CHAPTER 6: VALIDATION OF PROCESS

This Chapter aims at providing further validation of the process described in Chapter 5. The validation was completed on a part requiring a simple pressed mould. The part selected is a JS1 instrument panel. A plug was manufactured for both the inner and outer moulds, both the moulds and the first part were produced. The process of Chapter 5 was followed and the plug, mould and part surface roughnesses were measured to provide proof of the process validation. Appendix D should be consulted for the manufacturing processes.

6.1 PLUG FINISHING RESULTS

The plug was manufactured on the CNC machine from Nuceron651 and was finished using a conventional 1K paint finish. Figure 6-1 show the plugs after cutting and then Figure 6-2 shows the plug after spraying, sanding to a P3000 grit and polishing. The cutting parameters and finishing process are illustrated in greater detail in Appendix D.

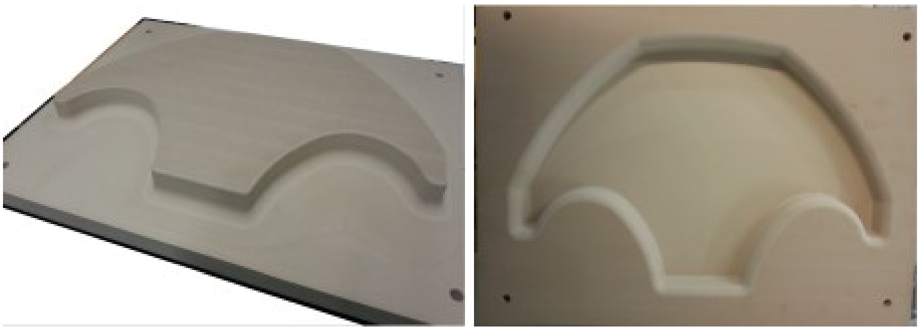
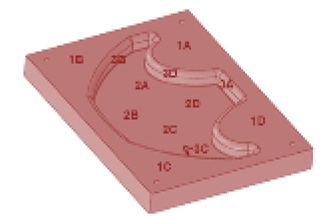
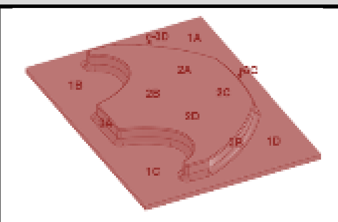


Figure 6-1: Plugs after cutting

Figure 6-2: Plugs after sanding to P3000 grit and polishing to a Class A finish

The surface roughness (Ra) was measured after cutting, after spraying and after polishing on the positions indicated in Table 6-1. The measurements were divided into the three types of surfaces on the plug – the split surfaces, the part face surfaces and the side wall of the plugs. Four values on each type of surface were measured, from which an average value was calculated:

Table 6-1: Surface roughness measurements in plug finishing processes

1- On split surface 2- On part surface 3- On side wall			After CNC cutting (Ra [um])			After spraying (Ra [um])			After sanding & polishing (Ra [um])		
			1	2	3	1	2	3	1	2	3
BOTTOM PLUG		**A**	4.187	8.002	6.058	0.785	0.892	0.895	0.054	0.045	0.065
		B	6.170	7.254	6.028	0.825	0.748	0.746	0.052	0.049	0.057
		C	4.289	8.189	8.187	0.724	0.648	0.789	0.047	0.051	0.061
		D	4.987	9.556	6.526	0.895	0.687	0.739	0.043	0.050	0.059
AVERAGE			4.908	8.250	6.700	0.807	0.744	0.792	0.049	0.049	0.061
TOP PLUG		**A**	7.478	4.468	6.842	0.895	0.847	0.801	0.048	0.042	0.061
		B	10.02	4.281	6.225	0.712	0.785	0.892	0.046	0.049	0.067
		C	7.740	4.297	6.784	0.648	0.789	0.799	0.042	0.051	0.069
		D	8.024	4.978	6.218	0.784	0.748	0.715	0.051	0.053	0.062
AVERAGE			8.316	4.506	6.517	0.760	0.792	0.802	0.047	0.049	0.065

The average Ra of each process for each plug was converted into Figure 6-3.

Figure 6-3 shows that the surface roughness of the plugs improved from cutting through to sanding. The time spent on proper cutting also reduced the finishing time. The total time spent on finishing, excluding curing times, was approximately three hours.

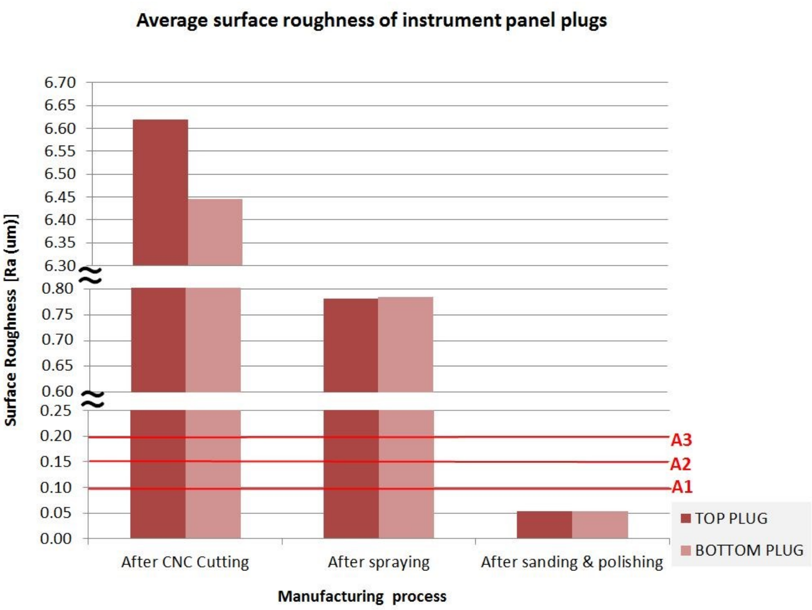


Figure 6-3: Average surface roughness of instrument panel plugs during manufacturing

This finding verifies that the plug manufacturing process suggested in Chapter 5 is appropriate and that a Class A finished plug can be obtained. The next step is to ensure that proper moulds can be manufactured from these plugs.

6.2 MOULD FINISHING RESULTS

The moulds were manufactured using the process described in Chapter 5. The moulds consisted of a tooling gelcoat surface, backed with four layers of glass veil and structurally reinforced with a layup schedule, as indicated in Appendix D. Stainless steel alignment pins and bushes were inserted during layup for alignment. The moulds were left to cure for 36 hours at an average of 22°C. The moulds were demoulded using demoulding wedges and wooden spatulas. After demoulding, the moulds revealed to have removed the plug surfaces, as illustrated in Figure 6-4.

The pulled plug surfaces were investigated and it was determined that the 1K paint surface used on the plug was much softer than the tooling gelcoat used on the mould surface, and did not adhere to the plug structure. This was due to the fact that the paint lacked a hardener, which would have provided the sufficient hardness to withstand the forces applied during demoulding. It is thus crucial to finish the plug surfaces with a 2K paint, as this type of paint would produce sufficient hardness to withstand the forces applied during demoulding.

Figure 6-4: Mould and plug surfaces directly after demoulding.

The moulds were sanded with a P1000 to P2000 grit and polished, as seen in the Figure 6-5:

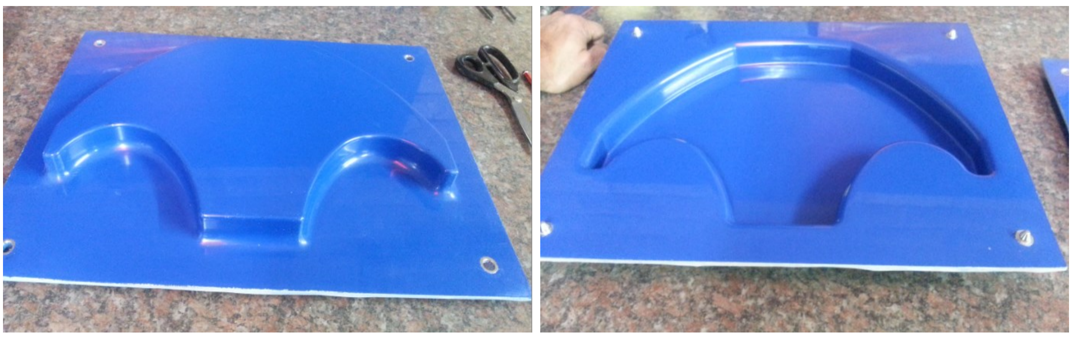
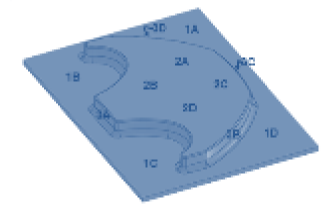
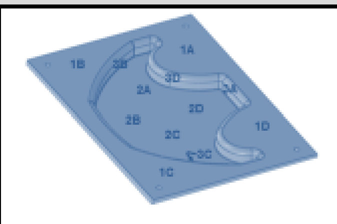


Figure 6-5: Finished top and bottom moulds

The surface roughness of the mould surfaces were measured after demoulding and after sanding and polishing. The measurements were divided into the three types of surfaces on the mould – the split surfaces, the part face surfaces and the side wall of the plugs. Four values on each type of surface were measured, from which an average value was calculated in Table 6-2:

Table 6-2: Surface roughness measurements in mould finishing processes

1- On split surface 2- On part surface 3- On side wall			After demoulding			After sanding & polishing		
			1	2	3	1	2	3
BOTTOM MOULD		A	0.121	0.162	0.198	0.100	0.087	0.089
		B	0.151	0.532	0.132	0.105	0.081	0.071
		C	0.146	0.343	0.135	0.081	0.074	0.092
		D	0.188	0.157	0.435	0.077	0.085	0.076
AVERAGE			0.152	0.299	0.225	0.091	0.082	0.082
TOP MOULD		A	0.182	0.106	0.312	0.071	0.084	0.092
		B	0.171	0.254	0.195	0.072	0.069	0.089
		C	0.239	0.164	0.148	0.086	0.079	0.083
		D	0.188	0.321	0.145	0.089	0.086	0.078
AVERAGE			0.195	0.211	0.200	0.080	0.080	0.086

The average values of all the surfaces were used to determine an overall average surface roughness, which would represent the surface roughness of the entire mould. These average values are indicated in Graph 6-2.

As seen from Figure 6-6, the average demoulded surface is around 0.225 um and 0.202 um for demoulded moulds. After sanding and polishing, the surface roughnesses are reduced to a Class A finish of 0.085 um and 0.082 um. These values are in range of Class A finished moulds and the moulds were prepared with Loctite Frekote 770-NC release system in preparation for the first part.

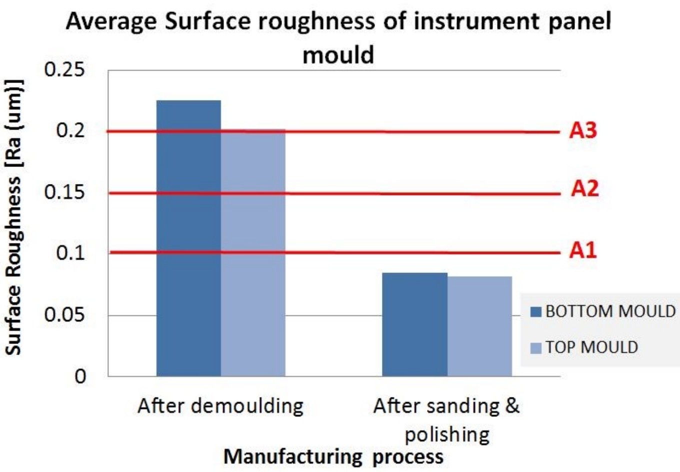


Figure 6-6: Average surface roughnesses of instrument panel moulds during manufacturing

6.3 PART FINISHING RESULTS

The part was manufactured in accordance with the process described in Chapter 5 and according to the manufacturing drawing indicated in Appendix D. The top mould surface was sprayed with a grey 2K paint mist coat and then one thicker final coat was applied. The surface layer was left to cure for two hours and then sanded with a P100 grit sandpaper in preparation for the layup. The layup commenced according to the manufacturing drawing; the moulds were closed, clamped and left to cure for 16 hours as indicated on the manufacturing sheets. The bottom mould was first demoulded, as seen in Figure 6-7, after which the part was demoulded.

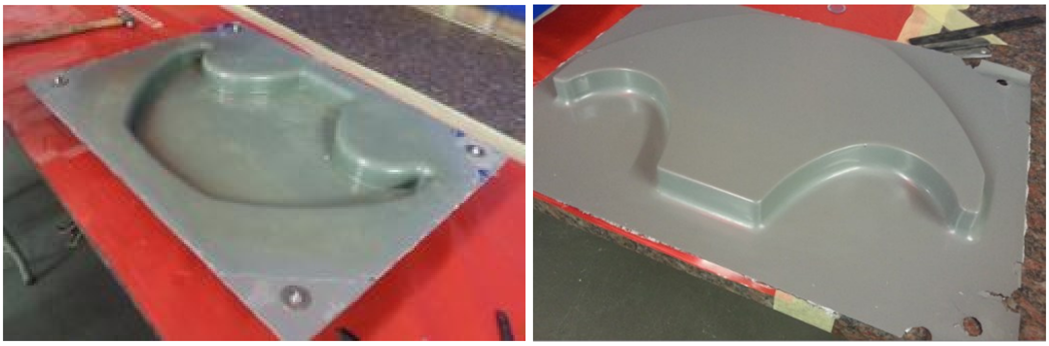
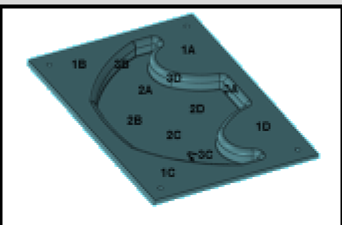
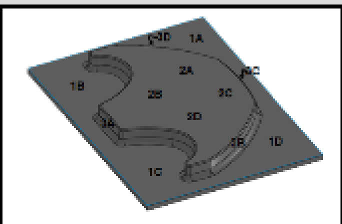


Figure 6-7: (Left) Bottom mould with part after curing, (Right) Demoulded part

The part demoulded without any complications and revealed a glossy surface on the part; the mould surface was left clean and very little cleaning was necessary before producing the next part. Two discrepancies, of about 2 mm in diameter each, were found on the part surface. This was due to the mould not being repaired in those areas. These discrepancies were repaired according to the processes described in Appendix E. After the reparation, the part was polished.

The surface roughness (Ra) of the part was measured after demoulding and after finishing. The average values of all the surfaces were used to find an overall average surface roughness, which would represent the surface roughness of the entire part. This data is captured in Table 6-3.

Table 6-3: Surface roughness measurements in part finishing processes

1- On split surface 2- On part surface 3- On side wall			After demoulding			After sanding & polishing		
			1	2	3	1	2	3
BOTTOM OF PART (EPOXY)		A	0.295	0.254	0.267	n/a	n/a	n/a
		B	0.236	0.219	0.298	n/a	n/a	n/a
		C	0.237	0.191	0.247	n/a	n/a	n/a
		D	0.239	0.267	0.287	n/a	n/a	n/a
AVERAGE			0.252	0.233	0.275	n/a	n/a	n/a
TOP OF PART (2K AINT)		A	0.296	0.152	0.203	n/a	0.056	0.069
		B	0.144	0.160	0.186	n/a	0.058	0.071
		C	0.154	0.170	0.161	n/a	0.054	0.062
		D	0.142	0.172	0.156	n/a	0.068	0.065
AVERAGE			0.184	0.164	0.177	n/a	0.059	0.067

n/a – Surface does not require finishing, as it is not a visible surface when installed, or surface was trimmed off final part.

The average values of all the surfaces were used to find an overall average surface roughness, which would represent the surface roughness of the entire part. These average values are indicated in Figure 6-8.

The final surface roughness of the face, which will be visible after installation, was revealed to be 0.063 um, Class A1. The same process of part manufacturing was followed to manufacture a second production part, with only cleaning the mould and not reapplying release agent. This part's surface roughness after demoulding was found to be 0.170 um, Class A2, and after finishing 0.064 um, Class A1. Compared to the average surface roughness, 0.33 um, of parts demoulded currently in the JS factory from composite tooling, from Chapter 3, this is a 0.160 um or 200% improvement.

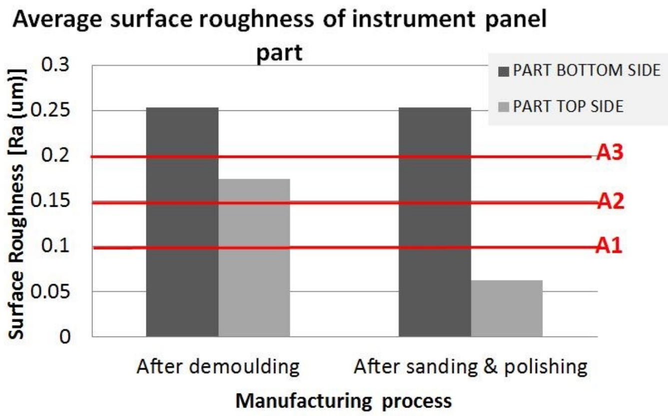


Figure 6-8: Average surface roughnesses of instrument panel part during manufacturing

6.4 CONCLUSION

Figure 6-9 shows the surface roughness of the bottom and top plugs, the moulds and the final part of the JS1 instrument panel, combined from Figure 6-3, 6-6 and 6-8. From the graph it can be seen that the average surface roughness of the plug was higher than 6.4 um, when it was sprayed it decreased to 0.8 um and then it was finished to 0.05 um, Class A1.

The projected mould surface from this was Class A3, 0.2 um. The moulds required further finishing to yield a Class A1 finish, from which it was possible to produce Class A2 and A3 parts. The final part produced from these moulds only required some polishing before a Class A1 surface finish was obtained.

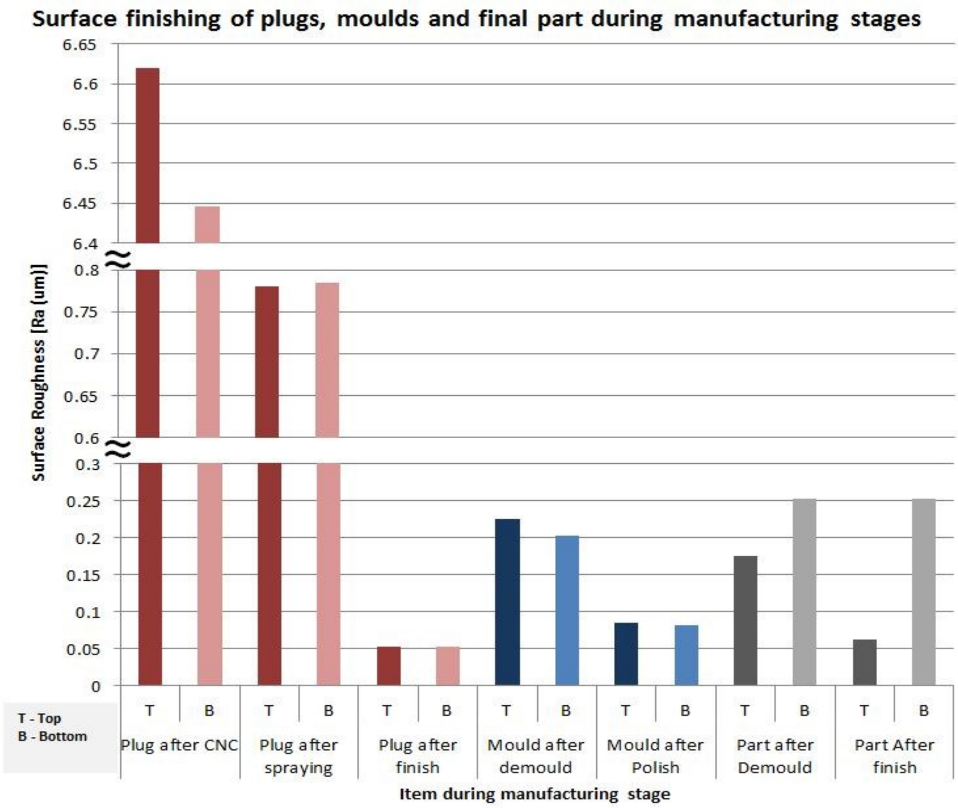


Figure 6-9: Compared surface roughness of instrument panel plugs, moulds and parts

It was noted that a Class A1 mould demoulds to a Class A3 surface on the part. This higher surface roughness could be due to the release agent residue left on the demoulded surface. If the demoulded surface is polished, however, this residue is removed and the surface roughness of the original mould surface is obtained. This proves that a Class A1 composite part can thus be obtained with IMC processes. The repeatability of the process is, however, dependant on how the moulds are stored and maintained during production.