journal of engineering for industry

discussion

Shape and Frequency Composition of Pulses From an Impact Pair[1]

M. A. Veluswami.[2] The discusser wishes to compliment Drs. Herbert and McWhannell for their scholarly ideas in extending the developments of the Dubowsky model of impact pair in a mechanical joint. This was carried out by Professors Crossley, Hunt, Hayashi and the discusser to the higher frequency range of dynamic analysis so that the analysis could be used in improving the reliability and the noise emissions of real mechanisms. The results obtained by the authors whose stiffness-related damping function was derived by a power series of the surface deflection closely agree qualitatively in many respects with the nonlinear model of Professor Crossley, even though quantitatively less errors are seen by the former model, as mentioned by the authors themselves. The serious limitation in the simulation of the model by the digital computer is the step length in the Runge-Kutta fourth-order integration, and this has been properly recognized by the authors. The authors are in agreement with the other investigators on the point that the surface compliance and the surface damping of the impacting members should not be linearized, not only to minimize the error, but also to make the model realistic to the practical system. The model developed by the authors would certainly be of high value in suppressing noise due to impacts in mechanical assembly. The discusser is interested in learning whether a comparative study has been made by the authors on the computing costs involved in the development of models with the digital computer for the least error, and with an analog computer which yields quick results with a higher but a tolerable error. He would also like to know whether based on this a nomogram can be prepared on the cost basis for various products so that industries can use the same right away.

The discussor offers his congratulations to the authors for their fine contribution.

J. N. Fawcett.[3] The impact pair model used can give interesting theoretical results, but the model is highly idealized compared to the situation which would arise in the usual type of plain bearing employed in mechanisms. The greatest difference between the model and a real bearing is that the real bearing represents a two-dimensional problem (assuming no out-of-plane effects), whereas the impact pair is only one-dimensional. The impact pair cannot, therefore, include tangential effects at impact, which could have a very significant effect on the predictions. In a real situation, the two components of a bearing at impact would usually have a relative angular velocity. If the relative tangential velocity at impact were high, slip would occur during the impact. Under these conditions, the energy loss due to frictional effects would be much greater than that due to normal effects, so that the assumption of a coefficient of restitution of unity would give a good approximation to the subsequent behavior of the system. The frictional force acting could be predicted by making the usual assumption of coulomb friction if the bearing were dry, or by considering the behavior of the oil film in a lubricated bearing. These tangential effects could be significant.

Additional complication can arise with a dry bearing when the tangential velocity is small compared to the normal velocity. Under these conditions, tangential elasticity can appreciably modify the behavior from that which would be predicted assuming simple coulomb friction.

A theoretical study of tangential effects in impact, for the case of a sphere impacting on a flat plate, is given by Maw, et al.[4] Good agreement between theory and experiment has been obtained for this case.

Have the authors any experimental results which indicate whether tangential effects are important in a real situation?

Author's Closure

The authors would like to thank Dr. Fawcett and Dr. Veluswami for their comments on the paper.

The authors accept the comments made by Dr. Fawcett that if oblique impacts take place the frictional forces may make the surface damping insignificant, but when considering a mechanism such as a push rod lever mechanism, excited by a small oscillating motion, very small angles of rotation are seen, and in this instance it may be adequate to model the joint assuming no out of place effects. No experiments have been carried out by the authors to investigate if the tangential effects are important in a real mechanism, but under real conditions of impact there are many problems which have not been considered in the simple impact pair, such as misalignment, surface finish and lubrication all of which could have a significant effect on the joints performance.

In reply to Dr. Veluswami's interesting question concerning the relative costs of performing the simulation on digital or analogue computers, the authors can only comment on the times used for the simulations shown in the paper, as no comparisons for different error criteria or costs of analog computer simulation are available.

Due to the British University system of charging for computer time it is difficult to give an exact cost for performing a simulation, but as an indication of computer time used, a 75 ms simulation of the impact pair with the "direct" surface solution took a total of 657 seconds of C.P.U. time on ICL 1907 computer. Only 400 seconds are used for the actual impact simulation the rest is used for plotting and performing the frequency analysis. Simulations incorporating the other surface models used approximately the same amount of time. It must be noted that the program uses the ICL SLAM simulation package that allows easy programming but in no way optimizes to reduce computing costs.

[1] By R. G. Herbert and D. C. McWhannell, JOURNAL OF ENGINEERING FOR INDUSTRY, TRANS. ASME, Series B, Vol. 99, Aug. 1977.

[2] Assist. Professor, Department of Mechanical Engineering, Indian Institute of Technology, Madras, India.

[3] Department of Mechanical Engineering, The University of New Castle upon Tyne, New Castle upon Tyne, England.

[4] Maw, N., Barber, J. R., and Fawcett, J. N., "The Oblique Impact of Elastic Spheres," *Wear*, Vol. 38, No. 1, 1976, pp. 101–114.