Production process optimization for an engineering textile

An analysis of the chemical coating

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Introduction

- A Dutch company produces high tenacity woven polyethylene terephthalate (PET) cords used in Lashing (to secure cargo on shipments). In order to increase the cord`s friction with buckles, a chemical finish is applied, composed of latex glue and a cross linker dispersed in water.
- The chemical finish is added and fixed to the PET yarns through the Thermofixation Line (TFL), seen on Figure 1. The cords are dipped in the solution containing additives and squeezed to release excess solution. Then, they go into the infra-red oven to dry the water. Finally, a gas oven is used to promote a reaction between the additives and the yarns.

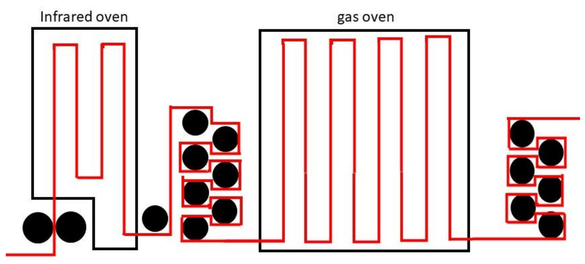

Figure 1: Diagram of the production line (TFL)

- The research`s governing question was: how to understand the process` chemistry while adding maximum value to the company regarding quality and recyclability?

Material & Methods

- Literature research throughout the project to substanciate findings.
- Study of additives: Attenuated Total Reflectance on Fourier-Transform Infra-Red Spectroscopy (ATR-FTIR), Nuclear Magnetic Ressonance (1HNMR, 13CNMR, COSY 1HNMR, HSQC), Thermogravimetric Analysis (TGA/DTG), Diferrential Scanning Calorimetry (DSC), Gel Permeation Chromatography (GPC), Gas Chromatography-Mass Spectroscopy (GC-MS).
- Study of virgin and coated woven yarns: ATR-FTIR, DSC, curing experiments varying kinetic parameters (amount of crosslinker, curing temperatures and times). Assessment of mechanical and thermal stabilities for the curing and recyclability evaluations.
- Measurements of temperature, residence times and humidity at the TFL.

Results

- FTIR, NMR, TGA, DSC, GPC and GC-MS confirmed the latex glue as an aqueous dispersion of polyvinyl acetate homopolymer.
- For the Cross linker the aforementioned techniques were not sufficient to determine the exact chemical structure of it although some considerations can be made; FTIR and NMR show that the compound is a non aromatic polyurethane with inactive isocyanate groups. The lack of an aromatic ring means that the compound requires higher temperatures to react, i.g. activate the isocyanate groups. GPC shows that the cross linker is an oligomer with two molecular weight distributions. This, allied with the decomposition profile recorded in the TGA measurement, indicate that the blocking of the isocyanate groups might be done via the uretedione method (isocyanate molecules that form dimers and trimers with themselves).
- GC-MS was attempted with WAX and HP5 columns on the additives. No peaks were observed.
- ATR-FTIR and DSC of fabrics before and after curing did not show any differences. Moreover, the former technique shows that the yarns do not have significant amount of hydroxyls present.
- Mechanical stability was tested by scraping the yarns with blades, which did not have any effect in removing the coating,
- Thermal stability of the coating in the cords was evaluated by immerging it in warm deionized water for two hours. After that time, the water had the additives color (opaque white) and smell. Furthermore, after evaporating the water, the residue was similar in weight as the theoretical amount of coating added, besides being yellow (color that glue acquires after being exposed to high temperatures). The results can be seen on Figure 2.

Figure 2: Water after cord immersion (left) and residue of evaporation (right).

- Measurements at the TFL show that the process does not ensure curing conditions (temperature and residence time) for the additives to react.

Discussion & conclusions

- Humidity and temperature measurements at the TFL show that the Infra-Red Oven is not capable of evaporating the water from the cords, which means that the evaporation mostly takes place in the gas oven, where only the reaction between the additives should take place.
- The thermal stability test and the measurements conducted at the Thermofixation Line together confirm that no curing (crosslinking reaction) happens between the PET yarns and the additives. This is due to the fact that time and temperature conditions to enable the reaction are not being stablished in the process. Furthermore, there might be an incompatibility between the compounds to react and form primary bonds (isocyanates react with active hydrogen containing compounds – it could require the PET yarns to have hydroxyls present in their structure).
- In addition, other factors could influence this system: small amount of additives in relation to the cord`s weight (approximately 0,33%) and occurrence of side-reactions (isocyanate reaction with water vapor present in the gas oven is favored);
- It was found that GPC cannot give accurate absolute molecular weight values. Moreover, ATR-FTIR and DSC techniques do not have enough sensitivity to evaluate the coating in the lashing.

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