Effect of Aging on Mechanical Properties of Polymers

Keywords: DMA, Viscoelastic, Aging, Polymers, Mechanical

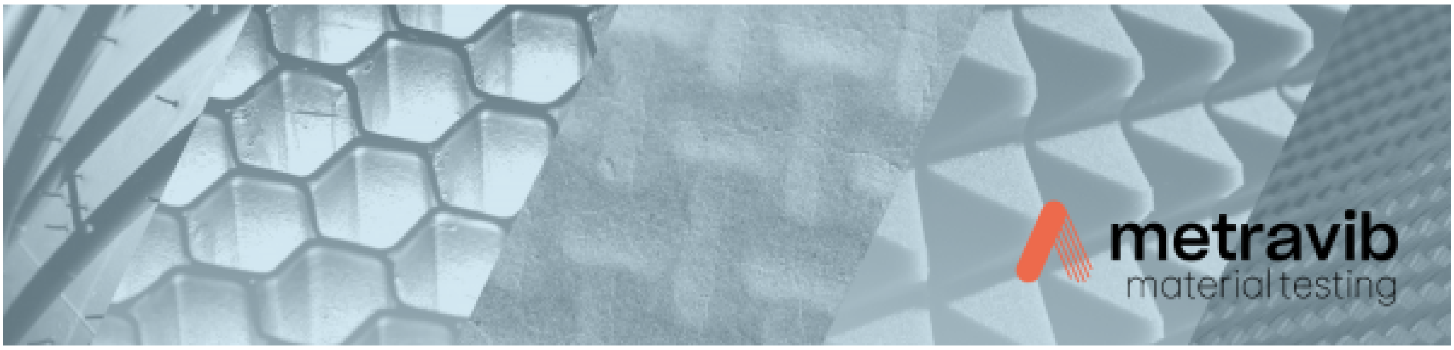
Figure 1. Metravib DMA+1000

Introduction

In polymers, during their manufacturing, the molecules do not have enough time to move into the correct position or shape that corresponds to the current temperature, resulting in freezing of polymer molecules far from their optimal positions. As a result an excess volume exists between the polymer molecules and hence moves closer together with time. With time, the polymer structure becomes more compacted, which affects mechanical properties. This phenomenon of changing properties with time is called "physical aging".

Aging of polymers can have a drastic effect on their durability and respective applications. Therefore, it is of prime importance to understand and to be able to characterize physical aging.

This study was performed to show the effect of physical aging on mechanical properties of polymers. This also shows the precision of Metravib DMA to characterize the physical aging phenomenon.



Materials & methods

The material tested in this study was PVC (polyvinyl chloride). PVC is the world's third most widely produced synthetic polymer. It is widely used in several industries such as construction, phonograph records, canvas production etc.

The specimens were studied in shear mode (see Figure. 2). The dimension of 1.5 mm thick, 1.5 mm wide and 11.3 mm length was used. The dynamic strain of 2.5 % was applied on the specimen, without static strain.

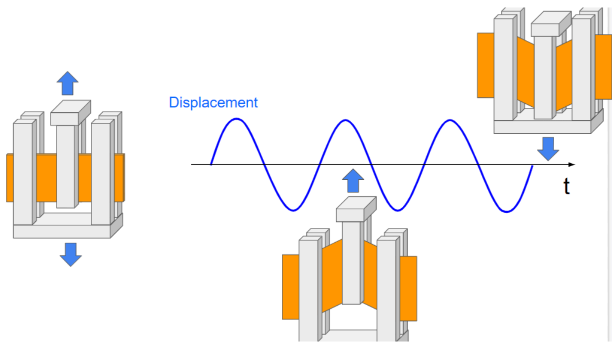


Figure 2. Schematic principle of shear mode measurements

Dynamic Strain (%)	2.5
Frequency (Hz)	5
Temperature (˚C)	-50 to 150 (2˚C/min)
DMA	DMA+1000
Test Mode	Shear film

Table 1. Test parameters

Since, the objective is to show the effect of aging on the polymers, 5 specimens of PVC were taken with different aging time (12, 24, 50, 100 and 200 hours). The parameters used for the measurements are mentioned in Table 1.

Results

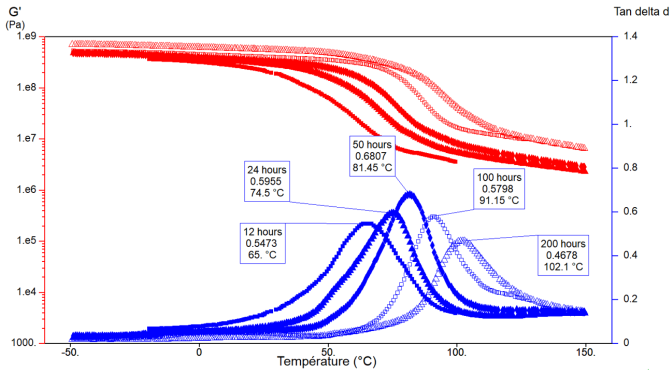


Figure 3. G' and tan δ as a function of temperature at 5 Hz for the five specimens.

Figure 3 shows the results obtained for the five temperature ramps for the five specimens aged 12, 24, 50, 100 and 200 hours. The results are shown in terms of shear storage modulus (G') and tangent delta.

It can be observed from figure 3, that the strength of material is increasing with the aging time. This behavior can be attributed to the fact that the polymer becomes denser and hence the mobility of the polymers molecules slows-down leading to the increased stiffness of the material.

This phenomenon of aging impacts the glass transition temperature (Tg) of the material too. The Tg of the 5 differently aged specimens (12, 24, 50, 100 and 200 hours) was found to be ~65˚C, ~75˚C, ~82˚C, ~91˚C and ~102˚C respectively. The polymers suffer a fast cooling from high temperatures during their industrial processing and hence are found in a thermodynamic non-equilibrium state. As a consequence of this non-equilibrium state, the molecular conformation of macromolecules changes slowly through a spontaneous relaxation to help them reach an equilibrium state [1]. As a result, aged polymers present a Tg above the un-aged Tg.

Conclusions

This study shows the importance of analyzing the aged polymers. This analysis could be helpful in determining the lifespan of the respective polymers.

The temperature sweep was performed from -50˚C to 150˚C on five different specimens aged 12, 24, 50, 100 and 200 hours. The G' and Tg were observed to increase with the increase in aging of PVC.

References

1. Rikardo Minguez et al. A simple approach to understand the physical aging in polymers. European Journal of Physics, 2018, 40, 015502.

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More info: www.metravib-materialtesting.com