

CHAPTER 7: CONCLUSION AND RECOMMENDATIONS

7.1 CONCLUSION OF THE STUDY

The purpose of the study was to develop a composite manufacturing process that could deliver Class A surface finished products by means of IMC methods. It was found that this can only be achieved if a system approach is followed where each step in the manufacturing process from initial component design to final production adheres to a specific manufacturing process. Literature showed that there were several gaps in the knowledge base which required experimental investigation. To this end several objectives were set for this study.

The first objective was to develop a guideline for defining surface roughness and finishing of composite surface layers. From the literature survey it was found that a Class B surface roughness is equal to a P600 grit sanded surface. Test 1 was then performed to determine the surface roughness of a P600 to P2000 grit sanded and polished surface. Test 1 concluded that a Class B surface roughness has a Ra value of about 0.250 μm and a Class A surface has a roughness of between 0.200 μm and 0.050 μm , with Class A1 below 0.100 μm . These values were then used to determine the class of the surfaces throughout the remainder of the study.

The next objective was to investigate the current mould status in the JS factory and determine which sections of the moulds that were more prone to damage; and then to propose solutions for those areas. These areas have already been determined in the literature study and it was confirmed, in the JS mould survey, that the area where the curve and split surface intersect, should be addressed. The proposed solutions in the literature were to strengthen this area with an epoxy and floc mixture, to butt layup the area with the first layers or to add rovings in these areas. Test 3.3 tested these strengthening methods and it was found that the best solution is to add rovings in these areas.

Objective three was to determine, through investigation, the best surface to use between tooling board and composite mould structures. This was determined by measuring all the surface roughnesses yielded by the current moulds, produced parts and parts after finishing in the JS factory. These values were then averaged and compared.

The investigation showed that the average tooling board Ra value is around 0.640 μm and composite surfaces around 0.330 μm , neither Class A. The demoulded parts from these surfaces are 1.4 μm for the tooling board and 0.620 μm for the composite surface. This showed that, on average, the composite surfaces did not only have about a 50% better surface finish than the tooling board surfaces, but it also produced a 60% better surface than the tooling board surfaces.

This result could be ascribed to the fact the finishing of tooling board surfaces is not of a high standard. This is due to the fact that tooling board moulds are usually considered as temporary moulds and do therefore not receive the same attention as is the case with composite tooling. The tooling board surfaces also showed to be more prone to damage, especially on intersecting corners. The composite moulds can be strengthened in those sections, and is thus less prone to damage than the tooling board moulds. It was thus concluded that the composite tooling would yield a better production mould surface than the tooling board moulds.

The next objective was to propose and validate a process for achieving Class A finished plugs, with CNC machining of tooling board as a baseline. This was achieved by conveying an optimising test of various influential CNC values for the purpose of time versus quality as well as a few guidelines for the programming and CAD modeling. The input parameter were determined for the roughening and finishing processes, by measuring the surface roughnesses of the test samples, and choosing the values of the sample with the best average Ra value.

The finishing of the plug's surface was determined by testing non-conventional finishing materials as well as conventional finishing materials. Among the non-conventional materials tested, the only material that proved to be usable was acrylic sheeting. For the plug's curvature finish, a finish of conventional 1K paint, followed by a 2K paint finishing process was suggested.

The optimised CNC values were then used on the JS1 instrument panel plug manufactured in Chapter 6. This plug was then sprayed with a 1K primer and finished and the average surface roughness's obtained from the plug proofed to be Class A. However, the plug's surfaces were destroyed after demoulding of the produced moulds and it was concluded that plug surfaces should rather be finished with a 2K paint, which has an added hardener, as

was used with the sample block used for the intersection corner tests. This method would then ensure that the plugs are intact after manufacturing of the moulds.

The manufacturing of Class A finished moulds was the next objective. In order to achieve this objective, a number of tests were conducted. The print-through test, Test 5, did not produce conclusive results, but was followed by Test 6 to find an answer.

Test 6 revealed that the use of two to four layers of glass veil, with a steady increase of GSM of structural glass fibres to prevent print-through. The mould surface application test, Test 6, revealed that gelcoat is a more appropriate surface than an epoxy, floc surface. The tests also revealed that performing the application with a heat gun yielded very few surface defects after demoulding.

All the test results were used to derive a proposed composite manufacturing process for producing Class A finished components with IMC methods. The suggested manufacturing process was validated through the manufacturing of the JS1 instrument panel plugs, moulds and part.

This process already proved to yield an improvement of approximately 300% in the quality of the average JS mould surface as determined the survey that was conducted prior to this study. Plugs were manufactured with CNC and finished to a Class A1 finish, but with only a 1K surface finish. A mould was manufactured from the plugs.

The moulds were manufactured with an average surface roughness of around 0.09 μm . Fewer surface discrepancies were found than was the case with the production of previous JS moulds. These results indicated that the proposed mould manufacturing method was suitable and efficient.

Producing the A Class A finished part with in-mould manufacturing methods was the final objective, and the ultimate aim, of the study. In order to obtain this goal, Test 7 was conducted to evaluate the spraying of 2K paint onto various different available release agents. The best release agent proved to be Loctite Frekote 770-NC release system and Mequiers Mirror Glaze 87 Wax. The Mequiers Mirror Glaze 87 Wax was used as the release agent between the plug and the mould and the Loctite Frekote 770-NC release system as a semi-permanent system between the mould and the part.

In Chapter 6 a sample part was manufactured using the suggested mould making method. It was found that the part had a surface roughness of 0.175 μm on average, which is a 200% improvement on the surface roughness of production parts at JS. This proved that a Class A3 part can indeed be produced with the proposed process. After just polishing, the surface roughness was 0.063 μm . This finding implied that if JS uses the proposed process, the P600 grit sanding processes could be eliminated, saving about 70 man hours per production unit.

The study proved that it is possible to produce Class A finished parts using an IMC process. All the objectives of the study have been achieved, and the proposed composite manufacturing process for producing Class A finished components was proved to be successful.

7.2 RECOMMENDATIONS FOR FURTHER STUDIES

During the course of the study a few critical aspects of the moulds, plugs and part manufacturing were noticed, but these did not have a direct bearing on the study's outcomes. These aspects are, however, recommended for future studies:

- The following mould features were only briefly explored in this study and should be investigated further in order to obtain the best mould manufacturing guidelines:
 - Mould backup structures
 - Mould alignment methods
 - Mould clamping methods
 - Trimming features of parts
 - Demoulding features
 - Mould heating features
 - Vacuuming features
 - Mould handling and moving features.
 - Bonding methods of parts manufactured with two skins bonded together, such as wings and fuselages.
- Release agents used in this study was limited to the agents already in used at JS in production. This was done in an attempt to simplify the introduction of new mould making procedures in the production units. Further investigation into different release agents might be beneficial.
- The use of materials other than tooling gelcoat and composite structures should also be further investigated.

- The post-curing of parts in the moulds could also be further investigated. JS makes use of post demould post-curing processes, but in mould post-curing is an option which has not yet been used in the factory, because the current moulds were manufactured from materials that are temperature unstable. The maintainability of moulds used in a production cycle requires further investigation with regards to storage, cleaning, repairs and release system applications. These aspects influence the quality of the mould surface during production. If these are not properly implemented, the best mould can deteriorate in only a few cycles.