VACUUM ACTIVATED DAMPING PADS: A NEW, CLEAN AND MORE EFFICIENT TOOL TO CONTROL IMPACT NOISE AT THE SOURCE

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1- INTRODUCTION

Impact noise is very frequent in industries where operations are mostly performed on metallic parts. This type of noise is very damaging to the hearing and may permanently destroy the hairlike cells in the cochlea, leading to a permanent hearing loss. Over a long period of time, various solutions have been looked into in order to control this particular type of noise with very few success (discovery of non-ringing metallic materials such as incramute, which is good but expensive, vibrations damping by friction with the use of heavy metallic chains, and more commonly the use of damping pads, with or without a constrained layer, applied by gluing, bolting, soldering..., and dissipating vibrations, thus noise, by heat with extensional or shear mechanisms). Furthermore, most of those solutions were cumbersome or presented risks to spoil the structure on which they were applied, and they were discarded by the operators because they introduced delays in their production schedule. An original tool has been developed and patented at Bombardier/Canadair as a remedy to these noise problems in the aeronautic processes. It consists in vacuum applicated damping pads with a metal plate constrained viscoelastic layer. The originality of this device is the method of application giving rise to an important vibrations dissipation mechanism based on microslip at the friction interface and also the nature of the polyurethane used as the viscoelastic material. This device remains in place as long as the riveting operation (or other impacting operations) takes place. Further research has been sponsored at École Polytechnique de Montréal by the I.R.S.S.T. to optimise those "Vac Damp" devices and investigate their performances in other industries (trains, busses, boats, heat exchangers). Benches have been mounted with real parts of some of those structures in parallel with a more classical and well studied experiment, a simply supported thin metal plate to optimise this new impact noise control device on well controlled experiments. Part of the shear mechanism associated to well glued damping pads with constrained viscoelastic layer has been advantageously replaced (about 3 dBA better) by a partial slip (microslip) mechanism at the friction interface when applying the Vac Damps on each side of the impacted area. Furthermore, two important parameters in the radiated impact noise control (ringing noise as well as acceleration noise) seemed to be the fraction of the impacted structure covered and the thickness of the viscoelastic material selected, which can also compensate partially for a smaller fraction covered.

2- DESCRIPTION OF THE "VAC DAMP"AND OF THE SET UP FOR MEASUREMENTS AND OPTIMISATION

2.1 Vac Damp: Description and Advantages

The damper is constituted of a constraining plate (about 1/16" thick) made of very hard and rigid aluminum composite (type 75 T 6) on which a shock-resistant polyurethane called RhinoHyde (1/8" to 1/4" thick), and presenting good internal damping properties, has been bonded. The contour of the rectangular constraining plate (with rounded corners) was covered with a rubber gasket specially designed for best sealing but also for covering the sharp edges of the constraining plate in order to protect very expensive airplane structures. A hole has been drilled in the middle of the damping pad to enable the installation of the vacuum line and to exert with a vacuum pump a partial vacuum of about 28" of mercury (13.75 PSI) in the thin air volume between the Vac Damp and the impacted part. The device is reusable and applied temporarily during riveting without deforming the structure at all because the forces exerted by the atmospheric pressure are well balanced and, furthermore, those pads resist very well to the rough handling at the workplace.

2.2 Experimental Set Up Description

The mechanism of sound radiation associated to a random, repeated impact process is very dependent on the geometry, weight, rigidity and dimensions of the colliding object and of the receiving structure. We have, for the optimisation of the "Vac Damp", installed a very well documented (2) set up consisting of a small metal sphere colliding with a simply supported thin plate. The noise radiated is related to rapid surface deformation (acceleration noise), then with the ringing of the plate (reverberation or ringing noise). A pseudo-steady state process takes place with regularly spaced in time impacts (or triggering on those impacts) to obtain a statistically good average of impact noise measurement (about 30 consecutive blows are necessary to have a good standard deviation on the noise measurement average). The two parts of the impact noise (acceleration and ringing noises) have been separated by two methods in order to evaluate and compare their control successively with glued viscoelastic pads with an aluminum constraining layer, and the same simply applied by vacuum effect. The first one is a mechanical separation obtained by using a partial enclosure shaped like a quarter cylinder with acoustically absorbing foam inside in order to leave the impacting pendulum free and to measure only the ringing noise, the impact noise (mostly above 2 kHz) being stopped by this partial enclosure. The second one is an electronic separation in the time domain with a well adjusted rectangular window to separate in time the first peak associated to the acceleration noise from the rest related to the ringing noise. The two methods give very comparable results and validate each other. Measurements were taken for various partial coverages of the plate with three types of double damping pads (small, average and large) covering respectively 10 %, 16 % and 80 % of the free-base plate.

3- MECHANISM OF VIBRATIONS DISSIPATION

The response of the impacted plate will be monitored on the axis of the impacts independently of the fact that the sound radiated from the impact-excited plate may have directivity patterns with frequency dependance as shown in reference (2). This spot seems to be the most exposed to the combination of impact-radiated noise associated both to acceleration noise (maximum on axis of the impacts) and to the ringing noise, and this choice is related to the fact that the operators are situated in front of the impacted area. The mathematical microslip model is presented in reference 3 for an elastic bar with an elastoplastic shear layer. In this model, it is assumed that the friction force is transmitted across an interface rather than through a point of contact (6) and that a distributed version of the Coulomb's law of friction determines which part of the contact surface slips.

Figure 15 of this same reference shows that for high relative normal loads and more rigid shear layer, yielding develops gradually giving rise to microslip of the joint. For a given load of the order of the atmospheric pressure, the presence of microslip diminishes significantly the peak responses of the atmospheric pressure. Experimental data, taken on the plate with two Vac Damps, also show that the trend is to increase the damping by microslip friction (replacing shear dissipation) with the increase of the rigidity of the viscoelastic layer (RhinoHyde instead of Dyad).

4- ANALYSIS OF THE RESULTS

Preliminary experiments, while riveting on real parts of a plane and of a bus (part of a fuselage and rear part of a bus), have shown that a hard polyurethane called RhinoHyde used as damping material on the Vac Damp gives its best performance to this device (up to 3 dBA better than other materials), and that, for large deformations associated to riveting. As described earlier, we have been using a simply supported thin plate excited by a metal ball suspended to a pendulum (small deformations) for a systematic optimisation of this device..

From the point of view of noise control, the total radiated energy is important. However, we need to separate in time the acceleration noise from the ringing noise in order to study the Vac Damp's performance on each component of the overall impact noise.

Thus, we have been measuring the radiated noise levels corresponding to the acceleration noise and to the ringing noise as a function of the type of material (the RhinoHyde is the hard one and the Dyad is the soft one), their thickness and the fraction of the plate covered by both Vac Damps successively with pads applied by the vacuum action, then by pads simply glued onto the base plate. The results of those experiments are presented on figure 1. It is shown for the ringing noise part of the impact noise that the RhinoHyde is the best viscoelastic material when 1/4" thick, mostly between 16 % and 80 % coverage of the base plate. We reach almost the same conclusion for the acceleration noise control, except that this material acts better with a thinner layer (1/8" instead of 1/4") for a larger surface covered (80 %). However, for the overall impact noise, the optimum attenuation for both components (acceleration and ringing) is obtained for the RhinoHyde 1/4" thick covering 80 % of the impacted base plate. By observation of this graph, it seems that the surface covered can be reduced if the thickness of the RhinoHyde is increased.

Finally, we did the same measurements in the same conditions for the total impact-radiated noise. The same trend occurs concerning the thickness of the rigid polyurethane versus its fraction of surface covered.

CONCLUSION

A new type of damping pad with constraining plate has been developed to control better the noise radiated by an impacted structure through the control at the source of the flexural vibrations. Its main feature consists in the fact that it is applied by vacuum action, but also that the viscoelastic material is a stiff layer of a polyurethane called RhinoHyde where the yielding develops gradually (under the shear forces provoked by the flexural vibrations associated to periodic impacts), giving rise to microslip of the joint. It has been shown that this type of dissipation process is more efficient (from one to five dBA depending on the surface covered and of the thickness of the RhinoHyde) than the one associated to shear effect only, when the damping pads are well glued to the impacted plate. The Vac Damps control the acceleration noise as well as the ringing noise parts of the impact noise mainly when they cover a large fraction of the impacted structure (about 80 %) and when their viscoeloastic layer is made of 1/4" thick RhinoHyde. These findings have been implemented with success on real structures such as bus panels, heat exchanger ducts and airplane fuselage parts, providing attenuations of the riveting, hammering and grinding noises of between 4 dBA and 12 dBA at the operator's ears.

REFERENCES

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