The Role of Rheology in the Morphological Properties of Injection-Moulded TPEs for Battery Applications

M.Fernandez[1], A. Burgoa[2], F. Garitaonandia[2], M.I. Itxaso[1], R. Aguirresarobe[1].
[1] POLYMAT and Faculty of Chemistry of Basque Country, UPV/EHU, Donostia-San Sebastian, Gipuzkoa, Spain.
[2]LEARTIKER S. Coop., Markina-Xemein, Bizkaia, Spain

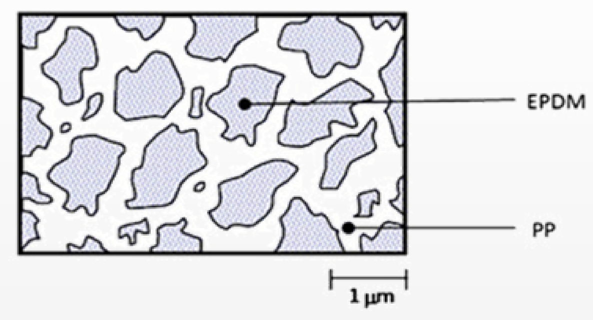
INTRODUCTION

Electric and hybrid vehicles are demanding new technologies and battery module designs incorporating solutions based on polymeric materials. This project explores the possibility of replacing the traditional aluminum plates in the batteries with plates made of **thermoplastic elastomeric materials** (TPEs) processed **by injection moulding**.

Although injection process is predominately dominated by shear flows, there are also **elongational flows** which will ultimately determine the phase morphology of the TPE. Therefore, the aim of this work is to **gain a better understanding of the effect of processing conditions** on the final phase morphology of injection moulded TPEs.

The elongational viscosity of a TPE has been determined at processing temperatures using different methods: convergent flow at the entrance of the capillary, by the analysis proposed by Cogswell, Rheotens device (melt spinning) and the 'Elongational Viscosity Fixture' (EVF), specifically designed to facilitate the measurement of the extensional viscosity of high viscosity materials.
The **effect of the pressure dependency of the viscosity** is considered trough Pressure-Volume-Temperature data. The pressure-viscosity coefficient is calculated by means of a revisited version of the Miller equation that accounts for pressure and temperature effects.

EXPERIMENTAL

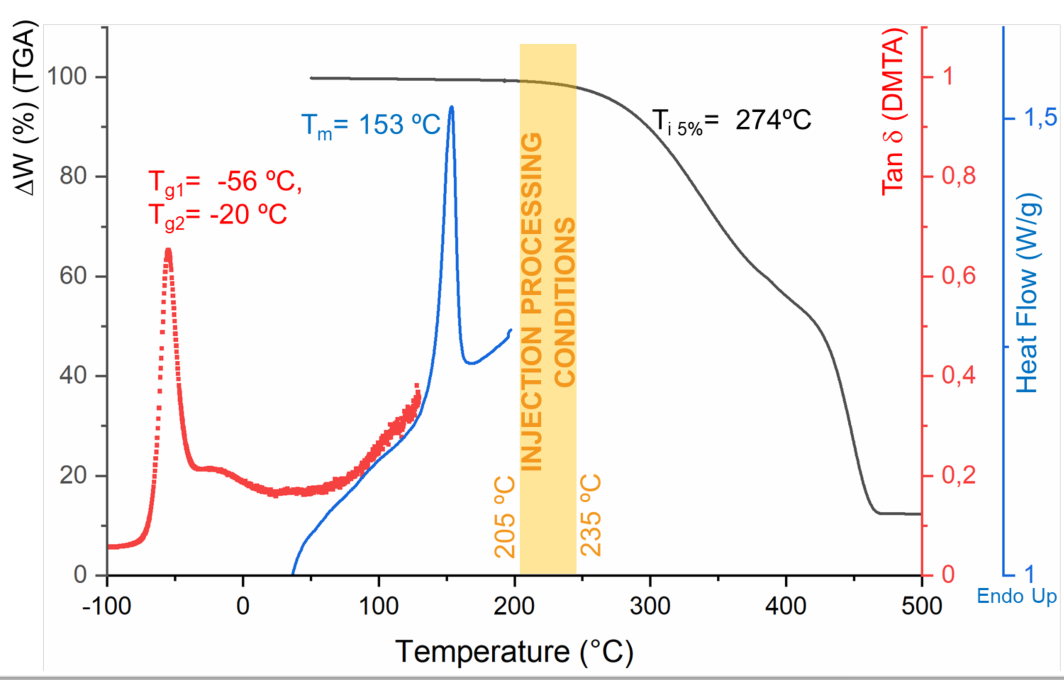


Material
Santoprene™ 101-55, polyolefin-based thermoplastic vulcanized (ExonMobbil).

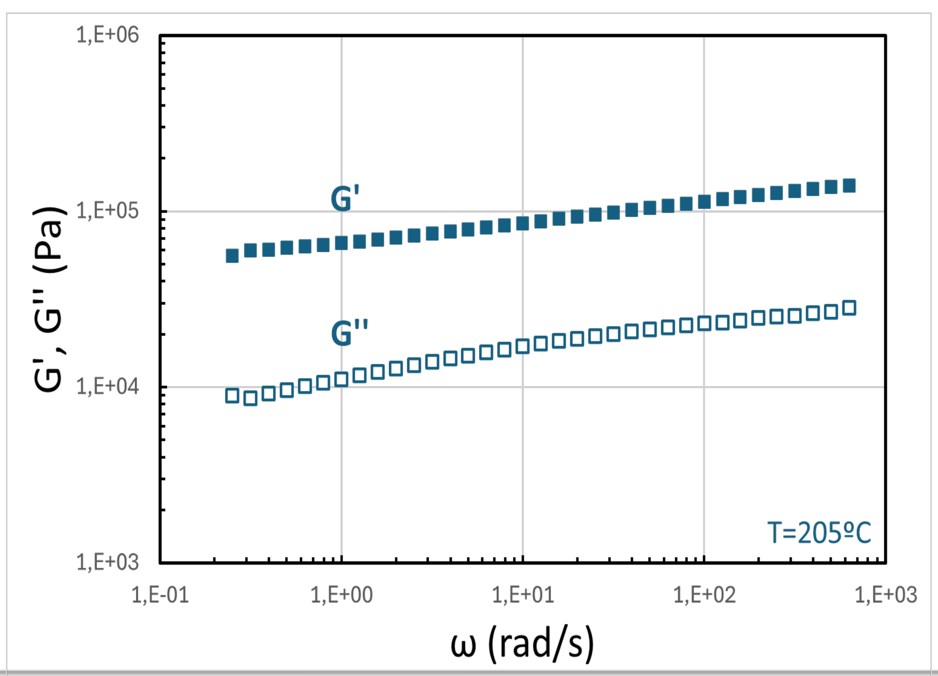
General characterization
Dynamic-mechanical analysis (DMTA, bending, 3 ºC/min), Differential Scanning Calorimetry (DSC; 20 ºC/min), Thermogravimetry (TGA, N_2, 10 ºC/min), Pressure-Volume-Temperature (PVT, 5 ºC/min).

Rheological characterization
Small Amplitude Oscillatory Shear (SAOS, LVR deformation), Capillary rheometry (L/D 60, 30, 20, 10, 0,2), Rheotens ($\dot{\gamma} = 100\ s^{-1}$, standard wheels, a= 2.4 mm/s²), EVF ($\dot{\varepsilon}$=0.03, 0.1, 0.3, 1, 3 s⁻¹).

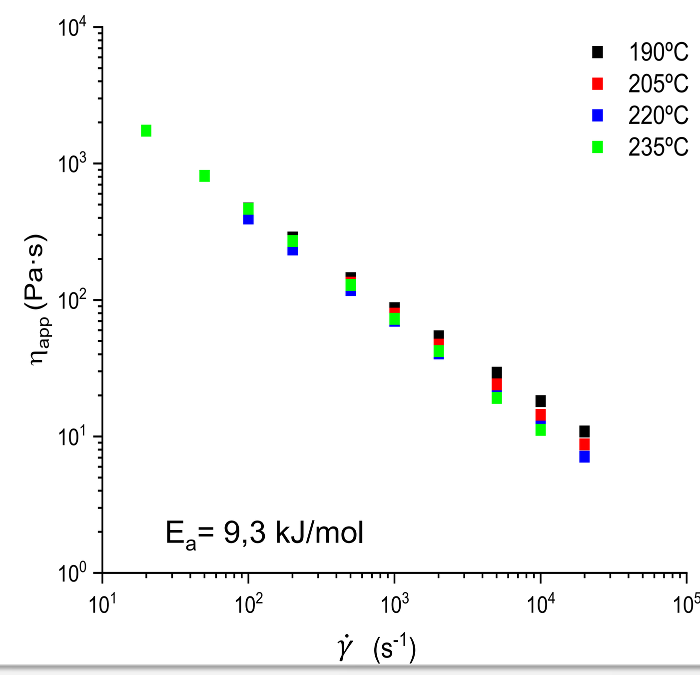
▪ THERMAL TRANSITIONS



▪ VISCOELASTICITY

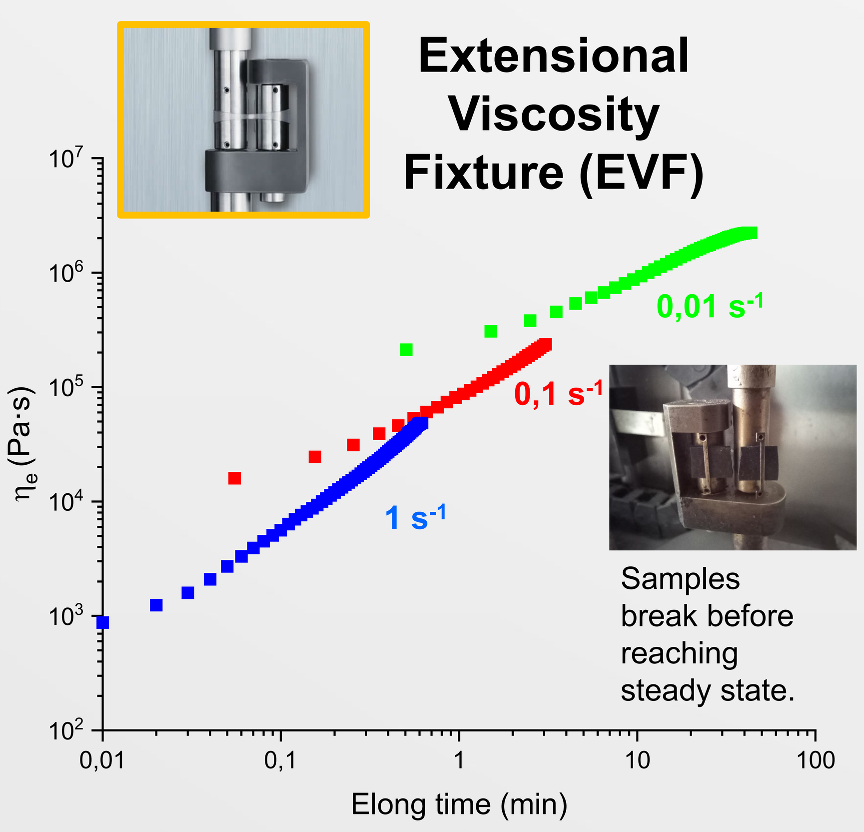


• CAPILLARY EXTRUSION

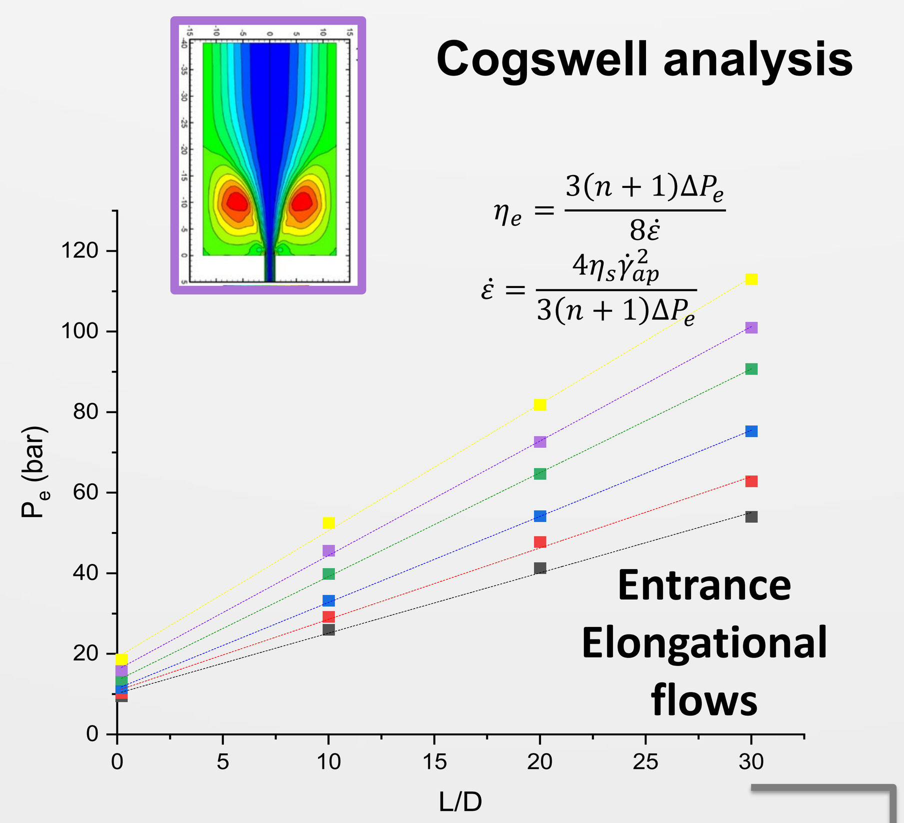


ELONGATIONAL VISCOSITY

Extensional Viscosity Fixture (EVF)



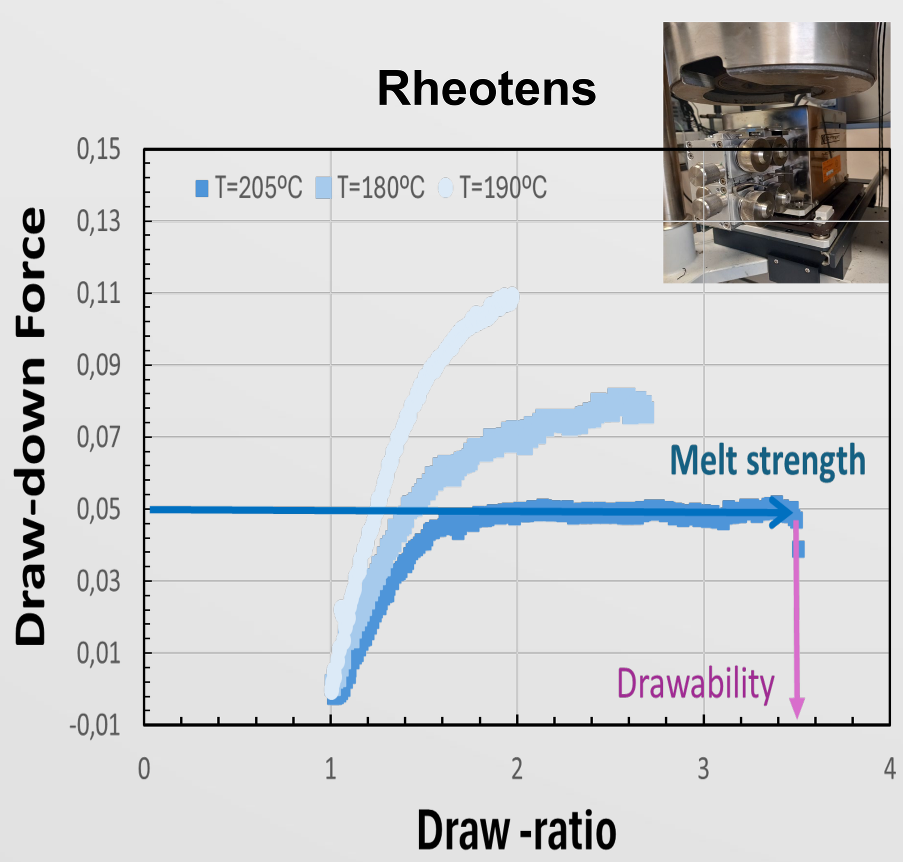
Cogswell analysis

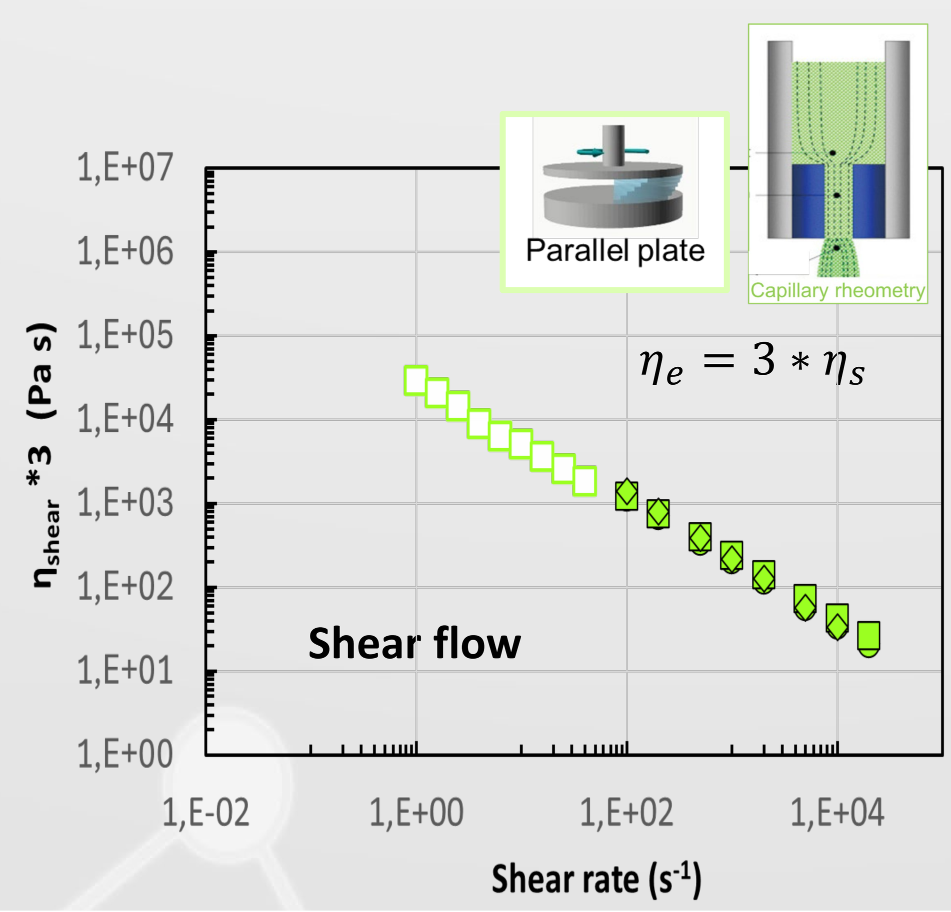


$$\eta_e = \frac{3(n+1)\Delta P_e}{8\dot{\varepsilon}}$$

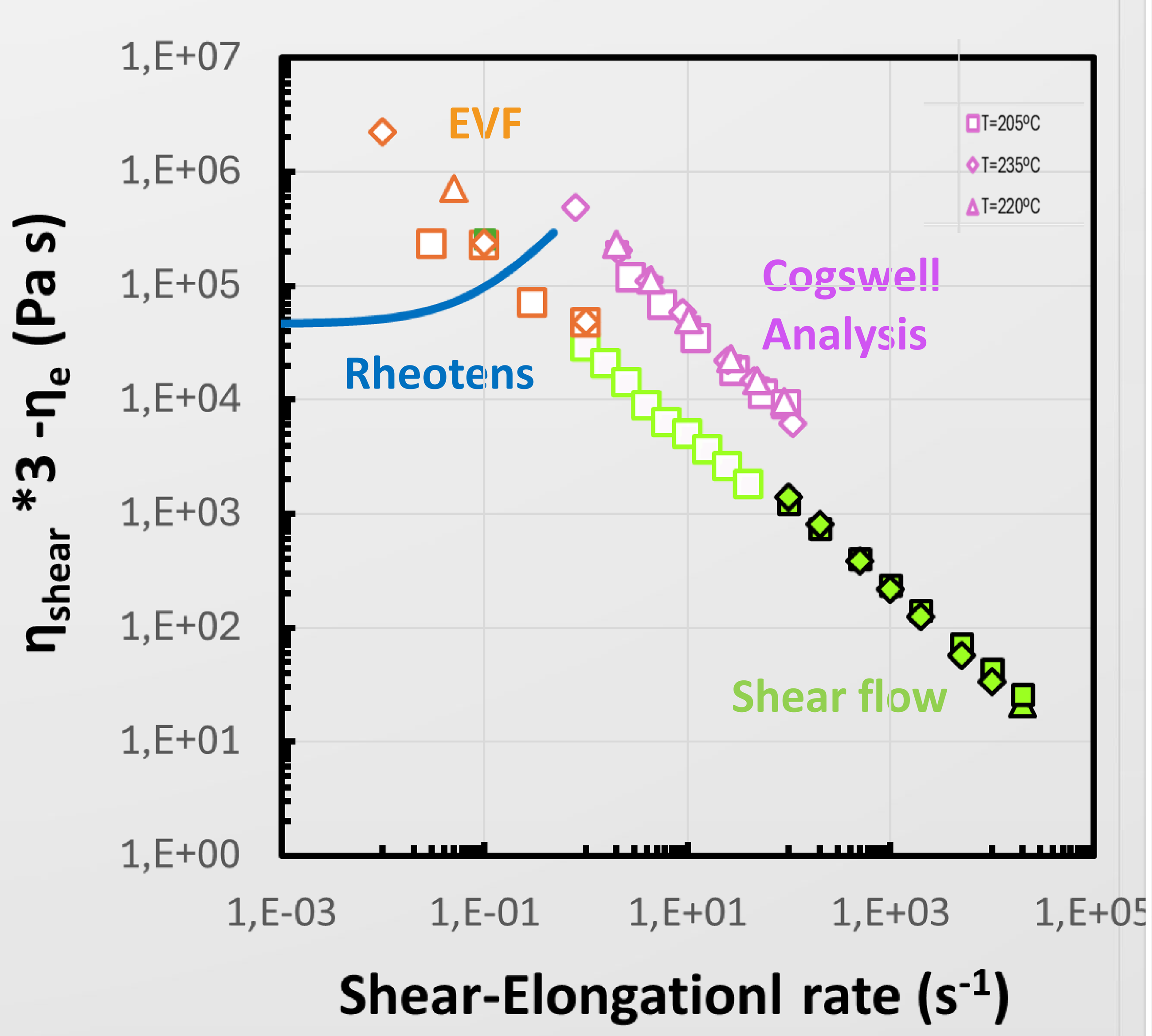
$$\dot{\varepsilon} = \frac{4\eta_s \dot{\gamma}_{ap}^2}{3(n+1)\Delta P_e}$$

Rheotens





$$\eta_e = 3 * \eta_s$$



VISCOSITY-PRESSURE COEFFICIENT

$$\left(\frac{\partial T}{\partial P}\right)_\eta = \frac{(\beta V)_T}{K} = \frac{(\beta V)_T}{(\beta V)_{T_g}} \frac{dT_g}{dP}$$

where β is the compression coefficient, V the specific volume and T_g the glass transition temperature.
Considering the Vogel–Fulcher–Tamman–Hesse (V–F–T–H) viscosity dependence on temperature [16,17]

$$\eta_0 = A + \frac{2.3B}{(T - T_0)}$$

the following expression was obtained

$$b = -\frac{2.3B}{(T_0 - T)^2} \frac{(\beta V)_T}{(\beta V)_{T_g}} \frac{dT_g}{dP}$$

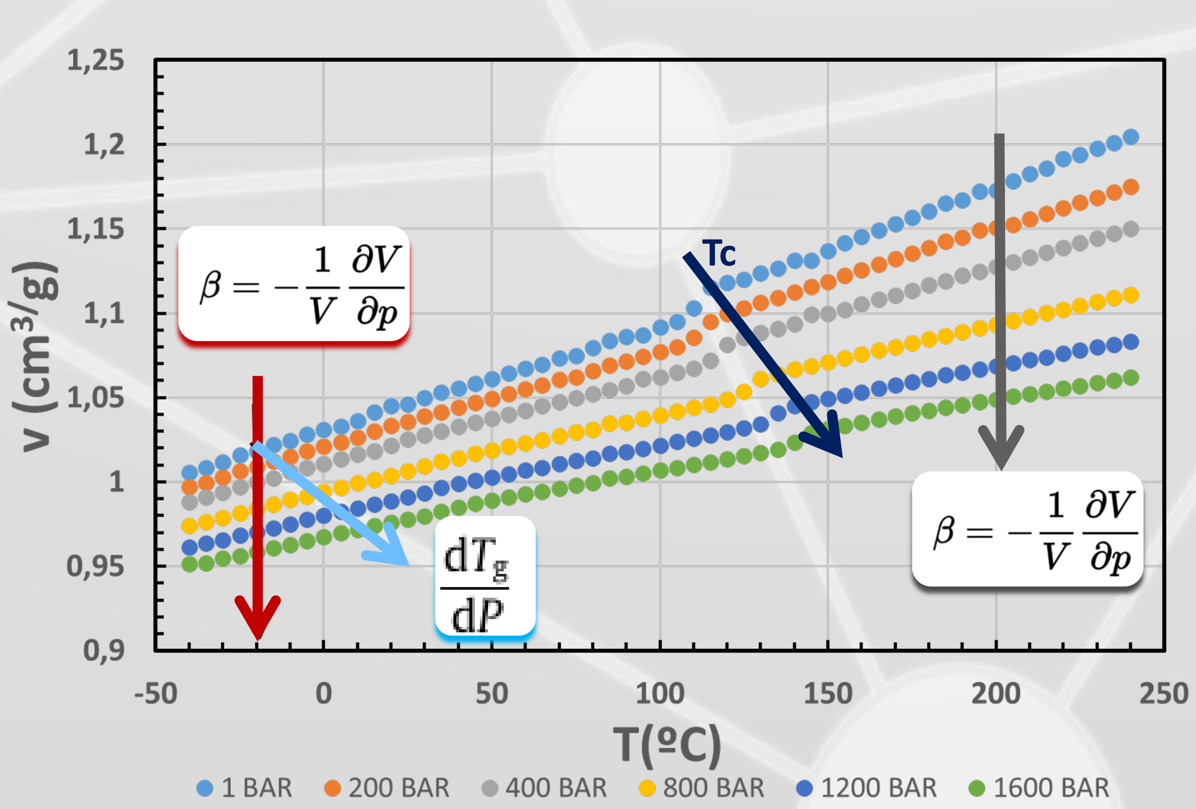
Temperature effect Arrhenius-like

E_a= 2,2 kcal/mol

Pressure effect

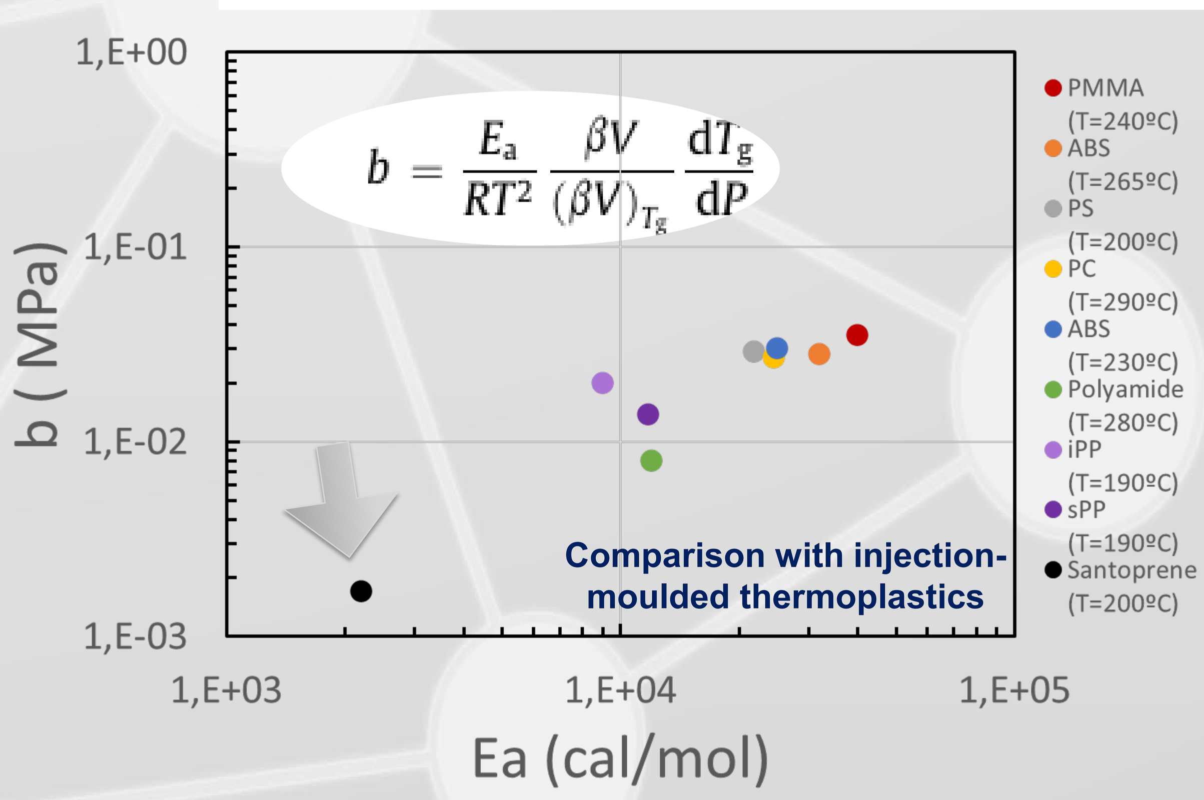
$(\beta V)_{T=200ºC}$=9,8 10^{-10} Pa^{-1}
$(\beta V)_{Tg}$=4,3 10^{-10} Pa^{-1}
dTg/dP= 1,5 10^{-7} ºPa^{-1}

doi.org/10.1016/j.polymertesting.2008.09.008



$$\beta = -\frac{1}{V}\frac{\partial V}{\partial p}$$

$$\frac{dT_g}{dP}$$



$$b = \frac{E_a}{RT^2}\frac{\beta V}{(\beta V)_{T_g}}\frac{dT_g}{dP}$$

CONCLUSIONS

Shear and elongational viscosity, and the effect of pressure on viscosity are key parameters for understanding injection processing.
We observe that extensional viscosity shows differences depending on the type of experiment: Trouton's rule provides the lower limit of elongational viscosity, whereas the use of EVF geometry provides the upper limit, as it involves unsheared sample subjected to pure elongational flow. The Cogswell's analysis allows data to be obtained at elongation rates similar to those during processing. The Rheotens experiments was consistent with Cogswell's analysis. The effect of pressure, determined from PVT parameters, seems to be negligible for this material, primarily due to their low activation energy of flow.

ACKNOWLEDGMENT

Polymat acknowledges the Basque Government for financial support associated with ELASBAT project (ELKARTEK 24/33, KK-2024/00091).

EPF European Polymer Congress
22 -27 June 2025