THERMOPLASTIC MATRIX COMPOSITES

Assignment 1-S1

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1. Introduction

The aim of this assignment is to describe and summarize how thermoplastic matrix composites are used in continuous fiber composites, the manufacturing processes, and the possible use.

Most of the thermoplastic matrix composites used today are injection-molded short E-glass fiber-reinforced thermoplastics. Increasing fiber length improves the modulus and strength, but long fibers are still much lower than the modulus and strength of continuous fiber-reinforced thermoplastics.

Continuous fiber-reinforced thermoplastics are more difficult to produce than short fiber-reinforced thermoplastics, mainly due to the difficulty of wetting the fiber surface with highly viscous thermoplastic liquid. However, several different processes have been developed to produce thin sheets of continuous fiber-reinforced thermoplastics.

The main problem of continuous fiber-reinforced thermoplastics is that the process is significantly more difficult and expensive than injection molding short fiber-reinforced thermoplastics due to the difficulty of incorporating continuous fibers in thermoplastic polymers. For this reason, even though continuous fiber-reinforced thermoplastics possess several advantages over continuous fiber-reinforced thermosets, such as lower processing time, higher fracture toughness, long shelf life, and recyclability, their applications are still very limited. [6]

In order to understand the differences between thermoplastic and thermosetting matrices it is possible to compare the main characteristics:

Thermoplastic Polymers	Thermosetting Polymers
• The polymer molecules are not chemically joined. • Are processed and formed by heat softening and/or melting. • High viscosity during processing • Are directly recyclable; however, the polymer properties may deteriorate with repeated recycling. • Have lower hardness then thermosetting polymers. • Are usually more ductile.	• The polymer molecules are chemically joined (crosslinked) at the processing stage. • Cannot be represented by heat softening or melting. • Have low viscosity during processing. • Cannot be directly recycled. • Have higher hardness than thermoplastic polymers. • Are usually more brittle.

2. Industrial applications of CFTPs

Continuous Carbon-Fiber-reinforced thermoplastic composites have been used in the aerospace, weaponry, automotive, and chemical industries because of their potential for construction of lightweight materials, high strength and stiffness, recyclability, repairability, and corrosion resistance.

Thermoplastic-matrix composites can be also used to make recyclable and eco-efficient products. In the automotive sector, it is required to have a minimum of natural based or recyclable content in the car.

Composites materials made with natural fibers are widely used, but their matrix is usually thermoset, making them impossible to recycle. Composites made of natural fibers and a thermoplastic matrix solves the problem, as the material is recyclable and a part of it is bio-sourced.

Research has been made to develop natural long fibers thermoplastics composites for frontal beams, made of polypropylene with glass and twisted kenaf fibers [1]. The polypropylene has been used because it is a very cheap material, and its mechanical properties are sufficient when mixed with fibers.

3. Manufacturing processes

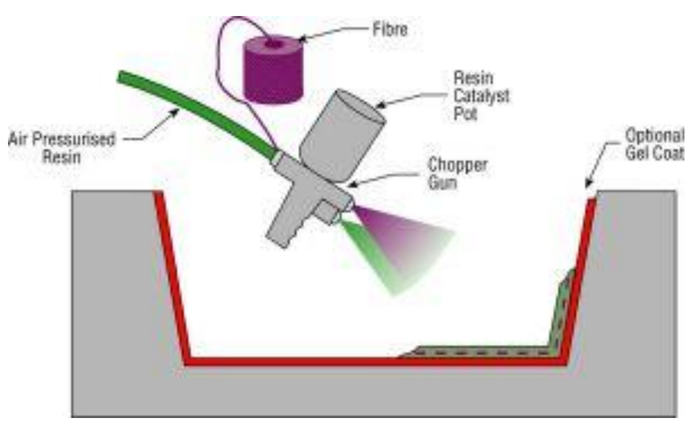
When manufacturing TP matrix composite pieces, two goals must be achieved:

The main goal in manufacturing TP matrix composite is to bond the fibers to the thermoplastic resin. This is the trickiest part. If the mix is not correct the mechanical properties will be lower than expected. Other problems can arise if this step is not respected, such as delamination, which is the most common problem with composites.[6] The second goal is to get the good shape for the piece. To orient the fiber in the desired way and in the required shape.

Multiple processes are available to complete these two objectives, several of which will be described here.

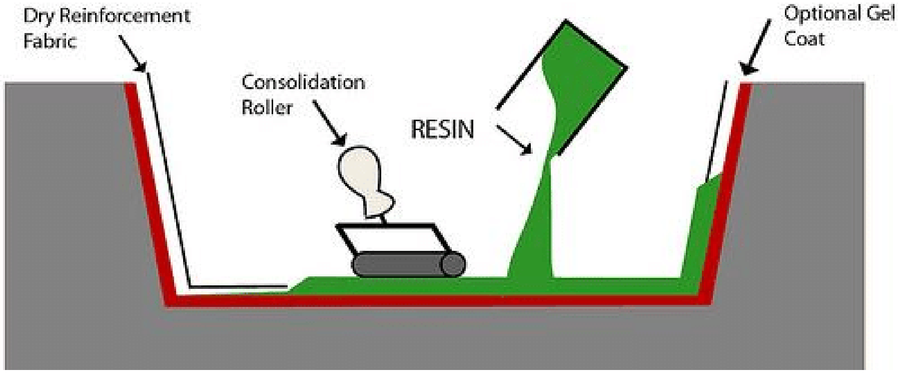
During the fabrication and shaping of polymer matrix composites into finished products, often the formation of the material itself is incorporated in the fabrication process. These processes include:

3.1.Spray lay up.



The fiber is mixed with the resin and the catalyst and then spray in the mold print.[6] A gel coat can be used to improve the surface quality and the demolding. The curing process depend of the resin used, it can be in an oven or a ambient temperature. This technique is simple and requires little investment. This process can be used for simple enclosures, lightly loaded structural panels.

3.2.Wet lay-up, Hand lay-up.



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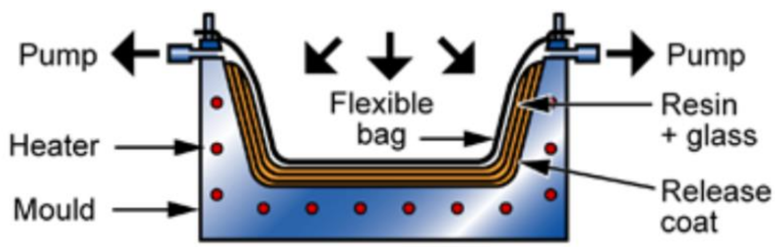
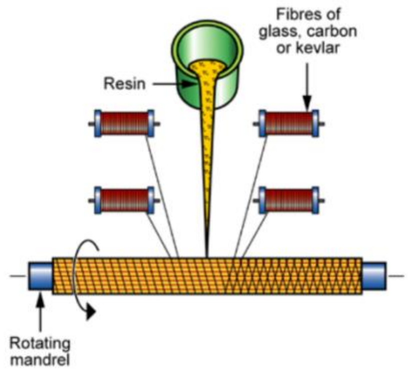
The difference between wet lay-up and spray lay-up is that the fiber is first put in the mold, and the resin/thermoplastic is added by hand with a brush or a roller.[6] The addition of resin is usually done by hand. Here too, the gel coat can be added before the fiber to improve the quality of the final product. This technique is easily learned, versatile and suitable for a wide range of fibers and resins. This process is still cheap compare to the next ones. This process is use for Wind-turbine blades and a lot of application.

3.3. Vacuum bagging.



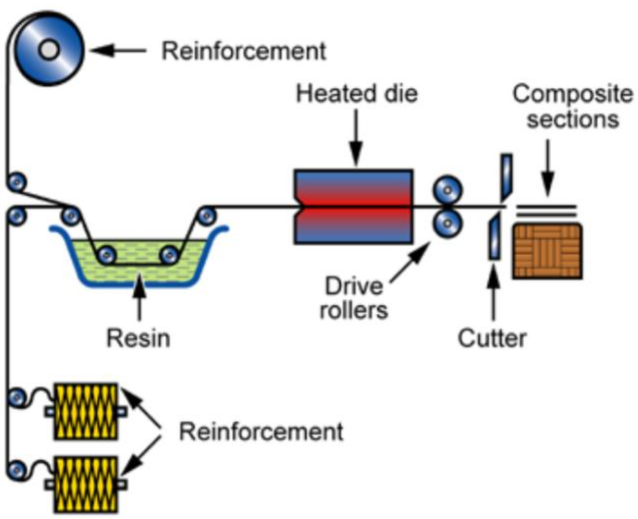
Vacuum bagging largely follows the same principle as wet lay-up. The difference is on the curing process. The curing is made this time in a vacuum bag.[6] Mold may be heated if the process is used to make finished goods. Compare to the wet lay-up, this process allows a Higher fiber contents, a lower porosity, and a better process control. This is used for large boat hulls, aircraft structures.

3.4.Filament winding.



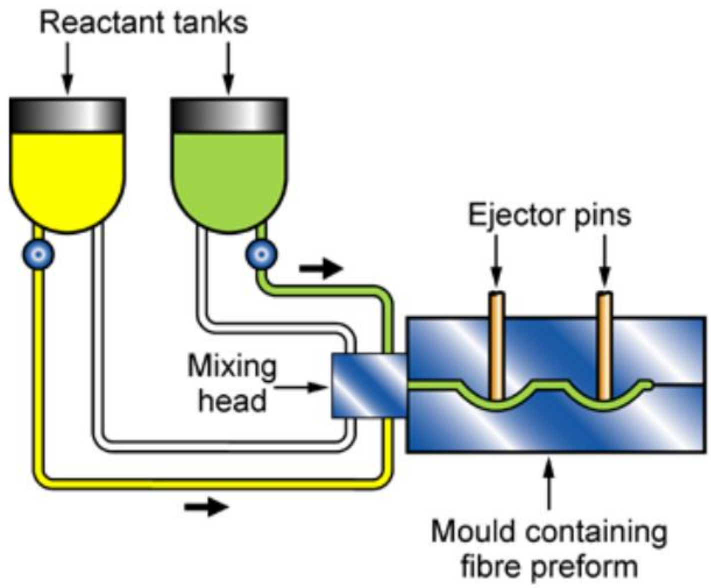
This process involves winding filaments under tension over a rotating mandrel.[6] The fibers are impregnated in a bath with resin as they are wound onto the mandrel. Further, the method allows for precise control of the direction of the fibers in the product. This process is usually use for pipes or another cylindrical object.

3.5.Pultrusion.



Pultrusion allows the production of profiles of constant section in large series.[6] The fibers are impregnated with a bath of resin and then heated in an oven. This temperature increase will provoke the polymerization of the resin. The final product is cut with the length wished.

3.6. Resin transfer moulding (RTM)



This method allows high-tech composite pieces.[6] The main advantages of this process is the precision and the surface quality of the molded pieces. A dry preform fiber pieces is introducing in the print of the mold, then with high pressure the resin is injected in the mold. The mold stay closed until the curing is finish and then the piece is ejected. However, this process is really expensive and only use for high quality composite.

3.7. Induction welding

Induction welding is a technique that has been widely used in metal manufacturing since the 1920s.[2] The process utilizes an induction coil that locally heats the desired components. The effect relies on the treated components either being electrically conductive or ferromagnetic. The method can be applied to thermoplastics reinforced with non-conducting fibers by supplying conductive or ferromagnetic particles (susceptors) at the weld-point. On the other hand, TPCs reinforced with e.g., carbon fibers can be heated by induction without introducing additional materials, as the fibers themselves function as susceptors.

The advantages of induction welding include precise control of the heated area, low energy consumption and the removal of the need for heated equipment to be in contact with the workpiece.[3] These advantages, combined with the greater ease of automating induction welding processes has made this technique gain popularity in recent years. Still, there are challenges regarding control of the heat distribution around the susceptors.

3.8. Ultrasonic welding

Ultrasonic welding is one of the most common methods of joining thermoplastic components and is considered to be one of the most promising welding techniques for CFTCs.[4,5] The technique uses vibrations at a frequency of 20-40kHz with an amplitude of 1-25µm to generate heat at the weld site.[4] This is the fastest known welding technique allowing for weld times in the range of 0.1-1s. Control of heat distribution in the weld is achieved by constructing energy directors (EDs).[5] These consist of protrusions or asperities designed to concentrate the thermal energy generated in such a way that areas that reach melting temperature can be precisely controlled.

4. Discussion

Thermoplastic matrix composites are very interesting regarding their recycling properties and their low prices, but they usually have worse mechanical properties than thermosets. There are also challenges involved with their manufacturing, because the polymer matrix requires heat to remain as a viscous liquid and be possible to manufacture.

Assembly of thermoplastic components poses a challenge regarding automation and control of heating depth. Contact between heated equipment and thermoplastic components leads to an increased need for maintenance and cleaning of equipment, as well as making automation difficult. Contactless heating components that are to be welded by induction can be a large advantage in this regard. Ultrasonic welding solves the problem by generating heat at the weld site. However, currently none of these methods are capable of complete large area welds in a single mounting.

5. Conclusion

The governing trend in manufacturing of all kinds is automation. Therefore, both ultrasonic and induction welding appear to be good contestants in the future of manufacturing complex CFTP parts that require assembly of different components. These methods cover different industrial applications, with induction welding offering precise control of the depth to which the work piece is heated, and ultrasonic welding being easily compatible with non-conducting materials. Therefore, these methods can be expected to coexist in future industry.

References

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