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Experimental procedure and characterization of the thermo-elastic behaviour of rubber-like materials

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Rubber-like materials are more and more used in the industry of transport to assume for instance damping function. In such a case, rubber-like materials are submitted to cyclic loading which are inducing strain, stress and temperature evolution. However, very few studies dealing with the thermo elastic behaviour of rubberlike materials are available. This work aims to identify and characterize the evolution of temperature of rubberlike materials during cyclic mechanical loading under large strain.

In order to achieve this aim, we have established a reliable and reproducible protocol to measure precisely the temperature of the specimen during the loading test by measuring the infrared radiation of the sample.

Using thermocouple in the material would have highly affected the uniaxial tension state we wanted to have. Thus, during a first stage, we placed a thermocouple in the heart samples (heavy line) and another on its surface (thin) in order to assess that temperature might be measured on the surface of the sample. The responses were similar. Measuring the temperature on the surface of the sample allows having representative information of the thermal behaviour of rubber-like under stretch.

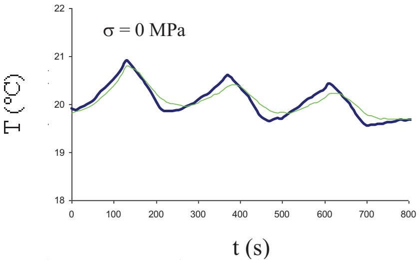

Fig. 1: Comparison of the temperature on the surface and in the material during loading

In order not to disrupt the test, on one hand the environment of the sample are protected from environmental radiation and heat surroundings and on the other hand measurements are realized with contactless equipments. For temperature measurements, pyrometer has been used to measure infra red radiation, leading consequently to temperature. Strains are measured with a video extensometer. Indeed, the pyrometer measurement allows us to obtain the value of the energy radiated by the surface of the sample, known as brightness temperature. Knowing the emissivity, ξ, of the material, we can deduce the brightness temperature of a black body (ideal body absorbing all the energy) at the same temperature than the one of the sample and therefore the temperature of the sample via the relation of Planck.

The challenge therefore consists in determining the emissivity, ξ, of the rubber-like materials. For such purpose, we submitted a specimen to different strains. For each strain, fifteen minutes have been waited, in order to let the sample reaching the thermal equilibrium with the ambient, before measurements are realized. The ambient temperature is measured in order to define the brightness temperature of a blackbody brightness temperature at the ambient temperature, equivalent to the sample temperature. The pyrometer measures the brightness temperature provided by the material. Thus we can deduce the evolution of the emissivity:

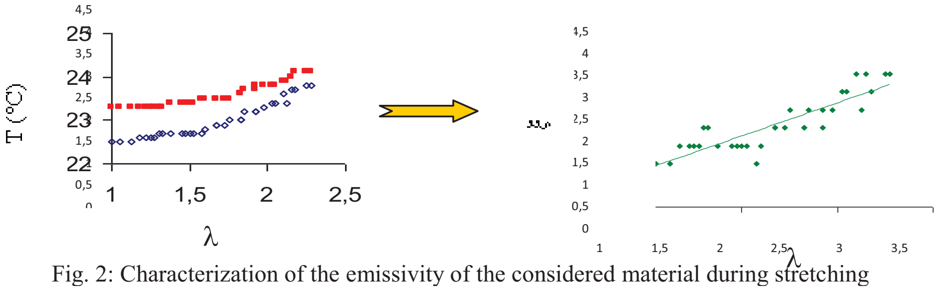

Fig. 2: Characterization of the emissivity of the considered material during stretching

Results are presented on figure 2. One may notice that the emissivity of rubber-like material evolves when stretch evolves.

This variation is a fundamental aspect to be taken into account in our measurement chain. Indeed we know that the emissivity depends, amongst other things, on the roughness of the surface of the material. Rubber-like materials have very small stiffness and the surface may be deformed by the imposed global deformation. In order to asses such explanation, we realised, for different level of stretch, λ, coupled measurements on the same surface of emissivity, made with the protocol previously described, and a measurements of roughness of the considered surface, using an optical profilometer. Results are presented on figure 3.

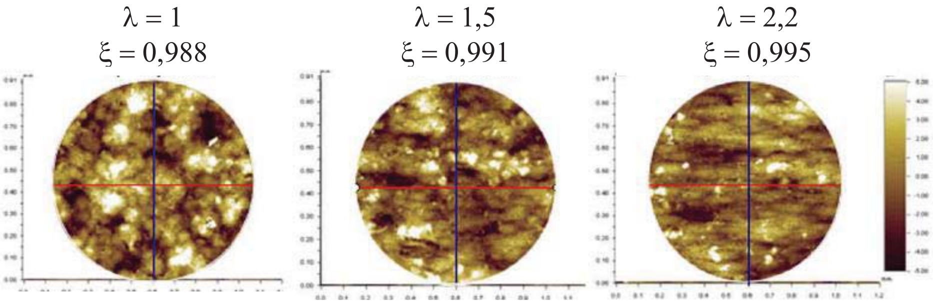

Fig. 3: Measurement of the roughness and emissivity of sample for different stretch

Figure 3 reveals that the noticed variation of the emivissity is really linked to the variation of roughness of the sample.

As figure 2 reveals the variation of emissivity are very small. However, as we can see on the following graphs, figure 4, the error between the experimental measurement (pyrometer) and the real temperature of the sample (ambient thermocouple – full squares) is bigger when we assume the emissivity as constant (lozenges) than with a linear approximation (triangles). Figure 4 prove the requirement of taking the emissivity as not constant.

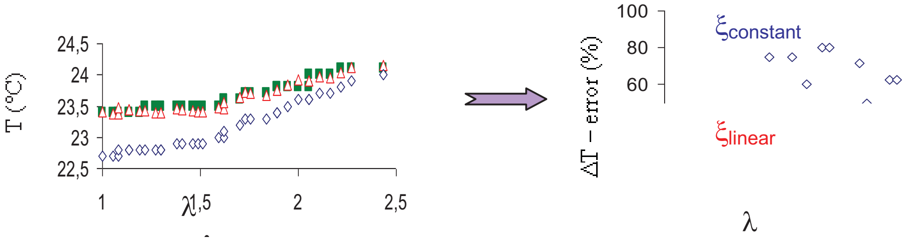

Fig. 4: Comparison of the error induced by assuming the emissivity as constant or not

Finally, we highlighted, on figure 5, the importance of the evolution of the temperature of rubber-like material under stretch, for instance when damage occurs, such as the Mullins effect occurring during the first load only. We also present results, figure 6 which shows that temperature evolution are also linked to strain rate, and thus to viscosity.

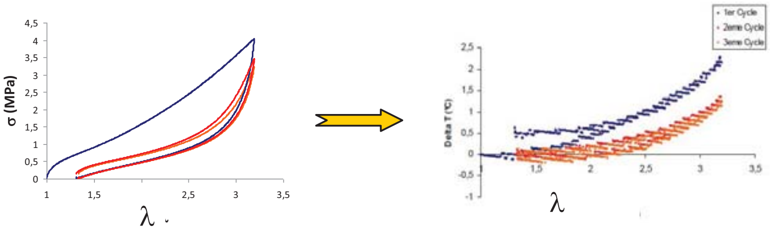

Fig. 5: Comparison of the evolution of temperature, during the first cycle of loading, when Mullins damage is occurring, and during the second cycle of loading, when no damage occurs.

The following results, figure 6, deal with the total increase of temperature during the first loading cycle for different range of strain rate (from 5 10^{-3} to 5 10^{-2} s^{-1}). As we can notice, an increase of the strain rate goes hand to hand with an increase of the total stress and the total increase of temperature at maximum strain.

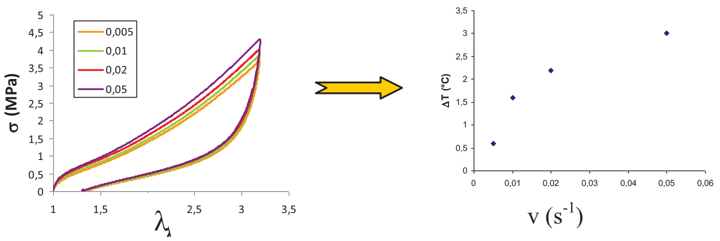

Fig. 6 : Comparison of the temperature evolution at different strain rate

Using infrared measurement method allows us to accurately measure the temperature during stretching. However, this method requires perfect knowledge of the emissivity, which itself depends on the rate of deformation of the material. Then we can identify through their thermal signature well known phenomena such as viscosity or Müllins effect. These methods are new and innovative and will develop models capable of taking into account more accurately the thermal dissipation of rubber-like materials.