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Bachelor degree in Materials Science

Analysis of the effects of Hot Drape thermal cycle and material exposure conditions in the mechanical and physical properties of prepreg materials

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of the requirements for the degree of

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Materials Engineering

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[1] https://github.com/joaomlourenco/novathesis [2] http://www.di.fct.unl.pt

"Put your desk in the corner and everytime you sit there to write, remember yourself why it isn't in the middle of the room. Life isn't a support system for art. It's the other way around"
- Stephen King

Acknowledgements

The acknowledgements. You are free to write this section at your own will. However, usually it starts with the institutional acknowledgements (adviser, institution, grants, workmates, ...) and then comes the personal acknowledgements (friends, family, ...).

Abstract

Since it's first use on Edison's incadescent lamp, carbon fiber has been studied and developed into an important resource in industry. This material is used in many forms but mainly in fiber rolls or tapes and is usually preimpregnated with resin. As such, it is processed and transformed using molds, whether it's only deposited using either Automated Tape Laying (ATL) or Automated Fiber Placement (AFP) or it's also hot pressed into a shape. Embraer has such processes and there's a need to assess the materials response to its exposure and its response to being processed.

Accordingly, to answer this need, a test proposal is made in order to evaluate the material and the process. This provides a guide on how to make the necessary arrangements and how to conduct said tests. Furthermore, exposure conditions are disclosured as well as the size of the specimens and panels to process. In the end, we'll be able to understand how different exposure conditions and how hot drape thermal cycle affect this materials.

Keywords: hot drape, carbon fiber, exposure conditions, aeronautics, prepregs.

Resumo

Independentemente da língua em que está escrita a dissertação, é necessário um resumo na língua do texto principal e um resumo noutra língua. Assume-se que as duas línguas em questão serão sempre o Português e o Inglês.

O *template* colocará automaticamente em primeiro lugar o resumo na língua do texto principal e depois o resumo na outra língua. Por exemplo, se a dissertação está escrita em Português, primeiro aparecerá o resumo em Português, depois em Inglês, seguido do texto principal em Português. Se a dissertação está escrita em Inglês, primeiro aparecerá o resumo em Inglês, depois em Português, seguido do texto principal em Inglês.

O resumo não deve exceder uma página e deve responder às seguintes questões:

- Qual é o problema?
- Porque é que ele é interessante?
- Qual é a solução?
- O que resulta (implicações) da solução?

E agora vamos fazer um teste com uma quebra de linha no hífen a ver se a LaTeX duplica o hífen na linha seguinte...

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Sim! Funciona! :)

Palavras-chave: Palavras-chave (em Português) ...

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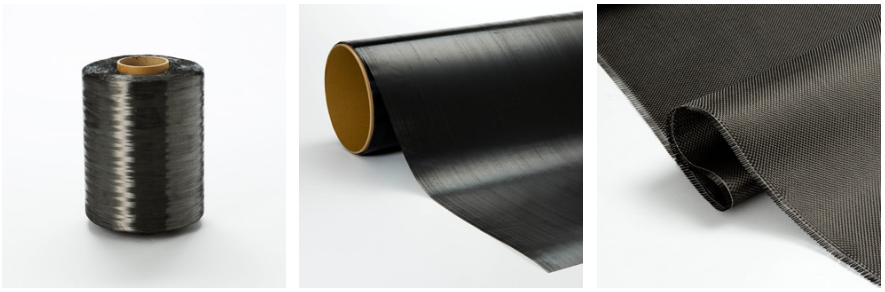
1.1 Carbon fiber based materials

Since the beginning of mankind, history has been separated into Ages, i.e. Stone Age, Bronze Age, Iron Age, etc. We are living in an Age which can't be described by a single material, since mankind is using more and more resources, which have a lot of diversity. Mankind can mix different resources now and call them "*composites*", make tiny little structures and call them "*nanostructures*" or use carbon based materials and make them one of the most rigid materials to existence. There is not a main field of resources which can be use to describe this Age we're living in. However, we are living in the best time to develop carbon based materials - with special regard to carbon fiber based materials. When talking about carbon fiber based materials, usually we refer to:

(a) **Carbon fiber** - simple rolls of carbon fiber;

(b) **Carbon fiber resin-impregnated tape or prepreg** - carbon fiber is unidirectionally aligned and then resin (typically epoxy) is impregnated;

(c) **Carbon fiber fabrics** - frabrics made with carbon fiber that can already be impregnated with resin;



(a) Carbon fiber rolled (b) Carbon fiber prepreg tape (c) Carbon fiber fabrics

Figure 1.1: Examples of carbon fiber based materials adapted from refs.

1.1.1 History and Applications

Despite being considered a modern technology and state-of-the-art, the use of carbon fiber filament was registered in Thomas Edison's electric incadescent lamp. To this day, carbon fiber fabrication has evolved, as it began with Edison's way: Carbonizing cotton and using it as filament, to the use of PAN precursors in Japan in the early 60's, to the batch fabrication we know from 1968 RAE patent, where it was highlighted this important conditions:

1. The oxidation temperature must be controlled below the temperature at which a thermal runaway occurs.

2. The degree of oxidation must be sufficient to penetrate to the center of the PAN (polyacrylonitrile) fiber.

3. Length shrinkage must be restricted during oxidation, or even some stretch applied to the fibers during oxidation.

4. After the oxidation stage, there no tension was needed in any subsequent carbonization stages.

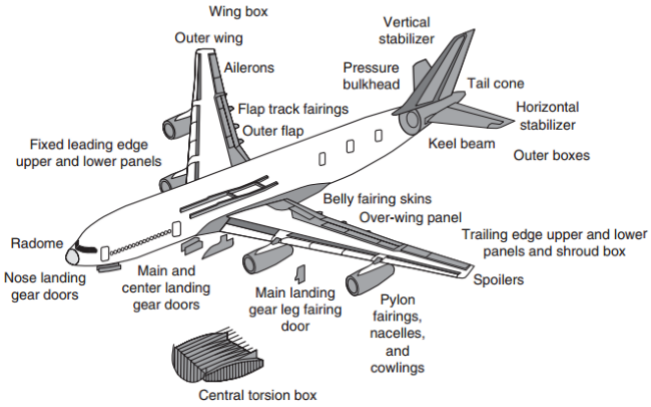
Carbon fiber range of applications vary depending on which precursor polymer is used, with many precursors being studied to produce carbon fiber while easy conversion to carbon fiber, high carbon yield and cost-effective processing being the main searched characteristics of the precursors used. The most popular precursors used are:

1. **Acrylic precursors** - Which have been the most sucessful in the industry world, with PAN being the most popular acrylic precursos for quite some time now;

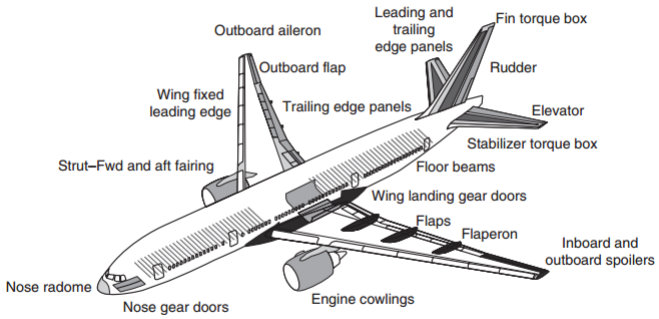
2. **Cellulosic precursors** - While containing 44% carbon, the process is more than simple dehydration, like Edison's filaments, and the carbon yield is only 25%.

3. **Pitch-based precursors** - In spite of having a 85% carbon yield, these precursors give carbon fiber a high modulus, due to the graphitic nature of these fibers, although the fibers have poorer compression and transverse properties compare to Acrylic precursors.

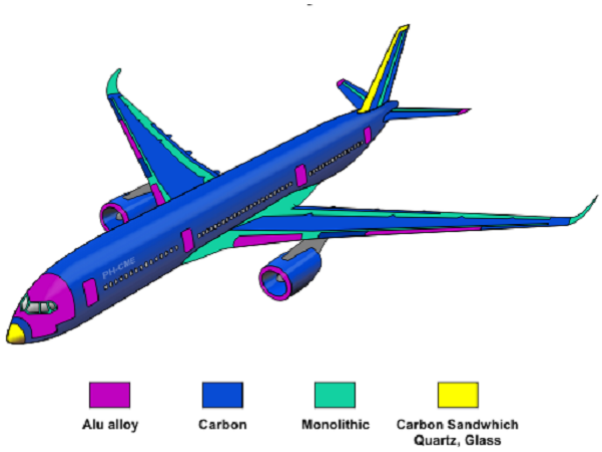
Other precursors, like Vinylidene chloride and phenolic resins are used as well, but were found not commercially viable. These materials have outstanding properties, like high stiffness, high tensile strength, low weight, chemical stability, good thermal and electrical properties, etc., which makes them the choice materials to the aeronautics and automotive industry, sporting goods, military and medical applications. In the aeronautic world, these materials have been meeting the demands, with the new Airbus A350 being made with more than 50% of this kind of material, including the wings and fuselage.



(a) Airbus A380



(b) Boing 777



(c) Airbus A350

Figure 1.2: Carbon fiber components in two major airplanes

1.1.2 Advantages and disadvantages of prepreg carbon fiber materials

Using a set of materials always starts with a study of why to use that specific material against other options, in order to find out exactly which material is the most capable of getting the job done faster, better and if possible, cheaper. The prepreg carbon fiber materials provide quickness in processing and better overall quality of the laminate. Although it's more expensive than just hand layup and it has a lower shelf life, unless stored in a freezer in -18ºC, to reduce the cure process.

One thing that has to be considered is the amount of resin as well, since most prepregs can be specific from the customer and can me from 30 to 45%, which result in less brittleness and better overall mechanic properties. This means less waste as well, since otherwise the impregnated carbon fiber would "bleed" resin in excess which is hard to clean up from the mold as well.

1.2 Processesing preimpregnated carbon fiber materials

1.2.1 Automated Tape Layup - ATL

1.2.2 Automated Fiber Placement - AFP

1.3 Hot drape process

1.3.1 Pressure and Thermal cycle