The understanding and interpretation of the macroscopic mechanical behaviour of polymers require the monitoring of the morphology evolution during deformation spanning several scale-lengths. This multi-scalelength approach enabled the identification of deformation processes, intensively studied for semicrystalline polymers (e.g., polyolefins) [1-4], mainly for simple initial microstructural states (spherulite or highly oriented structures). The availability of synchrotron X-ray sources allowed the study of complex morphological changes during deformation at relative high strain-rates, by collecting time-resolved simultaneous WAXS and SAXS and stress-strain data [1, 4]. This enables the correlation of the evolution of the crystalline phase features to the macroscopic behaviour. Recently, Davies et al combined tensile testing and synchrotron radiation WAXS to investigate the morphology changes during deformation of polypropylene with different thermal treatments[4].

This project aims at study deformation mechanisms at different temperatures and strain-rates taking into account initial polymer morphology, combining structure sensitive characterization techniques (e.g., SAXS and WAXS) and true stress-true strain behaviour. Particularly, it is investigated the evolution of the crystalline morphology of polypropylene, PP, during stretching from different initial morphological states. Specimens were compression moulded with variations of the melting and cooling temperatures. They were stretched at different strain levels at synchrotron source at HASYLAB, A2 soft condensed matter beam line, DESY, Hamburg, Germany, while acquiring two-dimensional SAXS and WAXS patterns. Fig. 1 shows the evolution of the width of the specimens, \( W \) (taken at its middle position) and respective WAXS patterns. At low strain levels, \( W \) decreases rapidly as the neck is formed. The level of crystalline phase orientation changes dramatically once neck is fully developed (\( \lambda = 1.35 \)). These variations are qualitatively similar for the other specimens having distinct initial morphological states, except for high melt temperature processed specimens that show a higher degree of brittleness (no neck).

Figure 1: Evolution of the specimen width (at its middle position) and WAXS patterns with draw ratio, \( \lambda \) (compression moulding conditions: low melt and cooling temperatures).
Figure 2 shows the evolution of the relative degree of crystallinity and level of crystalline phase orientation with the draw ratio ($\lambda = l/l_0$) for specimens moulded with different cooling temperatures (and the same melting temperature). The trends are identical for all the specimens, but with distinct evolutions between different initial and reached levels of both morphological parameters. This structure dependence (also shown in the variations of $W$ with $\lambda$) are reflected on the stress-strain curves (the initial modulus and yield stresses increase with the cooling temperature, as also slightly do the flow stress (stress level in cold-drawing region) and the strain-hardening, but the strain at break is reduced).

The orientation level increases locally with $\lambda$ until a maximum is reached, corresponding to the fully development of the neck. On the other hand, the local relative degree of crystallinity remains almost constant during the initial deformation stages and dramatical changes only occur just after the full neck is developed.

Future developments of the work will consider: a) a more quantitive analysys of acquired data (e.g., the slopes and patamars of the curves shown in Fig. 2); b) the simultaneous aquisition of in-situ structural data and true stress-true strain curve (the stretching device has been automated (motor) and instrumented (being measured force, displacement, and specimen geometry); c) the effect of other initial morphological parameters (e.g., level of orientation, crystalline forms).

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