# DEVELOPMENT OF EXPERIMENTAL METHODS FOR DETERMINATION OF RHEOLOGICAL PROPERTIES OF POLYMERIC FILMS

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## 1. Introduction

PVC or poly(vinyl chloride) is one of the most widely used synthetic materials in the world. Its usage ranges from biomedical devices, electrical cable and telecommunication cables and wires, insulation, construction, clothing, non–food packaging, heritage collections, artificial leather for automotive interiors and many other products where rubber can be replaced, e.g. [1]. PVC long-term stability depends on loading conditions. The literature contains reports presenting mechanical and electrical stability studies [2].

Tensile strength is the most often specified property of thermoplastic materials used to indicate the inherent strength of the material [3]. Tensile strength is dependent on the molecular structure and the orientation of the macromolecules within a particular sample. Tensile strength and elongation are also affected by the velocity of deformation to which the samples are exposed [4].

The goal of the research is to perform the experimental analysis on thin films with the aim to provide necessary information for determination of their viscoelastic mechanical properties. In this study, the tensile stress/strain behaviour of PVC consumer thin film materials was characterized using the commercial tensile machine Instron 3342.

## 2. Experimental

In our work, we observed the influence of different loading velocities on the stiffness of polymer films at room temperature. The test samples were prepared in the shape of strips with an average size of 10 x 70 mm, with a thickness of 0.1 mm. All strips were checked for any imperfections and were measured by a micrometer.

DSC measurements were performed on PVC films to determine $T_g$ and melting temperature of the material. The measurements were performed with the heating rate of 10 K/min under air atmosphere using thermal analyser Netzsch STA 449 F3. For the selected PVC foil, glass transition temperature was $T_g$ = 36 °C, and the melting temperature was 121°C.

The specimens were exposed to axial deformation with a constant rate of deformation using the commercial tensile machine Instron 3342, controlled by a digital controller. Motion of the cross-head measured the change in gage length and hence the strain. A high precision load cell with a resolution of mili-Newton measured force on the test specimens and hence the stress. The measurements were performed at five different constant strain rates. The samples were clamped 5 mm from the edges of the strip using clamping pressure of 2.5 bar for all measured samples. After clamping, the material was left to relax for approximately five minutes. After the samples were preconditioned, the distance between the grips was accurately measured, and the measured values were considered as the initial length of samples (gauge length), from which strain was calculated.

Measurements were conducted at five different loading velocities, i.e. 0.1, 1, 10, 50, and 100 mm/min. All measurements were made at room temperature. The samples were tested five times for every loading velocity, and the average values with corresponding deviations were calculated.

Experimental results show that PVC films exhibit extremely viscoelastic (time-dependent) behaviour at room temperature. Loading velocities significantly affect the viscoelastic response of PVC films subjected to tensile loading. We observed significantly pronounced changes in stiffness at smaller velocities rather than at higher velocities. This is due to the fact that with increasing strain rate, polymer chains are less susceptible to relaxation mechanism and are less likely to be oriented in the direction of displacement.

## 3. Results and discussion

In this study, tests were performed at a different range of strain rates. The stress-strain curves at different strain rates under tensile loading conditions are shown in Fig. 1. The observed behaviour of PVC at a wide range of stress rates and is much dependent on loading velocity. We observed higher stiffness of the material for higher loading velocities, and stress relaxation continuously occurs along with deformation. A stress relaxation process randomly orientates coils of polymer chains and aligns them in the displacement direction [3]. As the strain rate increase, polymer chains are less prone to relaxation mechanism and, have less chance to be oriented in the displacement direction resulting in a shorter effective length of polymer chains supporting the load, and the material exhibits a higher tensile modulus (Fig. 2).

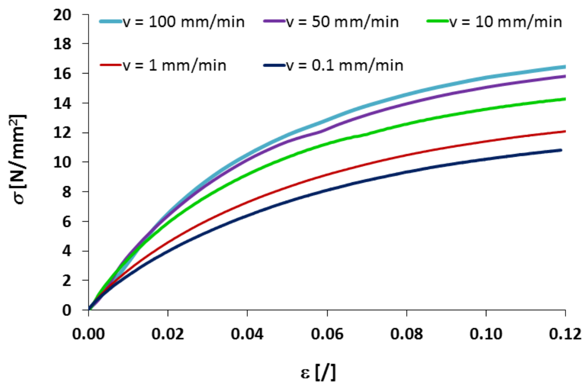


**Fig. 1.** Stress-strain curves of measured PVC foils at five different velocities.

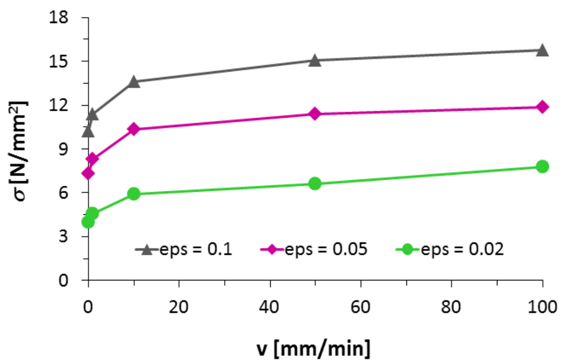


**Fig. 2.** Stress as a function of loading velocities for PVC foil at three different strains.

## 4. Conclusions

Prepared PVC samples were exposed to uniaxial tension with five different loading velocities. Uniaxial tension mechanical behaviour of PVC is significantly affected by the strain rate. Increase in strain rate results in higher apparent toughness and higher apparent stiffness. From the obtained results we concluded, that loading velocities have a significant influence on the viscoelastic response of PVC films subjected to tensile loading and that stiffness changes are more pronounced at smaller loading velocities than at higher speeds. The experimental results showed that PVC films exhibit extremely viscoelastic behaviour at room temperature and understanding its rheological properties (viscoelastic moduli) in confined geometries, such as in thin polymeric films, is critical to the stability of structures of many applications.

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