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INVESTIGATION OF THE DAMPING TREATMENTS SUITABLE FOR HIGH TEMPERATURE APPLICATIONS

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INTRODUCTION

Conventional and nuclear power generating plants are essentially constructed from plates, shells and beam type components connected by bolting or welding. Damping levels of these components should be as high as possible to minimise the vibrational responses. The damping techniques available for high temperature applications are, however, very limited and is a subject of current research studies.

Following the literature review of the current state of the art of the high temperature damping work [1], experimental work was carried out towards finding damping techniques and materials suitable for high temperature damping applications. This paper describes some of this experimental work and theoretical modelling.

An experimental anvil rig capable of measuring the dynamic properties of polymer or ceramic-fibre materials at elevated temperatures with preload capability was built in ISVR. The measured results of rubber-like materials agreed with previously measured data. The measured data of ceramic-fibre material was used in the theoretical models for loss factor predictions when the fibrous material was sandwiched by steel plates. The theory developed for the plate sandwich system was also used to predict loss factors of concentric pipes in a sandwiched system. The comparison of experimental and theoretical results is given and discussed. Other experimental and theoretical modelling work not mentioned in this paper can be seen in references [2] and [3].

THE DESIGN OF THE EXPERIMENTAL RIG FOR HIGH TEMPERATURE MATERIAL DYNAMIC PROPERTIES TESTS

A schematic sketch of the experimental rig is given in Figure 1. An MI band heater capable of operating to 1400° F was tightly screwed on the outside surface of a steel cylinder, 1 mm thick with an inner diameter of 44 mm, which was bolted on to a massive steel block. The height of the cylinder above the massive steel block is adjustable. A thermocouple, which was attached to the inner wall of the cylinder, was connected to an RS temperature controller. A casing made of aluminium was used to accommodate an accelerometer (B&K 4366) so that it was in line with the force transducer (centre of the glass discs). The glass was chosen for its low thermal conductivity index. A spring was welded onto a brass metal piece which was then bolted onto a U channel guide for applying precompression to the test material via the aluminium casing which houses the accelerometer.

The high temperature rubber dynamic properties were measured using this rig and the results agreed with previously measured data [2]. A typical rubber stiffness measurement result is displayed in Figure 2. Therefore, other high temperature material dynamic properties such as ceramic-fibre material were measured using this rig and the results were used for loss factor prediction. The theoretical modelling of the loss factor of the plates sandwiched with this high temperature material is described in the following section.

THEORETICAL MODELLING OF THE LOSS FACTOR OF PLATES WITH CERAMIC-FIBRE INFILL MATERIAL

With reference to Figure 3, the ceramic-fibre material interlayer is assumed to move longitudinally. The layer in these circumstances can be assumed to be locally reacting, each supporting element of plate has a rod of ceramic-fibre material attached. By using an impedance approach and assuming that the attached plate has a higher wavenumber than the thick excited plate, the impedance of the attached plate Z_{33} is mass controlled.

By using the progressive wave solution to the longitudinal vibration of the internally damped rod and setting $V_2 = 0$, the blocked and transfer impedance per unit area of the interlayer were calculated [3]. The treatment impedance per unit area of the interlayer and the attached plate can then be calculated as:-

$$Z_t = \frac{P_1}{V_1} = Z_{11} - \frac{(Z_{12})^2}{Z_{11} + Z_{33}}$$

where $Z_{11} = \dfrac{k_l E\,(1 + e^{-i2k_l d})}{\omega\,(1 - e^{-i2k_l d})}$, $Z_{12} = \dfrac{-k_l E\,(2e^{-ik_l d})}{\omega\,(1 - e^{-i2k_l d})}$, $Z_{33} = i\omega m_3$,

$$k_l = \frac{\omega}{C_l} = |k_l|\left(1 - i\,\frac{\eta}{2}\right),\ E = |E|\,(1 + i\eta)$$

The loss factor of the system can be calculated as [3].

$$\eta = \frac{\text{Energy dissipated/radian}}{\text{Kinetic energy of excited plate and attached plate}}$$

$$= \frac{\mathrm{Re}\,\{Z_t\}}{\omega\left\{m_1 + m_3\left|\dfrac{-Z_{12}}{Z_{11} + Z_{33}}\right|^2\right\}}$$

where m_1, m_3 are the mass per unit area of the excited and attached plate respectively, d is the interlayer thickness.

EXPERIMENTAL WORK

An experiment was conducted using 0.5 m x 0.5 m steel plates sandwiched with a 16 mm thick ceramic-fibre material. The loss factors were measured from the decay of third octave signal. Figure 4 shows the measured and predicted loss factors and the trends are the same. The peaks of the predicted curve correspond to mass-rod-mass resonance frequencies. The measured values display a much smoother curve. It is likely that the loss factors at different parts of the interlayer are different and the measured values are average values, thus giving a smoother curve.

An experiment was also carried out using two steel pipes of length 1.13 m. The inner pipe has an internal diameter of 50.8 mm and is 3.175 mm thick. The outer pipe, of thickness 1.59 mm, has a slot and allows the pipe diameter to vary. Jubilee clips were used to tighten the outer pipe and to change the diameter, thus altering the interlayer gap. Figure 5 displays the measured and predicted loss factor using the theory developed for the plate sandwiched system and the agreement is reasonably good. Again, the measured loss factor gives a smooth mean curve.

The experiment was repeated using pipes with the same diameter but with length 100 mm. The measured loss factor (Figure 6) is roughly the same as those obtained with pipes of length 1.13 m. The predicted values give peaks and troughs which suggest that they are not related to the length of the system, and possibly related to the variation of the interlayer loss factor.

CONCLUSIONS

This paper describes some of the work carried out in ISVR towards finding damping techniques and materials suitable for high temperature damping applications. Theoretical loss factor modelling of plates sandwiched with fibrous material was also used to predict the loss factor of pipes with sandwiched fibrous material. The dynamic properties of the interlayer material was measured using the ISVR built experimental rig. The agreement between the measured and predicted loss factors are reasonably good.

ACKNOWLEDGEMENT

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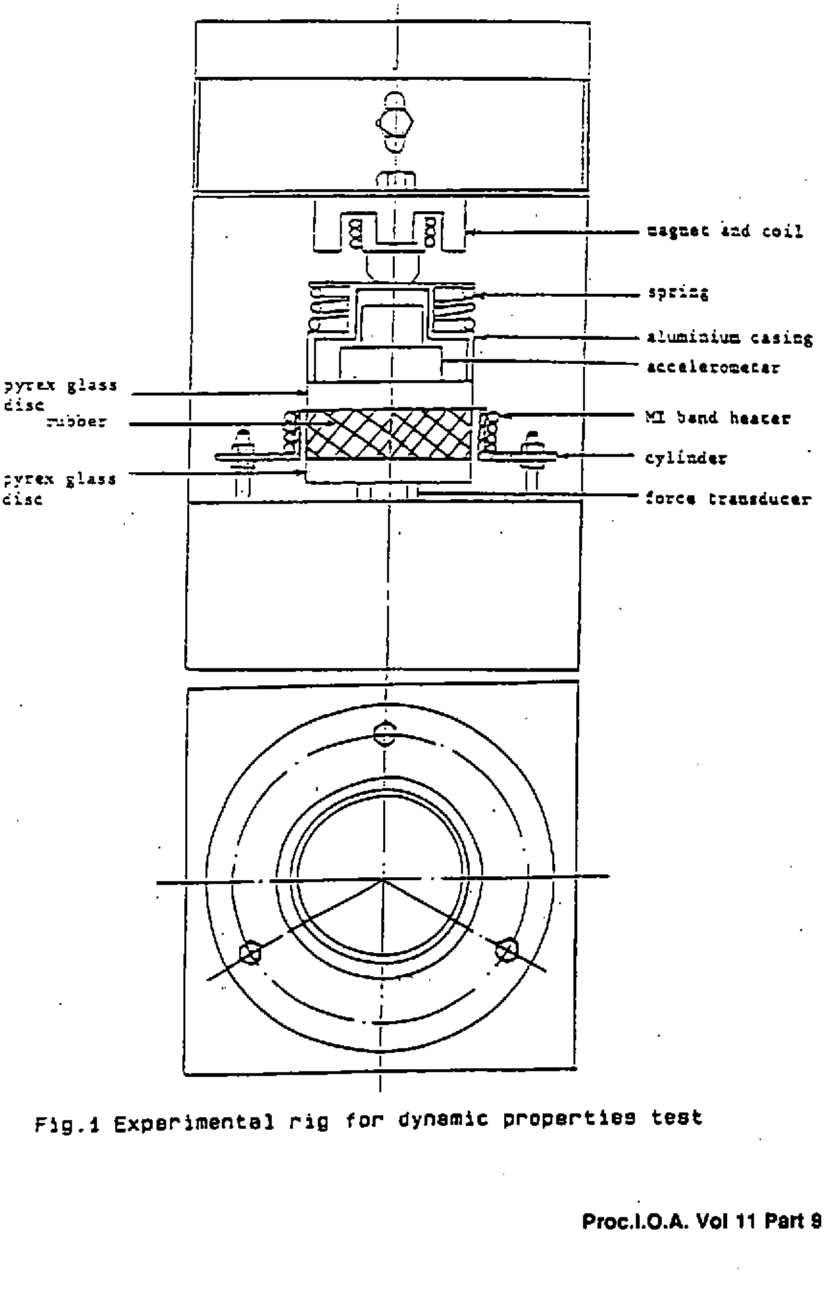

Fig.1 Experimental rig for dynamic properties test

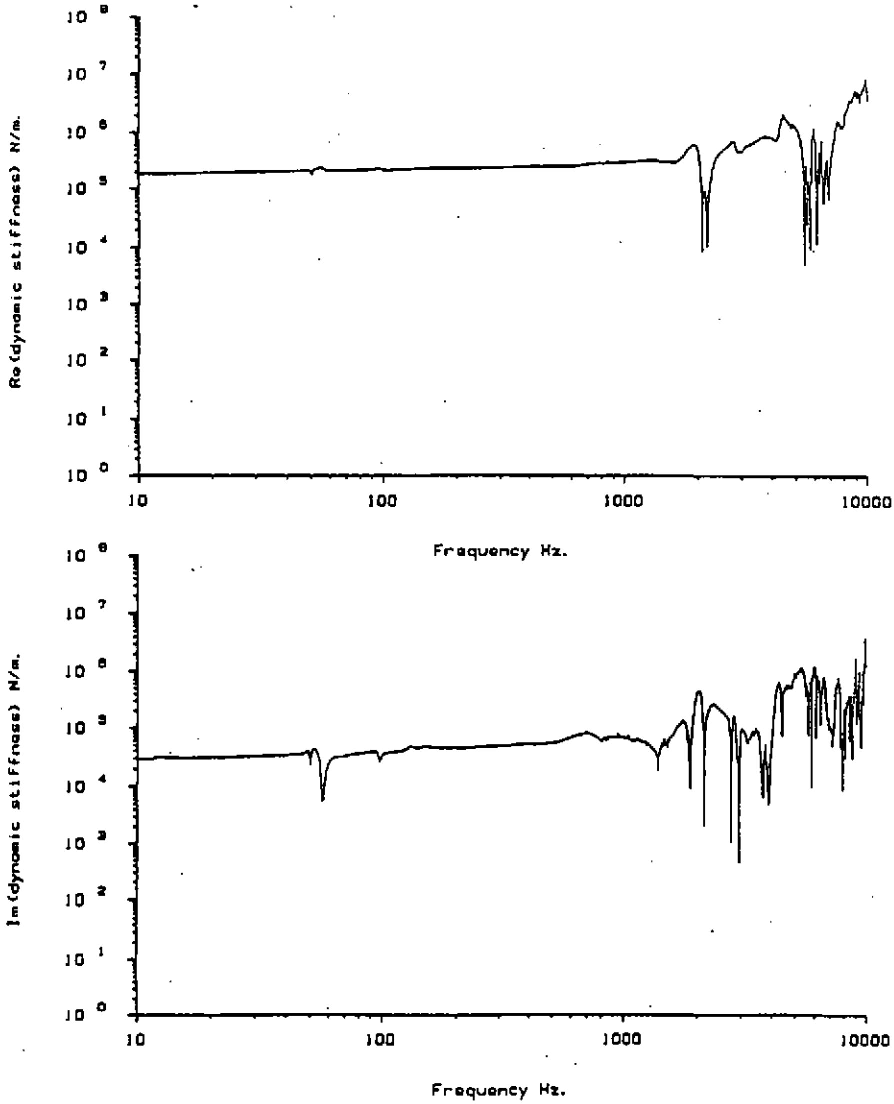

Fig.2 Real and Imaginary part of rubber stiffness with 2% preload at 100°C

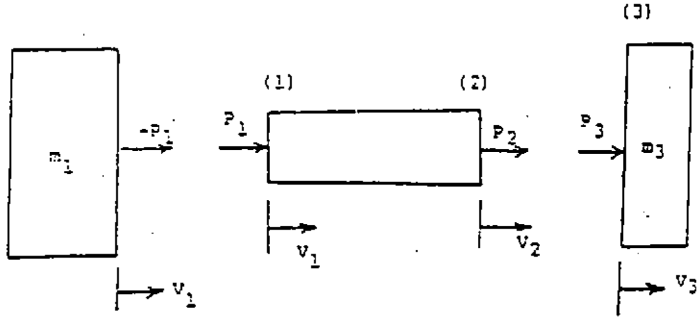

Fig.3 The system for loss factors calculation

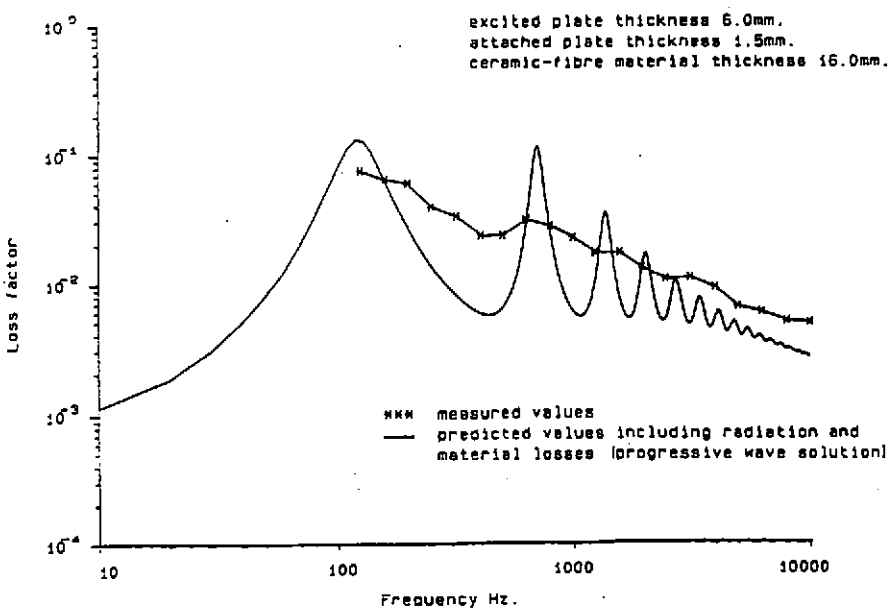

Fig.4 Predicted and measured loss factors of plates sandwiched system

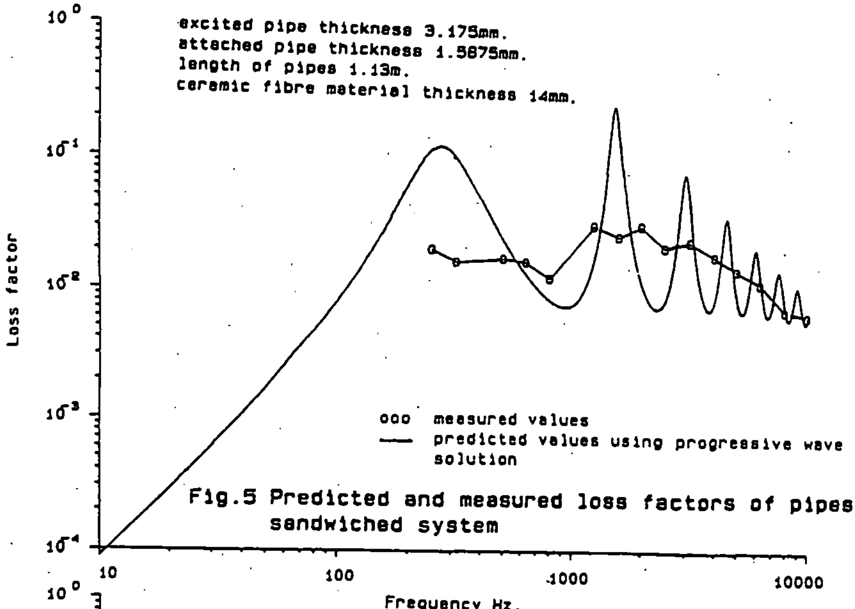

Fig.5 Predicted and measured loss factors of pipes sandwiched system

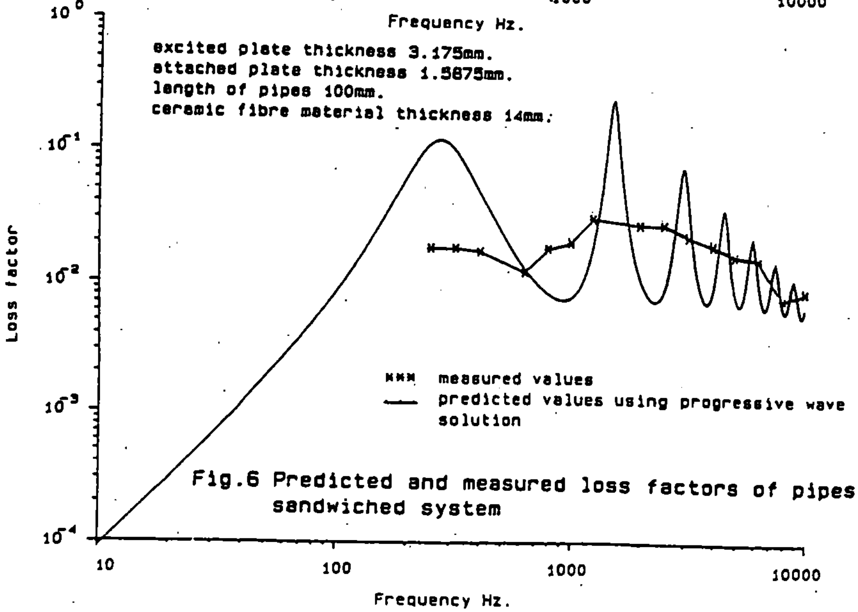

Fig.6 Predicted and measured loss factors of pipes sandwiched system