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EXPERIMENTAL MESUREMENTS OF THE DYNAMIC PROPERTIES OF VISCOELASTIC MATERIALS AND SYSTEMS

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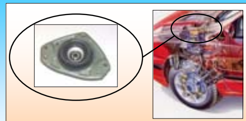
INTRODUCTION

This contribution deals with the experimental characterisation of the dynamic behaviour of rubber to metal visco-elastic systems. An innovative methodology, using an electro-dynamic shaker and a measurement chain based on ICP accelerometers and thermocouples, has been designed to investigate and measure the dynamic interesting quantities on standard geometry rubber test pieces and also on complex rubber to metal vibration damping devices used for automotive applications (such as engine mountings, adaptive journal boxes, elastic hinges, etc.).

Rubber-to-metal devices



Vibrations-damping device for Mc-Pherson suspensions

Engine support

Adaptive journal boxes

Standard elastomer test pieces

Elastomer cylindrical standard specimens and fixture components for axial tests

MATERIALS

Elastomeric materials have typical properties of:

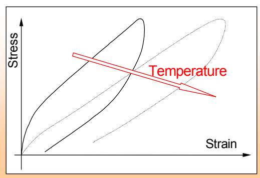
- Viscoelasticity
- Non linearity

Their Young's modulus E and shear modulus G depend from:

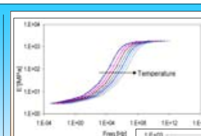
- Frequency
- Temperature
- Static pre-strain (pre-load)

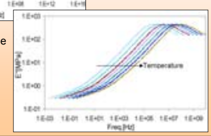
Dynamic quantities have to be considered as complex numbers. So stiffness is a complex value and also the Young's and the shear modulus are complex values. The real part takes into account effects of elasticity, while the imaginary one relates to dissipative effects.

Static stress-strain curves are **non linear** and they describe **hysteresis** cycles. Curves change with **temperature**.



Master curves
Coming from **DMTA** analysis





Those curves show the dependence of the complex Young's Modulus E (=E'+jE'') from **frequency** and **temperature**

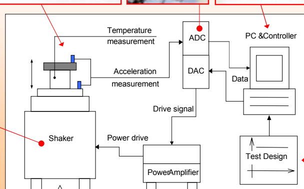
EXPERIMENTATION

THE MEASUREMENT CHAIN

Accelerations are measured by ICP accelerometers.

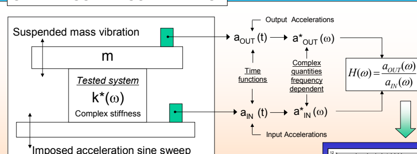
Temperatures are measured by standard industrial thermocouples.

Test are conducted on an elctro-dynamic shaker.



Acceleration functions sent as input signal for the vibrating board are **sinusoidal sweeps** (typically in ranges going from about 30 Hz to about 500 Hz, depending from the analysed system). By the controller those functions are defined giving amplitude values for each frequency tested in the sweeps, to have an almost **constant strain amplitude**.

STIFFNESS MEASUREMENTS



$$H(\omega)=\frac{a_{OUT}(\omega)}{a_{IN}(\omega)}$$

Frequency response function H

It's a complex function of the frequency ω.

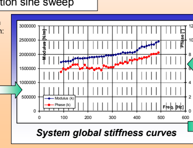
Imposing the dynamic equilibrium for the inertial suspended mass m:

$$m\ddot{x}+k^{*}(x-y)=0$$

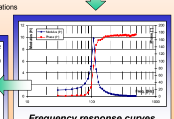
$$k^{*}(\omega)=\frac{m\cdot\omega^{2}\cdot H(\omega)}{H(\omega)-1}$$

System global stiffness

It's a complex function of the frequency ω.



System global stiffness curves



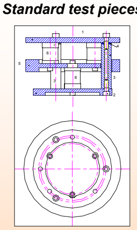
Frequency response curves

In the case of standard test pieces it is possible to estimate values of E and G as complex functions of frequency.

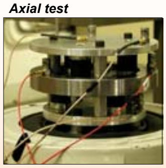
FIXTURES

Several fixtures have been designed to be mounted on the shaker to test standard test pieces or rubber-to-metal devices.

Standard test pieces



Axial test



By this test the **Young's Modulus E** may be estimated.

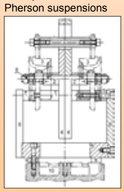
Transversal test

By this test the **shear Modulus G** may be estimated.

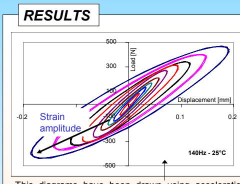
Rubber-to-metal devices

Example of fixture used for cylindrical adaptive journal boxes and engine mountings.

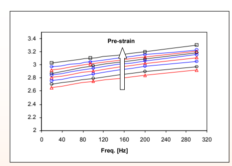
Example of fixture used for vibrations-damping devices for Mc-Pherson suspensions



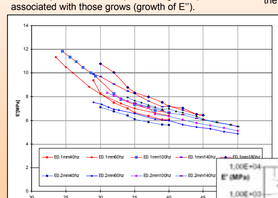
RESULTS



This diagrams have been drawn using acceleration data coming from acquiring of the phenomenon time history. It may be noted that increasing of strain amplitude causes changes in the shape of the Load-Displacement curves: the slope of the principal axis of those ellipses decreases (decreasing of E'); the area associated with those grows (growth of E'').



The graph shows the combined effects of frequency and static pre-strain. Increasing this there is a growth of the real part of the shear modulus G'. Curves of the same colour relate to the same strain amplitude.



The graph shows the combined effects of temperature, frequency and strain amplitude on the real part of the Young's Modulus (E'). It may be noted that: increasing of temperature causes decreasing of E' value, while increasing of excitation frequency causes a growth of that. Also effects of strain amplitude are evident: increasing this value E' decreases.

Results are in good accordance with those coming from traditional experimental methods and theory. The graph shows the superposition of some data pointed out by the shaker method and some master curves obtained by DMTA analysis.