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THE INCREASE OF STRUCTURAL DAMPING BY CONTROLLED SLIP IN JOINTS

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INTRODUCTION

In most structures about 90% of the inherent damping is frictional damping which occurs in the structural joints. This damping can be greatly increased by controlling joint clamping forces more carefully than is current practice. In this way, the inherent damping of a structure can be increased which for a given excitation, results in reduced vibration responses and lower stress and noise levels.

Frictional damping in joints usually arises from relative interfacial slip, although other damping mechanisms may exist when the relative motion is insufficient for slip to occur. For a given joint, the slip amplitude can be controlled by controlling the joint clamping force. If the clamping force is low, energy dissipated by interfacial slip is small and the stiffness is low; if the clamping force is high (the usual case), the energy dissipated is small but the stiffness is high. Between these extremes a clamping force exists when the energy dissipated is a maximum, so that if a loss in stiffness can be tolerated in a joint, the damping in the joint and therefore in the structure can be increased. That is, notwithstanding the loss in joint stiffness, the dynamic performance of a structure can be improved by careful control of the clamping forces and thereby the slip, in the joints.

FRICTIONAL DAMPING

The energy dissipation mechanism in a joint is a complex process which is largely influenced by the interface pressure. At low joint clamping pressures sliding on a macro scale takes place and Coulomb's Law of Friction is assumed to hold. If the joint clamping pressure increases, mutual embedding of the surfaces starts to occur. Sliding on a macroscale is reduced and macroslip is initiated which involves very small displacements of an asperity relative to its opposite surface. A further increase in the joint clamping pressure will cause greater penetration of the asperities. The pressure on the contact areas will be the yield pressure of the softer material. Relative motion causes further plastic deformation of the asperities.

In most joints all three mechanisms operate, their relative significance depending on the joint conditions. In joints with high normal interface pressures and relatively rough surfaces, the plastic deformation mechanism is significant. Many joints have to carry pressures of this magnitude to satisfy criteria such as high static stiffness. A low normal interface pressure would tend to increase the significance of the slip mechanisms, as would an improvement in the quality of the surfaces in contact. With the macroslip mechanism, the energy dissipation is proprotional to the product of the interface shear force and the relative tangential motion. Under high pressure, the slip is small and under low pressure the shear force is small: between these two extremes, the product becomes a maximum.

However, when two surfaces nominally at rest with respect to each other are subjected to slight vibrational slip, fretting corrosion can be instigated. This is a particularly serious form of wear inseparable from energy dissipation by interfacial slip and hence frictional damping. (1-9)

FRETTING CORROSION

Since frictional damping and fretting corrosion are inseparable, fretting can be controlled but not eliminated. Surface layers of grease or plastic are not suitable for controlling fretting because the asperities penetrate the layers and the layers tend to get squeezed out. Coatings of various sorts have been tried, but the most effective treatments of the joint interfaces have been cyanide hardening and electro-discharge machining. The EDM treatment is particularly useful since a joint with high stiffness is produced; the joint also has a greater damping capacity than joints with ground surfaces, whilst surface damage due to fretting corrosion can be reduced by an order of magnitude. (10-13)

Although fretting corrosion can only be controlled, the damage to the joint interfaces is often slight, and much less than the damage to the structure if damping is not increased in some joints, thereby reducing the vibration response.

STRUCTURAL VIBRATION

Controlled frictional damping occurring in the clamped joint of a built-in/clamped beam has shown an optimum clamping force to exist for maximum energy dissipation, and also that the beam mode shape changes from the built-in/free mode to the built-in/pinned mode as the clamping force is increased. Naturally, there is a corresponding change in resonant frequency. The ability to control the natural frequencies of a beam by controlling joint forces is a very useful one and may enable resonant conditions to be avoided, as well as increasing the damping in the structure.

The vibration response of frameworks have been greatly reduced by controlling the bolt torque in one of the joints, although the static stiffness was not much affected. Again, a shift in resonance frequencies occurred.

The damping in plate type structures can be significantly increased by using laminated plates, correctly fastened to allow controlled interfacial slip during vibration, or by allowing controlled relative slip between a plate and its supports. In some applications of these methods, the loss factor of the plate has been increased by a factor of 20. (14-16)

THEORY

It is not usually possible to obtain quantitative comparison between experimental and theoretical results, because in theory it is the tangential friction force in the joint which is important, whereas in practice it is usually the bolt torque and therefore the joint normal clamping force which is measured. Thus, unless the coefficient of friction is known, a quantitative analysis is not possible. Since μ is rarely known and not even constant during a cycle, a qualitative analysis is usually sought.

he analysis is often linearised, because the friction force can be approximated y a Fourier series or even, in some cases of light damping, by an equivalent iscous damping force. For plate vibration, the interfacial friction force has een considered as an in-plane force. (17-21)

ONCLUSIONS

t is possible to increase the inherent damping in most structures simply by ontrolling the clamping force in some of the existing joints; this need not ffect the integrity of the structure. Furthermore the frequencies of tructural resonances can be controlled to some extent. Although careful design nd special surface treatments may be necessary for some joints, this is an conomical method for increasing the inherent damping in structures.

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