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Research article
MATERIALS & FABRICATION

Hot Tensile Strength Micromachine for Aeronautics

JC James William Chuitcheu  DT Damien Texier  PB Philippe Bocher
SUMMARY

The article summarizes results achieved to date through the implementation of the design methodology. It briefly reviews the instrumentation (for the measurement of local deformation and non-contact temperature on the sample) used on the high temperature machine, as well as its limits, and presents the final solution. It describes the design created as part of this research, followed by numerical validations. And finally, it shows the technological benefits of implementing this design and its different areas of use.

Editor’s Note

This follows the article entitled *Determining Properties of High Temperature Materials*. This article presents the micromachine designed to characterize mechanical responses of materials at high temperatures.

Brief Description of the Micromachine

After implementing the methodology, a preliminary machine was designed, which addresses the above-mentioned issues. For the moment, the proposed solution is merely conceptual. It consists of a large cylindrical sealed enclosure used for testing under controlled atmosphere. Inside the enclosure, a semi-elliptical thermal oven with infrared lamps is used to increase the temperature of the samples. A mechanical actuator (not taken into account in the design) located outside the sealed enclosure applies force on the traction line by means of a sealed passage in order to perform tensile tests. The chosen heating solution works on all types of materials (conductors, insulators, etc.) and in all atmospheres (gas, vacuum, air), and also allows substantial thermal reactivity, needed to achieve

The preliminary micromachine designed as part of this research integrates scientific and technological developments from previous work [1, 5, 6].

Instrumentation Overview
In choosing the instrumentation for local deformation measurements, it should be noted that kinematic field measurement techniques have developed in the last twenty years in accordance to emerging needs for measuring structural deformation heterogeneity. Earlier extensometric techniques, basically strain gauges, provide only one-point measurements and cannot determine a structure-scale field without installing a multitude of measurement sensors. The new techniques led to deformation diffusion according to the geometry of each part, and to guiding the design of their shape, optimizing their thickness [10]. The experimental local fields determined by these methods served as the basis for validating numerical prediction simulations, such as finite element calculations. The fact that these techniques are based on the principle of “no contact with the sample” has also motivated their development. Indeed, having no contact with the observed sample avoids mechanical and thermal interactions between the measuring apparatus and the part, which can change results, particularly when dealing with ultrathin materials.

Later, these techniques were developed on a finer scale than that of the structure (tens of centimetres), on the one hand, to study the mechanical behaviour of heterogeneous materials like concrete and fibre composites and, on the other hand, to study deformation diffusion during draw-forming. More recently, with improvements in numerical simulation performance and refinements in behavioural laws, new techniques have emerged, intended for the microscopic study of metallic material behaviour [11, 12]. Of particular note are the studies on cracking mechanisms. This is why, in the current state of the art, many different techniques have been developed for very specific applications. They use different means of investigation (laser, white light, camera, optical microscopy) and their measurement is based on various physical principles (interferometry, optical imaging). Techniques are available with varying performance, particularly in terms of local measurement accuracy and size of the area being analyzed.
These techniques are classified into four main categories: methods using photoelasticity moiré techniques, holographic interferometry methods and image analysis methods. Among these techniques, photoelasticity and holographic interferometry methods are not applicable in our context. Their millimetre investigation scale is too imprecise. In addition, photoelasticity requires depositing a photo-elastic film on the sample surface, and holographic interferometry methods use optical materials and a laser. Such devices are not compatible with microstructure observation during the mechanical testing.

The other two techniques can be used with different observation devices: optical and laser microscopy, scanning electron microscope, etc. Moiré methods require the use of special systems that are too expensive for the small micromachine described in this paper in order to achieve higher accuracy. This technique was thereby rejected.
Image analysis techniques are the most appropriate for measuring local deformation coupled with complementary techniques of optical and electronic observation by marker tracking. Therefore, the image correlation technique, more suitable to our current needs, is the one selected. It allows for automatic evaluation with speeds that are compatible with current computer technology. It also provides sub-pixel precision (below-pixel) to measure displacements below the normal resolution of digital images.

The fact that this technique is capable of extended application to out-of-plane component displacement measurement through digital image correlation, for better evaluation of the plane stress tensor components, constitutes an additional argument justifying this choice. It should be noted that for this research, a translational motion mechanism was designed along the three axes (x, y and z) to move the microscope lens, facilitating focus and tracking of the observed area on the sample. With regard to thermal mapping, there are several temperature measurement techniques, with contact and without. In this research, non-contact techniques were selected for the above-mentioned reasons, and an optical pyrometer was used in addition to the thermocouples (type K) for temperature regulation [1, 4].

Digital simulations of the different micromachine sections were carried out in order to allow adequate design of the mechanical test bench.

Conclusion

Our goal was to provide a versatile and adaptable enclosure for any type of commercial mechanical test bench. To create the micromachine, which is the subject of this functional research, all the necessary components must also be selected and added as needed to make it work: brine pump, K thermocouples, vacuum gauges, gas pressure sensors, argon pump, air blowers, aluminum sheets for testing with corrosive or oxidizing gases, sample temperature control device, deformation and temperature measuring device, sealed enclosures (vacuum gauges, thermocouples, gas pressure detectors, gas inlet and outlet). The next steps involve drawing parts, machining the parts and, finally, performing the actual assembly of the micromachine to test its performance.
This micromachine could address industrial materials characterization issues found in many industrial sectors (issues including high-temperature surface reactivity, coated materials, irradiation, etc.). Moreover, this test bench would also meet the needs of fundamental research on environmental interactions/mechanical properties, free surface tests/interface, etc.

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**James William Chuitcheu**

James William Chuitcheu is a graduate student in the Department of Mechanical Engineering, and is also a Teaching Assistant at ÉTS.

*Program: Mechanical Engineering*

*Research laboratories: DYNAMO – Research Laboratory in Machine, Process and Structural Dynamics  
LOPFA – Optimization of Aerospace Manufacturing Processes Laboratory*

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**Damien Texier**

Damien Texier is a CNRS researcher at the Clément Ader Institute. He is working on the micromechanics of heterogeneous materials, graded materials and thin materials.

*Program: Mechanical Engineering*

*Research laboratories: LOPFA – Optimization of Aerospace Manufacturing Processes Laboratory*

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**Philippe Bocher**

Philippe Bocher is a professor in the Mechanical Engineering Department at ÉTS. His research includes manufacturing processes, aerospace, residual stress, characterization of manufactured parts, and improvement of material properties.

*Program: Aerospace Engineering  Mechanical Engineering*

*Research laboratories: DYNAMO – Research Laboratory in Machine, Process and Structural Dynamics  
LOPFA – Optimization of Aerospace Manufacturing Processes Laboratory*
References


Images references

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