TU/e technische universiteit eindhoven

TEIJIN

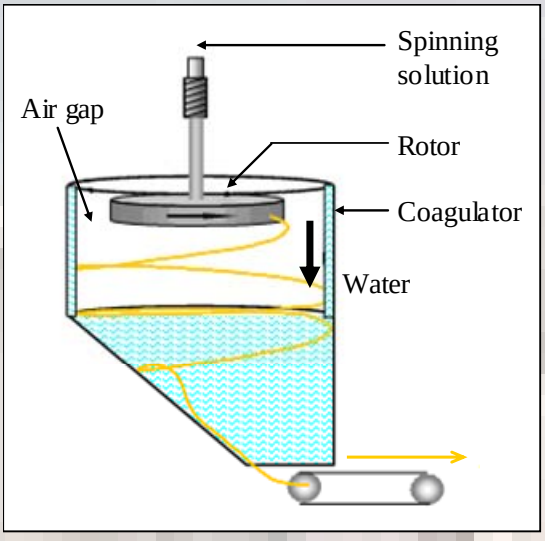
Mathematics for Industry

Filament Breakage in the Centrifugal Spinning Process

Carina van der Walt

Introduction

Teijin Aramid is an international company from the Netherlands which supplies customers with aramid polymers. Aramid fibers are a class of heat-resistant and strong synthetic fibers. Twaron, in particular, is used in a diverse range of products such as safety gloves, helmets, bulletproof vests, tires, and also as a replacement for asbestos. This project deals with one of the manufacturing processes of Twaron, the centrifugal rotor spinning process. In this process, polymers are spun from a rotating disk inside a coagulator.



Schematic view of the centrifugal spinning process

Problem Formulation

The lengths of the filaments produced in the rotor spinning process are restricted since filament breakage occurs. It is assumed that the filaments break between spinneret and coagulator wall. Understanding of the rotor spin process and reason of filament breakage can lead to the production of longer filaments and thus, improved products. Hence, the objective of this project is to perform a theoretical check on the mechanism of filament breakage between the rotor and coagulator wall, including the accompanying spinning conditions and machine geometry.

Mathematical Model

A dynamic mathematical model for the rotor spin process under isothermal conditions, without air friction, was developed using the balance of mass and momentum. We applied a linear stability analysis on the dynamic model which we implemented numerically. In the dynamic model we assumed a fixed filament position which gave us an analogy with traditional spinning including a volume force. The traditional spinning model was used to investigate the influence of a volume force on the stability of the traditional spinning process.

Solution Approach

Since the stability analysis is formulated around the steady-state solution, we investigated a numerical and analytical solution approach for the steady-state. However, the discrepancy found between the numerical and analytical solution of the steady-state rotor spin model, without air friction, still needs to be investigated further. The modeled filament trajectories are also validated against experimental trajectories captured close to the rotor.

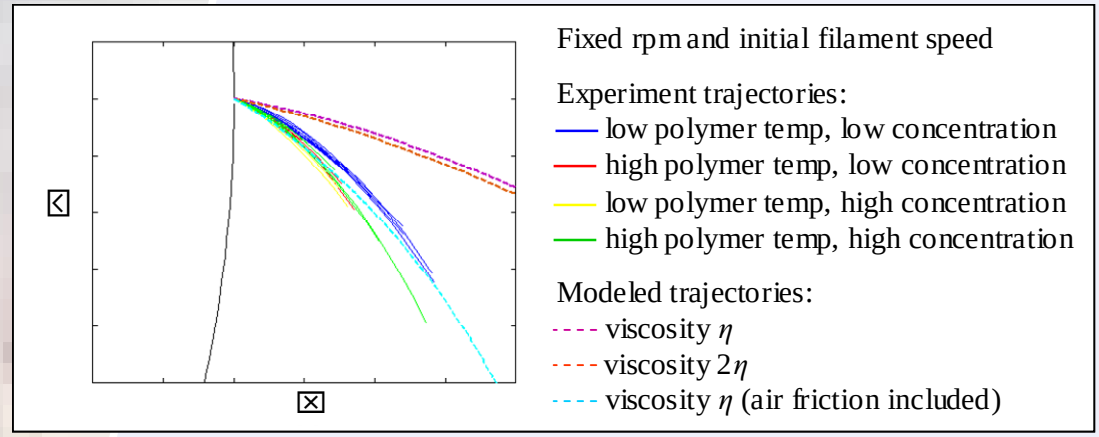
Filament Breakage in the Centrifugal Spinning Process

Carina van der Walt

Results

We were able to capture the filament trajectory close to the rotor to obtain better insight into the exit angle of the filament. The experiment results showed that from all the parameters varied the rotor speed has a significant influence on the filament trajectory close to the rotor.

In the dynamic rotor spin model we assumed a fixed filament position which gave us an analogy with traditional spinning including a volume force. Different volume force profiles were included into the traditional spinning model to investigate the influence of the volume force on the stability of the traditional spinning process. The results from the stability analysis on the rotor spin model strongly depend on both the steady-state solution and the dynamic boundary condition applied at the coagulator wall.



Trajectories of the rotor spin model (dashed lines) compared with experimental results (solid lines).

Conclusions

A few of the conclusions obtained from the project are as follows:

- We conclude from a comparison between the experimental and modeled filament trajectories close to the rotor, that air friction plays an important role in the position of the filament trajectory.
- We have derived a formula from the steady-state rotor spin model that gives us a relation between the momentum transport (the difference between the viscous force and inertia), the exit angle of the filament at the rotor, and the point along the filament where the momentum transport is zero.
- From the stability analysis we found that the centrifugal volume force along the spinning line of the filament trajectory has a stabilizing effect on the rotor spin model without air friction.
- The modes from the stability analysis indicate that the disturbance along the filament is a traveling wave from the rotor to the coagulator wall.

Contact

For further information please contact: A.C.T. Aarts, a.c.t.aarts@tue.nl, +31 40 247 2992.

Mathematics for Industry

Web site http://www.win.tue.nl/oowi/
Phone +31 40 247 4759 / 2808
Fax +31 40 247 2717
Email director s.j.l.v.eijndhoven@tue.nl
Email secretary w.w.p.warringa@tue.nl

Department of Mathematics and Computer Science
Mathematics for Industry
P.O. Box 513
5600 MB Eindhoven
The Netherlands