hysteresis work of the rubber elements in the flexible coupling is also proportionately greater than in normal rubbers.

Furthermore, in the course of the examinations it was established that silicone rubbers stand up well to periodic compression stresses and thermal loads, even over long periods. In possession of this information, it was able to evolve another torsional vibration damper of the silicone rubber kind, which is characterized by the damping effect being produced by the internal hysteresis of the flexible coupling between the vibrating ring and the body, exposed to compression stress. Accordingly, in this vibration damper there is no need for silicone oil. This system was the great advantage of extraordinary simplicity, while from the operational point of view it has the favourable property that at medium degree of damping, by its strongly non-linear flexible coupling, the harmful vibrations of the original system can be efficiently damped.

Calculations by digital computer as well as laboratory measurements have unequivocally verified the above statements.

There are various means available to absorb the dangerous torsional vibrations of motors. They can be divided into two categories differing in their operational principles: vibration dampers and vibration suppressors. Up to the appearance of silicone oil type torsional vibration dampers, both kinds were extensively used. But today, even in the countries which had formerly used pendulum-type dampers exclusively (Soviet Union), silicone-oil dampers have gradually gained ground.

From the category of vibration suppressors, the best known are the bifilar-suspension linear and non-linear kinds. The examination into, and knowledge of, the viscosity properties of silicone oils and the combination of the silicone oil vibration damper and the bifilar-suspended pendulum vibration suppressor in a uniform new system enabled the elucidation of the characteristics of the operation of pendulum-type silicone oil vibration dampers in which the pendulum is frictionally driven by silicone oil.

This damper, from the structural aspect, is characterized by the pendulums suspended in the conventional way on rollers which are located in an enclosed casing, filled with silicone oil, and when deflected, being in viscous friction against the side plates of the casing, along their own sides. The essential advantage they ensure is a considerable degree of damping through oil friction over a wide spectrum of the harmonics exciting the vibration system, which helps to prevent the chatter concomitant with minor variations in the angular velocity.

The tendency to combine pendulum-type vibration suppressors and dampers into a new system is also manifested in works by Soviet researchers. TERSKIH, for instance, studied the case in which the movement of a pivoted pendulum is controlled by the fluid resistance of mineral oil.

STEINWOLF and KARABAN elaborated a combination of bifilar-suspension pendulum-type vibration suppressor and damper for the case in which pendulum movement is controlled by semi-dry linear oil friction.

These researches — and more particularly the latter — have brought about very useful practical results.

In the course of the tests, in addition to the above enumerated systems of damping, the possibilities of designing a pendulum-type silicone oil vibration damper by combining the bifilar-suspended pendulum-type vibration suppressor and the silicone oil vibration damper was studied. In the first stage a pendulum damper coupled to a 1-mass system was examined, excited by a single harmonic, taking the non-linearity of the viscosity of silicone oil, only, into consideration. In the second step the problem of pendulum vibration dampers coupled to a multimass system was taken up, similarly with one excitation harmonic, considering the viscosity of silicone oil and the non-linearities caused by large deflections of the pendulums.

From tests with analog computers, the numerical calculations and from the laboratory measurements on pilot units several interesting conclusions could be drawn. Experimental results permit the assumption that pendulums tuned to a single harmonic ensure sufficient damping in a wide band of angular frequency with multicomponent excitation. On my pendulum-silicone-oil torsional vibration damper I was granted patent rights for Italy and Britain.

As a conclusion of this sketchy survey of the main results of my research I wish to underline that in elaborating new vibration damping systems to attenuate harmful torsional vibrations, silicone rubber, a new structural material, was examined and applied. Over and above what has been said, detailed examinations have shown that the application sphere of silicone rubbers in engineering is by far not exhausted by their utilization as a flexible element. Findings and practical uses call attention to the fact that the study of the physical-mechanical properties of silicone rubbers of various composition, prior to their engineering application, may open up new and great perspectives and that the prudent utilization of the findings may lead to the evolution of newer and better grades of silicone rubber.

Sándor BETLEJ; Járműfejlesztési Intézet, Budapest XI., Bartók Béla u. 104.
Hungary