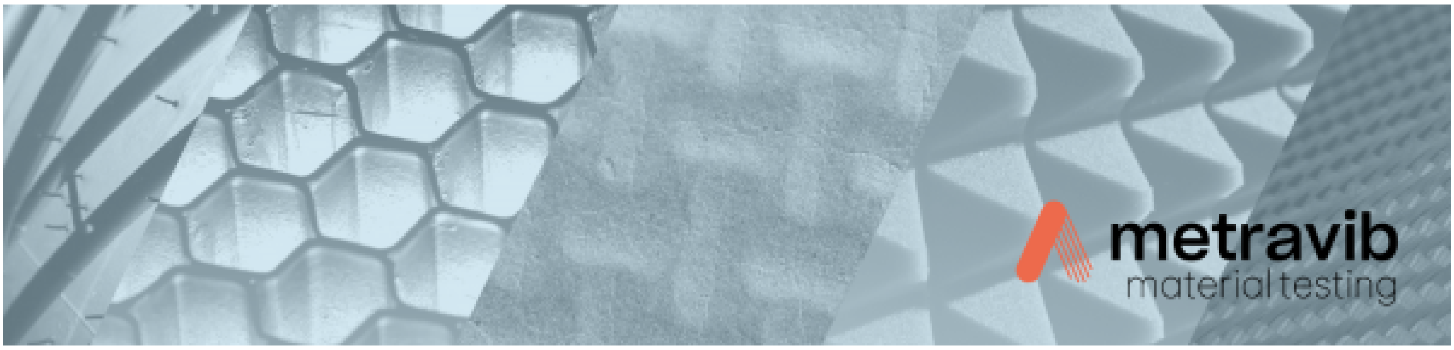


Creep and Time-Temperature Superposition (TTS)

Keywords: DMA, Viscoelastic Properties, Polymers, Creep, Time-Temperature Superposition

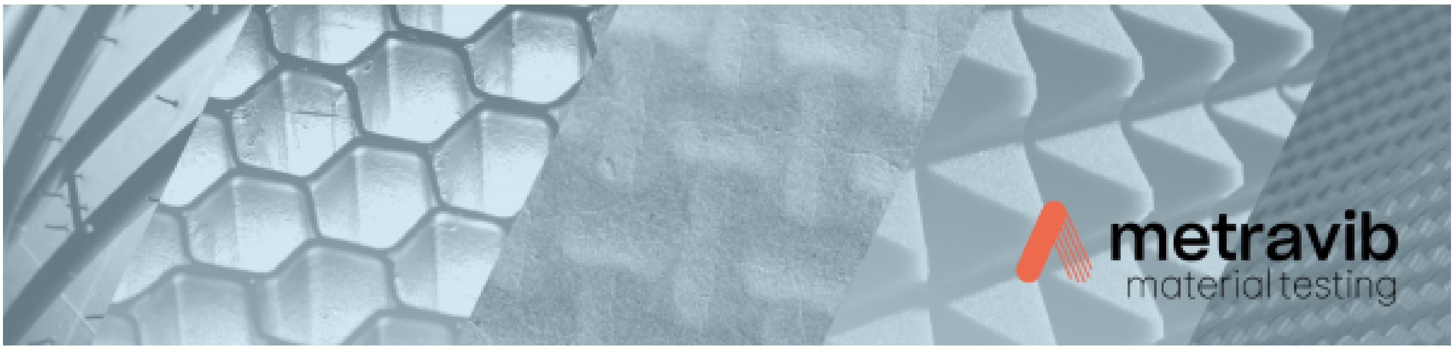
Figure 1. Metravib DMA+1000

Introduction

Creep is one of the most fundamental and dominant analytical tools to study material behavior. These measurements help study the response of materials to static load and its behavior when the same static load is removed. Creep tests can be utilized in two ways : (1) to get the fundamental information about the polymer, or, (2) to investigate the materials response under real applicable conditions.

These measurements could bring useful information on material, such as the relaxation time or the permanent deformation. From an applicative point of view, the possibility to create stable materials can be determined by using a creep measurement.

Moreover, results from creep measurements at different temperatures can be used to estimate the aging of a material. This aging estimation can be done by using the software Dyna+ inbuilt function, named as TTS (Time-Temperature Superposition). This function allows to build time temperature master curves by selecting a



reference temperature. The master curve building process has been explained in another application note (Ref : AN23004).

This creep study was performed on PP (Polypropylene) with the help of METRAVIB's DMA+1000.

Materials & methods

PP is characterized by its high toughness, rigidity and crystalline nature commonly used in industrial applications, such as piping systems. The dimensions (h x b x t mm) of the specimen used for this study were 6.5 x 19.3 x 2.9 mm, respectively. The specimens were studied in tension mode Figure (2). The static stress of 5e6 N/m^2 was applied for 1800 seconds with a maximum displacement of 0.005 m. This static loading step was followed by the recovery time of 1800 seconds.

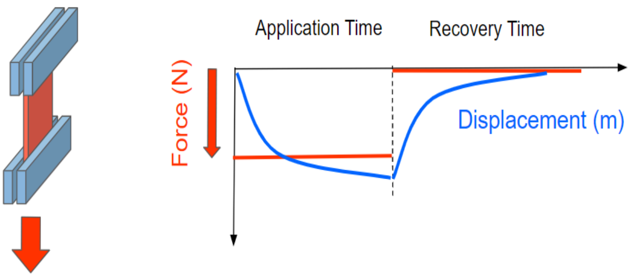


Figure 2. Schematic diagram of Tension test mode

Since the goal was to study the creep along with the TTS, the creep measurements were performed at several temperatures from 15˚C to 95˚C with stabilization time of 15 minutes for each temperature. The parameters used for the test are mentioned in Table 1.

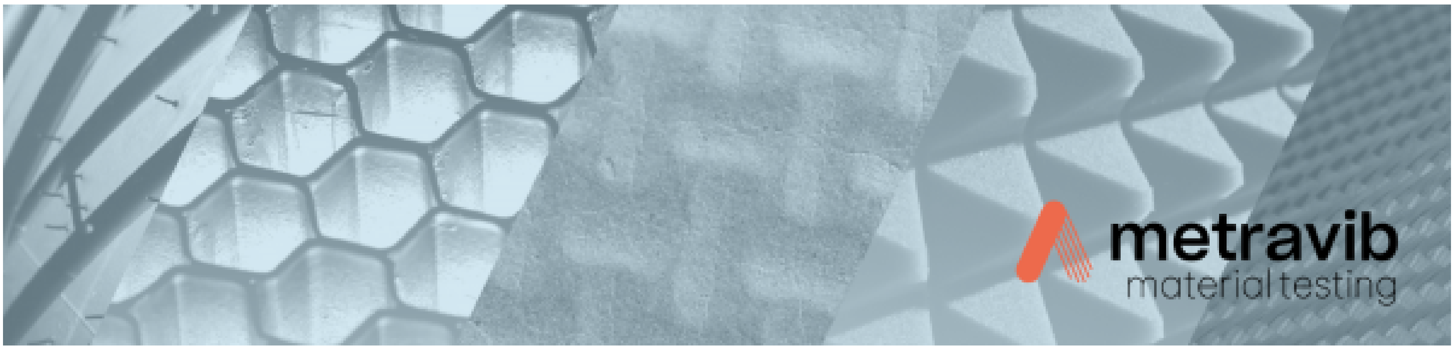
Static stress (N/m^2)	5e6
Duration (sec)	1800
Temperature (˚C)	15 to 95, with 5˚C steps
Stabilization time at each temperature (min)	15
DMA	DMA+1000
Test Mode	Tension

Table 1. Test parameters

Results

Figure 3 shows the static displacement obtained as a result of applied static force for different temperatures from 15˚C to 95˚C. It can be seen in the graph, that the application of static force for 1800 seconds was enough to get the displacement stable, except for the high end temperatures used in the measurements. Moreover, the recovery time of 1800 seconds was enough too.

Temperature is one of the most important variables, as most of the materials show striking different behavior below and above the glass transition temperature. Lowering the



temperature decreases the ability of the chains to move, which leads to the decrease in free volume and hence, the amount of creep decreases [1,2]. This effect of temperature can be observed clearly in Figure 3.

This creep data at several temperatures was used to construct a master curve at a reference temperature of 20˚C. This master curve helps to identify the creep behavior of material at reference temperature for a relatively very long duration. The master curve calculations were performed using WLF and Arrhenius theory. The coefficients can be seen on the graph in Figure 4. This TTS application helps analyze the creep behavior over a couple of decades. This module of TTS application could be very helpful if someone doesn't have a lot of time but is interested to get the properties on a long time scale.

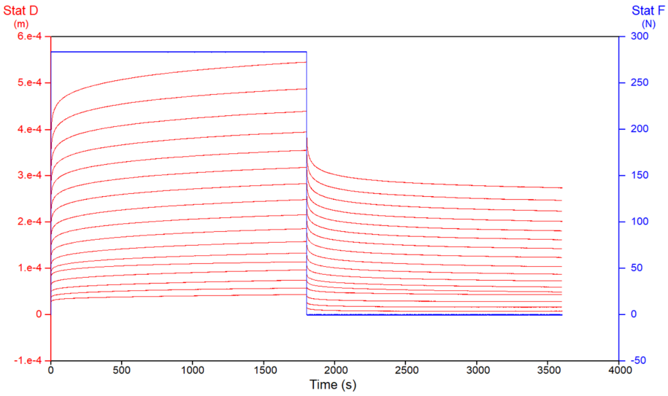


Figure 3. Static displacement and force over a time period at different temperatures.

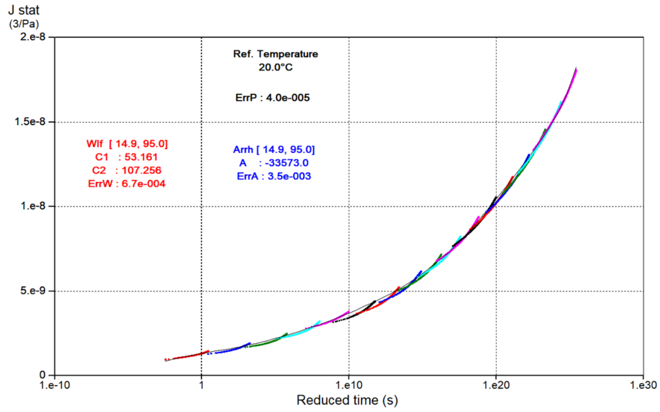


Figure 4. TTS master curve at 20˚C reference temperature

Conclusions

This study shows the ability of Metravib's DMA+1000 to perform creep measurements along with the in-built user-friendly software functions used to calculate and plot the master curve. This study allowed us to successfully calculate and plot the master curve at 20˚C as reference temperature. It also allowed us to calculate the WLF and Arrhenius coefficients.

References

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