DESIGN, ANALYSIS, FABRICATION AND TESTING OF A COMPOSITE GEARBOX FOR ROTORCRAFT APPLICATIONS

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ABSTRACT: Our current effort is to convert a metallic gearbox for rotorcraft applications to composite. The challenge in transmission components is being highly loaded, tend to be thick sectioned and of complex geometry. In addition to the structural challenges in designing such a part lies a manufacturing challenge. The complex layup and quantity of material used leads to an expensive part in both labor and materials. Therefore it is desirable to utilize virtual manufacturing to reduce risk in manufacturing. In this study a complex gearbox will be fabricated using Resin Transfer Molding. Flow simulation will be conducted to locate injection and vent holes, as well as estimate fill times. Permeability characterization is done on the fabric. Finally, during the infusion, in-process monitoring is used to track the progress of the resin into the mold. The resultant part will be examined for the existence of void-free regions, and the simulation will be compared to the experimentally collected data.

KEYWORDS: Permeability, Flow Modeling, Process Monitoring, Helicopter

INTRODUCTION

We were tasked with converting a metallic transmission component to composite. The major driving factor was eliminating corrosion, while weight savings was also desirable. A previous effort [1] demonstrated the design and structural analysis of this component. This effort will focus on the processing, and how virtual manufacturing was used to reduce risk. The final design, shown in Figure 1, is made of 2 components, the input housing and output housing.

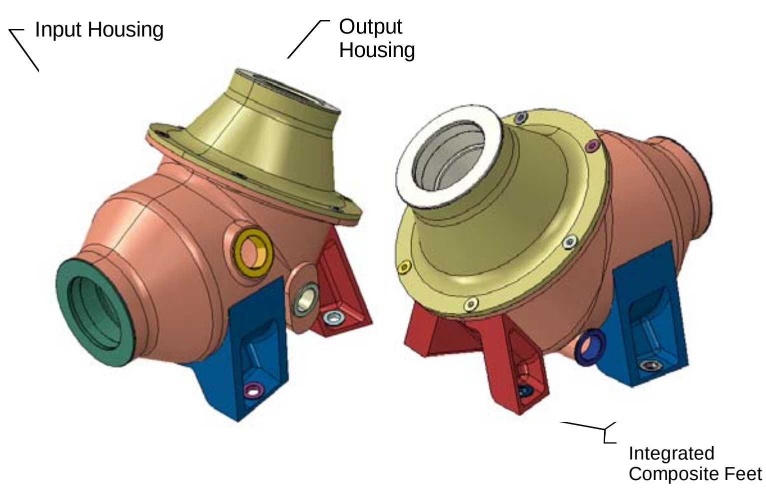

Figure 1: Final Gearbox Housing Design

Permeability Characterization

Prior to conducting the flow modeling, the permeability of the fabric was characterized. A series of 1-D constant pressure injection experiments were conducted. The flow front progression was tracked by a camera through the transparent lid. This was repeated for various fiber volume fractions by varying the number of layers placed into the mold. The results, shown in Figure 2, show an interesting result in that the warp and weft values of permeability cross at the lower end of the fiber volume fraction. Care was taken to ensure the data was properly analyzed, but these results do not make intuitive sense.

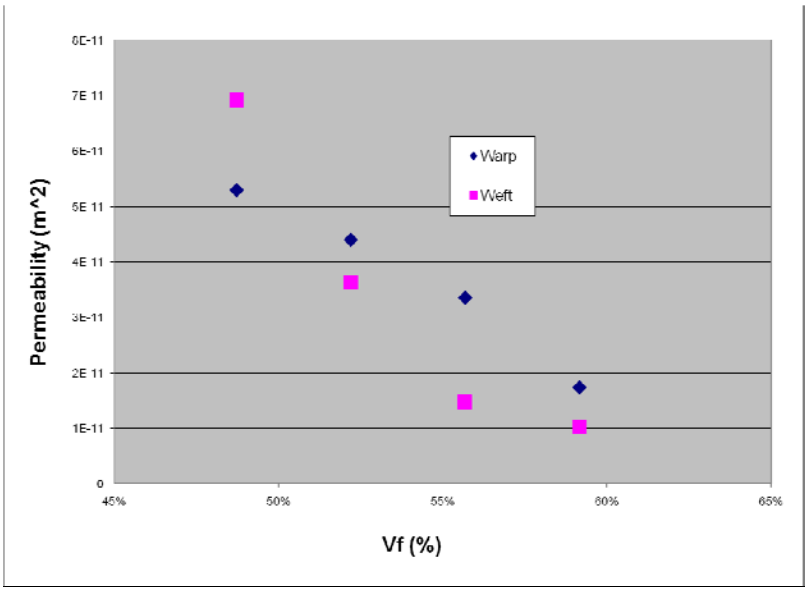

Figure 2: The permeability of the fabric

Process Simulation

The program LIMS [2] was used to conduct the resin flow simulation. A finite element mesh was prepared for both the input and output housings. Injection locations indicated in Figure 3 were selected to provide a uniform flow around the roughly cylindrical parts.

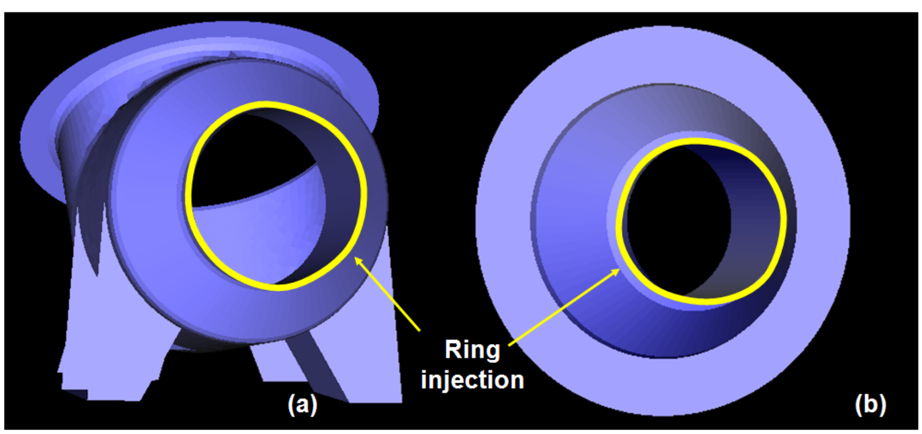

Figure 3: The proposed injection locations for (a) the input and (b) the output housings

With the gates set, the simulations were run. Figure 4 shows the results. In this, the different colors represent different times of resin arrival. Resin first arrives to the blue shaded region, and then proceeds to the green, than yellow, orange and finally red. Vents must be located at the last location of resin arrival, hence the venting at the two back feet. However, additional vents must be also placed where resin tends towards a corner or edge, potentially trapping air. For this reason, three additional vents were added.

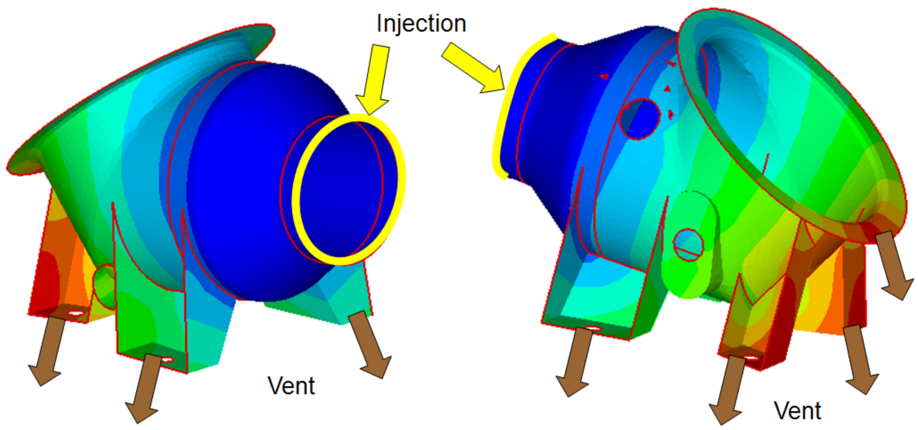

Figure 4: The results of the flow simulation for the input housing. Different colors indicate different times of resin arrival.

Figure 5 shows the results for the output, with vents location placed according to the same logic.

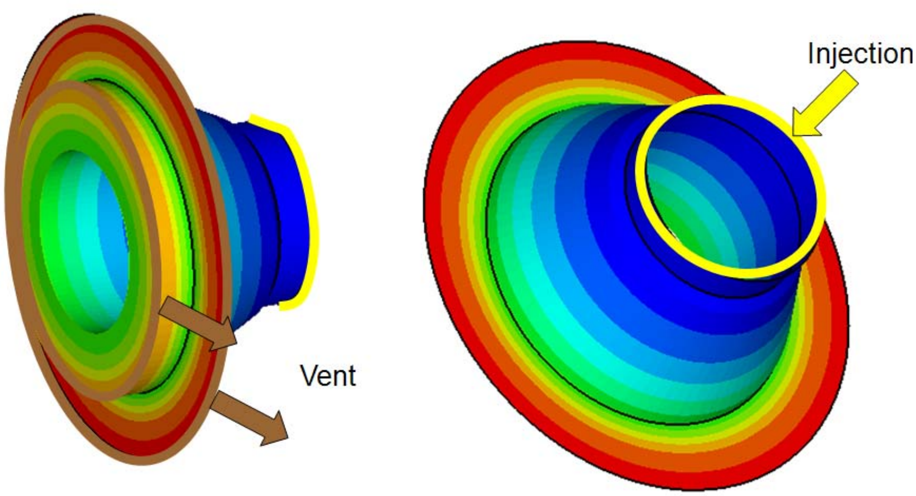

Figure 5: The results of the flow simulation for the output housing. Different colors indicate different times of resin arrival.

Tooling

With the gates and vents selected, the tool design and fabrication could be completed. The mold is a traditional RTM mold. It is meant to be closed and heated by a press. Additional heating is provided by internal cartridge heaters. It consists of a solid internal mandrel and an outer clamshell enclosure to form the necessary geometry.

Part Fabrication

With the tooling constructed, the composite gearboxes were manufactured. The first part fabricated was the tool proof, which was used to verify the fidelity of the mold, fiber layup, and processing parameters. Figure 6 shows the composite input and output housings assembled together. A quarter section of the output housing was removed to verify internal structure and reveals the foam core. Complete infusion of the part verified that the gate and vent locations decided upon through resin flow modeling were adequate. Due to geometrical complexity the first part fabricated posed some challenges in layup, mold closure, and de-molding. Great improvements were made over the next two parts fabricated.

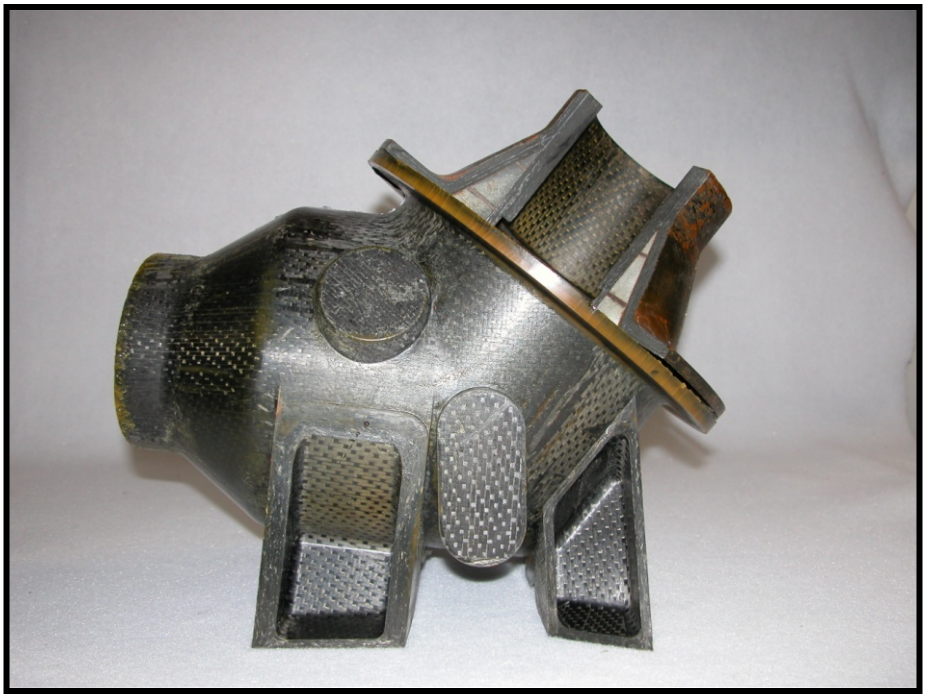

Figure 6: The fabricated composite input and output housings

Process Monitoring

While infusing the input housing, the resin progression through the mold was monitored by placing the resin bucket on a computer connected scale. Therefore the mass of resin in the mold could be tracked as a function of time. These results were compared to simulation, and the results are shown in Figure 7. Although the two do not compare exactly, the trend is similar, and the match was sufficient to ensure a complete wet-out of the part, which is of utmost importance.

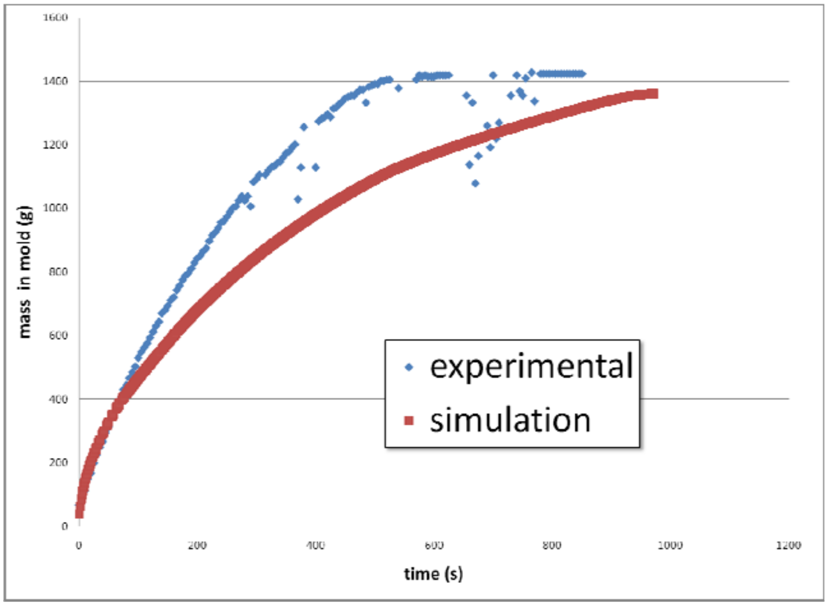

Figure 7: Comparison of experimental and simulated resin injection into the mold

Conclusion

In this study, the design requirements were understood for the next generation intermediate gearbox. To accommodate future needs, the gearbox was designed to handle a 50% increase in power throughput. VSC's composite design reduced the gearbox from three to two components and saves 25% in weight over the existing metal design. Virtual manufacturing aided in designing the appropriate mold and components were fabricated. Future testing will validate the analysis and applicability of this component for use and possible implementation.

REFERENCES

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