Mechanical performance of i-PP: the effect of cooling rate

Cavallo, D.; van Erp, T.B.; Peters, G.W.M.; Govaert, L.E.

Published: 01/01/2011

Document Version
Accepted manuscript including changes made at the peer-review stage

Please check the document version of this publication:

• A submitted manuscript is the author's version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
• The final author version and the galley proof are versions of the publication after peer review.
• The final published version features the final layout of the paper including the volume, issue and page numbers.

Link to publication

Citation for published version (APA):

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

• Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
• You may not further distribute the material or use it for any profit-making activity or commercial gain
• You may freely distribute the URL identifying the publication in the public portal ?

Take down policy
If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Download date: 07. Dec. 2018
Introduction
The production of any type of polymer goods involves a cooling step to consolidate the desired shape. In order to increase productivity, high cooling rates – typically spanning from a few to several hundreds of °C/s – are imposed. The industrially relevant example of isotactic polypropylene is considered in the Continuous-Cooling-Transformation diagram of Figure 1.

![Continuous-Cooling-Transformation diagram of i-PP.](image)

With increasing cooling rate from the melt, structure development takes place at progressively lower temperatures, and the thermodynamically stable monoclinic α-phase is progressively replaced by the metastable mesophase. The variation in mechanical properties associated with this structural transition is addressed in the present work.

Results and discussion
Polypropylene films around 200 um thick quenched at different rates were tested in constant strain rate or constant load experiments. Stress-strain curves of i-PP films (Figure 2 left) show a remarkable decrease of the yield stress with increasing cooling rate during solidification.

![Stress-strain curves (left) and creep curves (right) of i-PP specimens cooled at different rates.](image)

Moreover, when the same constant load is applied, samples crystallized under more drastic conditions are characterized by considerably shorter failure time (Figure 2 right).

Figure 2. Stress-strain curves (left) and creep curves (right) of i-PP specimens cooled at different rates.

The deformation kinetics can be used to predict durability of the material when submitted to constant load (Figure 3, right column). Indeed, for temperatures and load conditions where ductile failure is observed, the time-to-failure is simply calculated from the experimentally determined creep rate, \( \dot{\varepsilon} \), according to:

\[
t_f = \frac{\varepsilon_f}{\dot{\varepsilon}(\sigma, T)}
\]

where \( \varepsilon_f \) is a fitting parameter, constant for all the explored conditions, which represent the critical strain at failure.

Conclusions
The mesomorphic i-PP shows a drastic decrease of the mechanical performances respect to the α-phase, with a sensible reduction of material durability. This must be taken into account if a fast cooling step is involved in the production process.