

CHAPTER 4: TESTING AND RESULTS

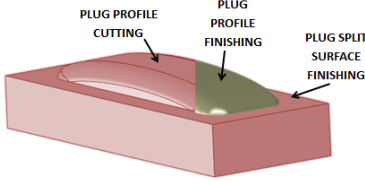
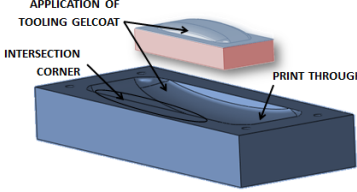
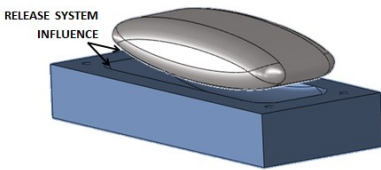
In Chapter 3 it was established that Class A finished parts can be obtained if well finished plugs are used in conjunction with sound manufacturing methods for moulds. Because the literature did not provide sufficient clarity regarding how one would have to go about in order to achieve these two requirements, experimental testing was required. This Chapter focuses on describing the experimental testing that was undertaken with a view to provide greater clarity to the issues raised in Chapter 2.

4.1 THE TESTING PROCESS

The purpose of the testing undertaken at this point in the study was to obtain enough data to provide clear answers regarding the manufacturing and maintaining of Class A finished composite parts. Testing the manufacturing and maintaining of Class A finished parts required a series of tests; these however are not presented in chronological order.

Table 4-1 classifies this required information into the applicable fields in the process and explains which tests were used to address each aspect. The remainder of this section sets out to explain the design, manufacturing and results of each of these tests.

Table 4-1: Testing requirements

ASPECT		REQUIREMENTS	TEST
SURFACE ROUGHNESS		Classifying composite manufacturing surface roughness	TEST 1
PLUG MANUFACTURING IMPROVEMENTS		Determining optimum CNC manufacturing methods and determining proper surface layers for CNC manufactured plugs	TEST 2 TEST 3.1 TEST 3.2 TEST 4
MOULD MANUFACTURING IMPROVEMENTS		Determining how to strengthen weak mould areas. Prevent print through of structural layers. Verifying application methods of tooling gelcoat	TEST 3.3 TEST 4 TEST 5 TEST 6
PART MANUFACTURING IMPROVEMENTS		Determining a possible release system to use with in mould coatings of gelcoats and 2K paints.	TEST 7

4.2 TEST 1: COMPARISON BETWEEN SAND PAPER GRIT AND SURFACE ROUGHNESS

A surface which is sanded to a P600 grit can be described as a Class B surface finish. Surface in the aerospace industry is normally finished to a grit of P1500 or even higher. This test draws a comparison between the sand paper grits and the surface roughness to verify the quality standard obtained from various sanding grits of composite painted surfaces.

4.2.1 TEST 1: DESCRIPTION AND MANUFACTURING

A composite manufactured sample consisting of a 2K paint surface layer was wet sanded starting with a sanding paper grit of P600 in one direction, as shown in Figure 4-1.

After each grit size sanding paper was sanded fully, the sample was dried and wiped to remove any depresses caused by the sanding. The surface roughness was measured on 5 locations, moving perpendicular to the sanding direction.

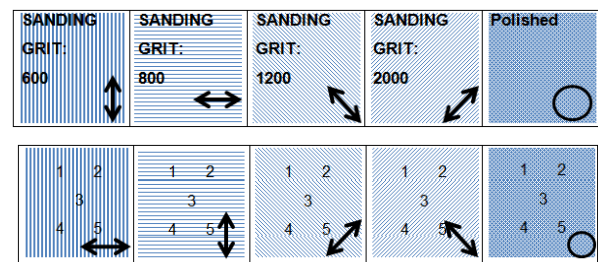


Figure 4-1: Sanding and surface roughness measurement directions and positions.

The process was repeated for each sanding grit size up to the polishing of the sample. It should be noted that the test did not make use of five individual samples; but rather of one sample which was sanded in different directions to simulate the actual sanding process.

4.2.2 TEST 1: DATA AND RESULTS

Table 4-2 shows the Ra (um) values measured from the various sanding operations performed on the test piece. Figure 4-2 was derived by calculating the average value of the values from Table 4-2.

Table 4-2: Various sanding grit surface roughnesses

	P400	P600	P800	P1000	P1200	P2000	Polish
1	0.649	0.244	0.188	0.119	0.088	0.071	0.049
2	0.455	0.251	0.167	0.125	0.082	0.065	0.031
3	0.546	0.247	0.158	0.126	0.108	0.061	0.057
4	0.475	0.255	0.154	0.121	0.091	0.073	0.052
5	0.607	0.244	0.192	0.129	0.099	0.063	0.051

From Table 4-2 it can be seen that a sand paper grit of P400 produces on average a surface roughness of 0.550 um and a P3000 polished surface a value of 0.05 um. The values in between these two values seem to follow an exponentially decreasing trend as the grit size increases. Table 4-2 also reveals that a P600 grit produces a surface roughness of around 0.250um and a P800 grit a surface roughness of around 0.175 um. If a P600 grit is thus 0.250 um and equal to a Class B surface, a Class A3 surface quality could thus begin at 0.200 um.

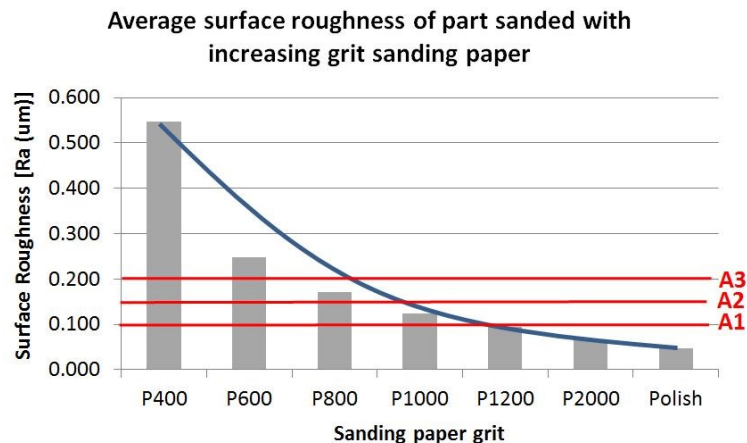


Figure 4-2: Average surface roughness of part sanded with increasing grit sanding paper.

4.2.3 TEST 1: CONCLUSION

From the test it can be concluded that the surface roughness exponentially decreases as the grit of sandpaper increases. A Class A composite painted surface quality can then be said to have a roughness value of maximum 0.200 um. A P800 finish has a roughness between 0.200 and 0.150 um and constitutes a Class A3 finish. P1000 to P1200 have a roughness between 0.150 um to 0.100 um and constitutes a Class A2 finish. Finally a P2000 and higher have a roughness of 0.100 um and lower and constitutes Class A1 surface finish.

4.3 TEST 2: COMPARISON OF VARIOUS CNC MACHINING PROCESSES

The purpose of this test was to obtain the optimum CNC cutting parameters to be used when cutting CNC moulds or plugs from Nucron651 tooling board. This matter was investigated by cutting the same shape and systematically varying the cutting parameters.

4.3.1 TEST 2: DESCRIPTION

A simple S-shape was chosen as the test shape for this experiment. A sample board which has been cut to a number of exactly the same S-shapes was produced using different cutting parameters. The following parameters were investigated:

- ◆ The feed rate
- ◆ The step-over distance
- ◆ The resolution, and
- ◆ The number of facets.

The tolerance, 0.001 of the program and the speed of the machine, 17 000 rpm was kept constant. The machine speed was kept at the highest rate that the machine can manage in order to decrease the cutting time. Figure 4-3 illustrates the layout of the samples. Please refer to Appendix C for a full description of the test parameters.

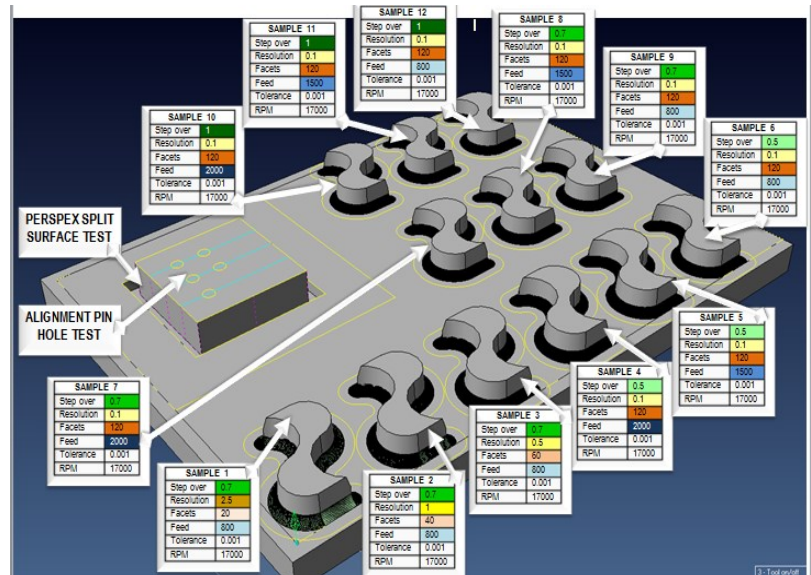


Figure 4-3: CNC test sample layout

4.3.2 TEST 2: MANUFACTURING OF SAMPLES

Visicadcam 3D / 5 Axis v19.0 was used to create the CAM tool paths. The samples were cut on Nucron651 tooling board. Appendix C shows a detailed picture of each of the samples surfaces. Each sample was then labelled for immediate identification. All the samples were marked with the areas where the surface roughness would be measured, as illustrated in the

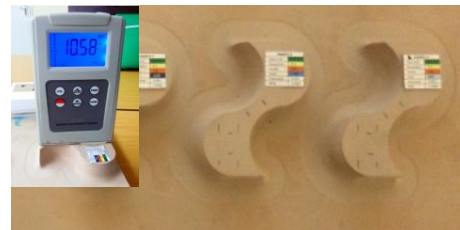


Figure 4-4: CNC samples with ID cards and roughness metering areas

Figure 4-4. The surface roughness was then taken on each of the indicated positions.

4.3.3 TEST 2: DATA AND RESULTS

Table 4-3 below provides all the individual measurements of each of the samples Ra surface roughnesses:

Table 4-3: Surface roughness values of CNC samples

TEST SAMPLE NUMBER					Cutting times (seconds)
	Top Ra (um)	Middle Ra (um)	Bottom Ra (um)	Angle Ra (um)	
1	9.77	13.26	11.78	3.472	1228
2	9.768	7.695	11.95	10.58	1228
3	10.58	8.404	11.84	3.723	1228
4	9.659	11.18	10.2	11.45	683
5	10.36	8.349	9.822	14.19	911
6	9.659	10.09	8.622	3.356	1704
7	9.331	8.895	12.11	9.822	491
8	10.96	10.25	11.62	11.35	657
9	10.15	10.96	9.877	3.8	1225
10	10.69	10.58	9.986	8.676	471
11	9.932	10.85	10.25	7.203	471
12	9.877	11.62	11.89	4.61	346

The data of the Table 4-3 was then used to create Figure 4-5. Figure 4-5 shows the average surface roughness value that resulted from the four individual measurements of each sample, along with the time in seconds it took to cut the sample. (None of the samples had a Class A finish.)

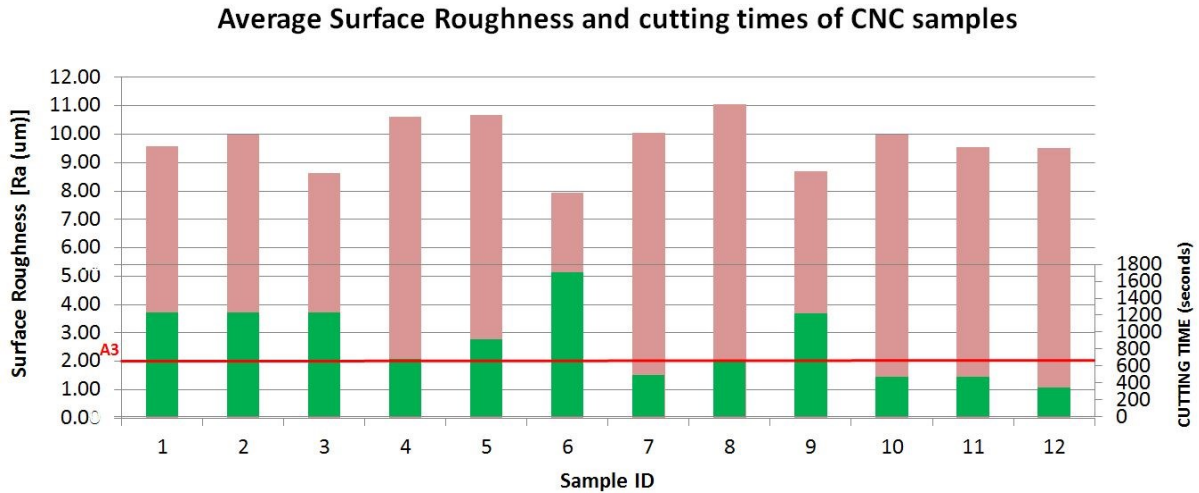


Figure 4-5: Surface roughness of CNC samples

From Figure 4-5 can be seen that samples 3, 6 and 9 have the lowest surface roughness, with sample 6 the lowest, measuring at 7.9 μm , sample 3 at 8.6 μm and sample 9 at 8.7 μm . These lower surface roughnesses are the result of a combination of higher resolutions and facet inputs, shown by sample 3, together with an increased feed and decreased step-over shown by samples 6 and 9.

The decrease in surface roughness came with a price, however: it took more time. Sample 6 was cut in about 1700 seconds and samples 3 and 6 both about 1230 seconds. Sample 6 took thus 250 seconds longer to cut than samples 3 and 9. Improving the surface quality thus implies increasing the cutting time. Choosing the optimal input values will therefore also depend on the time available.

4.3.4 TEST 2: CONCLUSION

Table 4-4 provides a guideline for CNC tool path settings to be used with Nuceron651, concluded from the results obtained from sample 3, 6 and 9:

Table 4-4: Optimum settings for CNC machining of Nuceron651

	Roughing	Finishing	
Types of cuts	Roughing, spiral In / out, milling	Constant step-over, steep/shallows, rest area	Face mill zig zag, planar faces
Tools used	End mill, slot mill	Ball nose	End mill, slot mill
Cut mode	Rough	Finishing	Finishing
Step-over	6 – 20	0.5	4 - 20
Speed [rpm]	16000 – 17500	17000	17000
Feed [mm/min]	7000-8000	800	800-2000
Resolution	0.1	0.1	0.1
Facets	120	120	120

These settings will produce a plug with a moderately good surface finish, but the values are at the lowest 7.9 μm , which are much higher than even Class A3 surface qualities of 0.200 μm . It is thus paramount to note that these plugs will still require a measure of finishing after cutting to become Class A1. The surface quality was, nonetheless, optimised with a view to ensure less finishing afterwards, resulting in a profile closer to the designed CAD model.

4.4 TEST 3: STRENGTHENING OF SHARP CORNERS ON MOULDS

It has been stated previously that sharp corners are often unavoidable in moulds, and are desirable where the product surface transits into the split surface. These are, however, prone to damage. In the following test, three aspects of sharp corners were tested. The first shows methods by means of which a sharp corner can be produced using CNC CAM methods and acrylic sheets (Test 3.1). The second (Test 3.2) provides information on the surface roughness obtained from conventional plug finishing methods, and the last (Test 3.3) tested reinforcing methods for sharp corners.

4.4.1 TEST 3: DESCRIPTION AND MANUFACTURING

The test layout is illustrated in Figure 4-6. A block in the CNC tests was cut, which was used in this test. The block was cut with a 10 mm slot running past the part split surface. The block profile was finished with 2K paint and Plexiglass™ positioned as the split surface, as described in Appendix C.17. This method was used to ensure a sharp

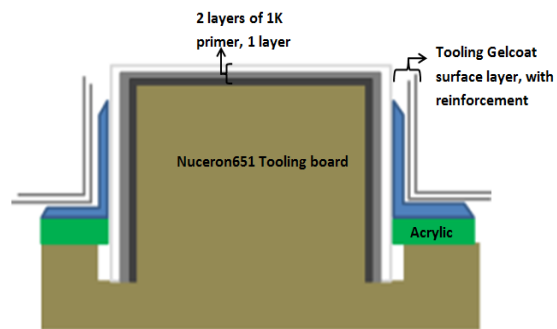


Figure 4-6: Side view of plug with acrylic sheet split surface and layup.

intersection corner between the profile and the plug surface, which cannot be directly obtained from CNC manufacturing. Meguiars Mirror Glaze 87 Wax was applied as a release agent. The tooling gelcoat for all samples was applied and 2 hours elapsed before the corner strengthening materials, followed by the structural layers, were applied. Figure 4-7 shows the manufacturing of the samples:



Figure 4-7: (a) Rovings and flox applied as strengthening methods; (b) Print barrier and glass 90070 applied with butt layup; (c) Glass 90070 applied as normal layup.

The reinforcement of the samples was varied in order to allow for testing the various strength methods of female radii. The following five different strengthening methods, illustrated in Figure 4-8, were used:

- Print barriers butt layered
- 90070 butt layered
- Flox mixture pressed into corner
- Rovings pressed into corner, and
- 90070 normal layup.

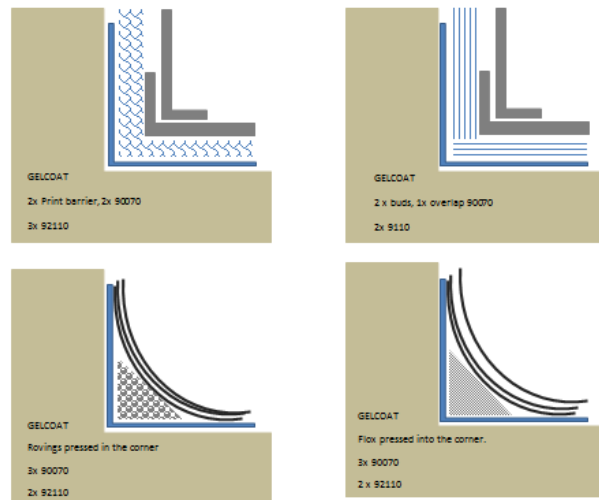


Figure 4-8: Female radii strengthening methods

4.4.2 TEST 3.1: DATA AND RESULTS

The purpose of Test 3.1 was to test whether it is possible to obtain a sharp plug intersection corner by means of CNC manufacturing. All the samples had a clear sharp demoulded corner. The samples were square when measured with a 90° angle protractor and did not have any discrepancies at the corners, as shown in Figure 4-9.

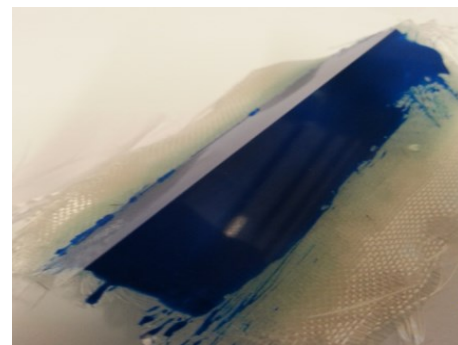


Figure 4-9: Sharp intersection mould corner demoulded from acrylic split surface

4.4.3 TEST 3.2: DATA AND RESULTS

Table 4-5 shows the data points collected from the acrylic split surface samples. A large number of points were measured on the sample side as well as on the acrylic and Plug profile side. It should be noted that two sides of the gelcoat profile could not be measured, as the “S” samples of the CNC tests prevented the profilometer from measuring there.

Table 4-5: Surface roughnesses of samples created from acrylic as a split surface

POSITION	ACRYLIC Ra	PROFILE SIDE Ra	SAMPLE Acrylic Ra	SAMPLE PROFILE Ra
Sample A1	0.015		0.059	0.161
Sample A2	0.031		0.066	0.107
Sample A3	0.048		0.085	0.162
Sample A4	0.032		0.059	0.144
Sample B1	0.085	0.091	0.198	0.066
Sample B2	0.014	0.059	0.071	0.160
Sample B3	0.114	0.060	0.171	0.085
Sample B4	0.018	0.065	0.091	0.134
Sample C1	0.074	0.059	0.129	0.077
Sample C2	0.021	0.077	0.119	0.094
Sample C3	0.073	0.069	0.083	0.171
Sample C4	0.023	0.150	0.204	0.127
Sample D1	0.070		0.077	0.085
Sample D2	0.027		0.030	0.144
Sample D3	0.042		0.069	0.119
Sample D4	0.012		0.064	0.089

Figure 4-10 shows that the surface roughness of an acrylic surface was approximately 0.045 μm , which matched Class A1 requirements according to Test 1. A conventional 2K finished plug surface is also Class A 1, measuring at 0.7 μm .

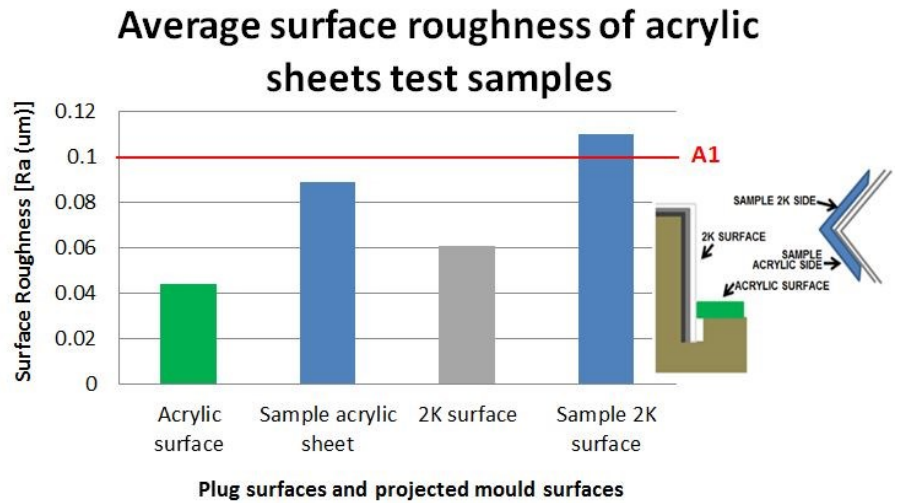


Figure 4-10: Average surface roughness of acrylic sheet test samples

The projected surface likely to be obtained from an acrylic sheet was on average 0.100 μm , which still complies with Class A1 requirements. From the 2K finished plug the surface was 0.120 μm , which is a Class A2 surface finish. Figure 4-10 reveals that both acrylic and conventional 2K finishing methods for plugs thus provided Class A finished mould surfaces directly after demoulding. Because all the samples were measured, the influencing factor of the different strengthening methods used in Test 3.3 could be eliminated and thus the finishes were independent of the strengthening methods used.

4.4.4 TEST 3.3 DATA AND RESULTS

After the samples have been demoulded, they were trimmed to reveal the construction of the corners, as shown in Figure 4-11:

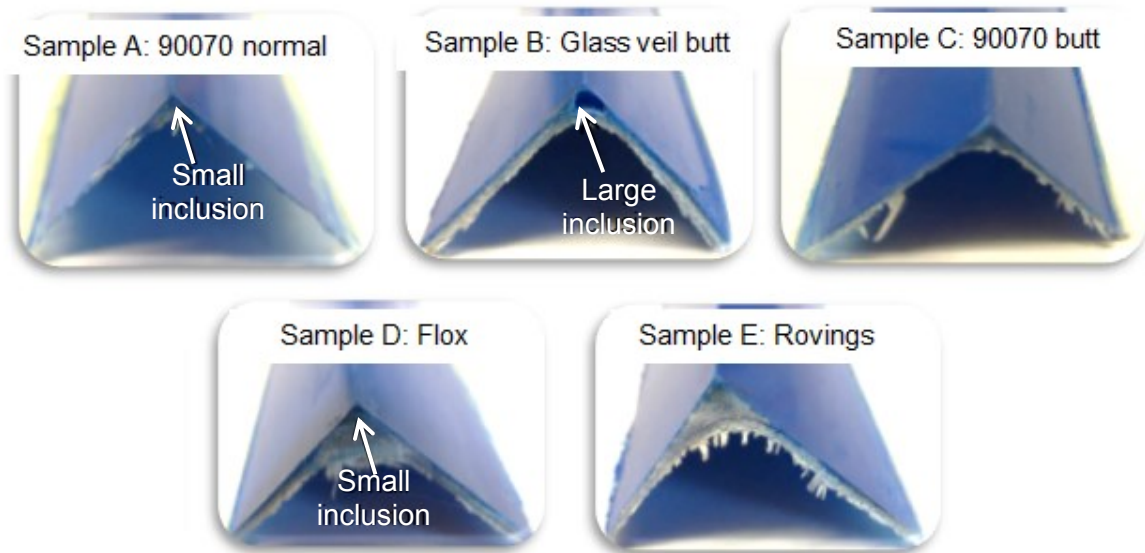


Figure 4-11: Comparison between different mould corner layups

After the surface roughness of the samples has been measured, the samples underwent destructive testing. The purpose of these tests was to expose any cavities created by the strengthening method. The test was completed by strategically mounting the sample onto a vertical surface and sending a swinging 100g weight, 100 times, onto the sharp corner of the sample, as illustrated in Figure 4-12. The results of the tests are shown in Figure 4-13.

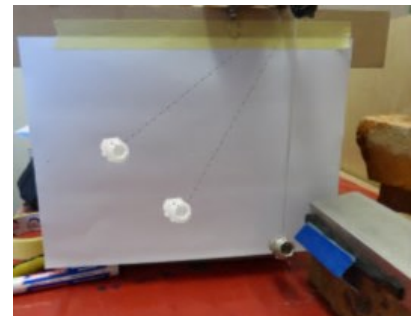


Figure 4-12: 100g object bounced repeatedly onto the sample

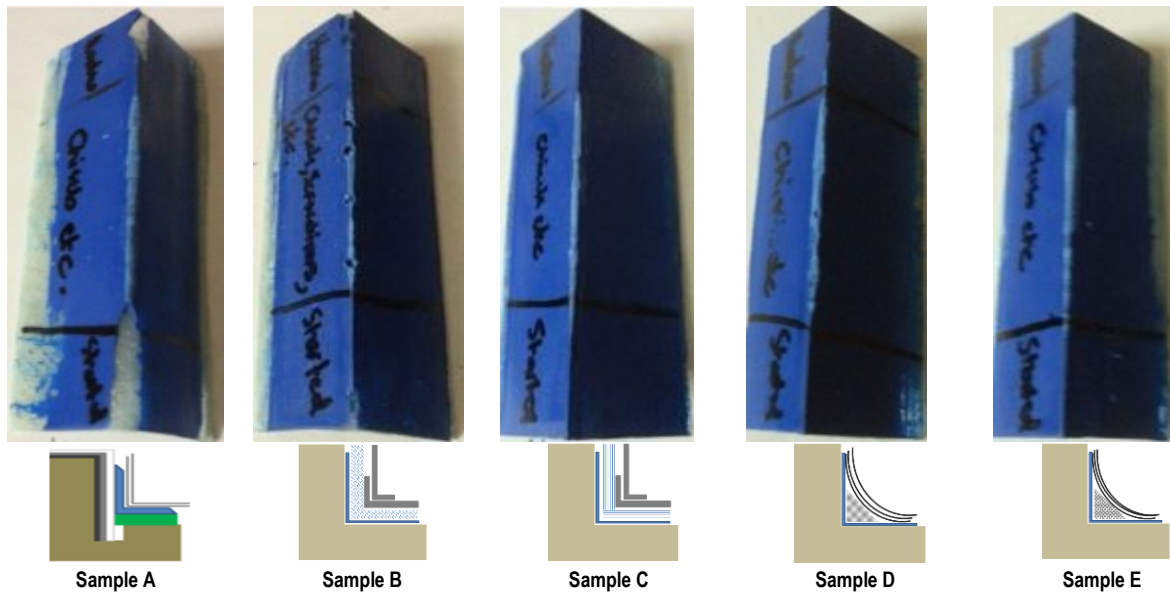


Figure 4-13: Comparison between the corner samples after destructive testing

Figure 4-13 shows that Sample A had large cavities that cracked open during impact loading. Sample B showed much smaller inclusions that also cracked open under impact. Sample C showed virtually no inclusions and looked similar to the results of sample E. Sample D showed small inclusions, smaller than Sample B but larger than Samples C and E. It can therefore be concluded from this data that reinforcing schemes C and E will give the most resistance to damage due to the absence of inclusions and air pockets.

4.4.5 TEST 3 CONCLUSION

From Test 3.1 it was seen that it is possible to obtain a sharp intersection corner when cutting plugs. By cutting a slot next to the profile, past the split surface, finishing the plug and closing the slot with an acrylic sheet, a sharp intersection plug corner is created.

Test 3.2 used the samples created to test the surface finish obtained from acrylic plug surface and 2K conventional paint plug finishes and their projected mould surfaces. It was revealed that both these surfaces are below 0.100 μm , Class A, and projected Class A2 and Class A2 surfaces.

Test 3.3 revealed that sharp corners and female radii on moulds can be strengthened by either reinforcing it with a 90070 butt layup or by forcing rovings into these areas. These two reinforcement methods yielded no initial inclusions and were found to be the most resistant to impact destructive testing.

4.5 TEST 4: NON-CONVENTIONAL MATERIALS: CONTOUR MATERIALS

The purpose of these tests was to explore various materials that already have good surface finishing in order to determine if they could be used as alternative plug finishing methods.

These materials will be used for the various samples and will be tested for their:

- Test 4.1: Surface quality of the parts it produced
- Test 4.2: Usability with various release agents
- Test 4.3: Comparison to values obtained from Test 3.2

4.5.1 TEST 4: DESCRIPTION

Figure 4-14 illustrates the test layout. The non-conventional plug materials which were tested are:

- 3M™ Ventureshield
- 3M™ Scotchprint 1080 Vinyl Wrap - Gloss White
- 3M™ ClearPlex®

These three materials were then tested with usage of 5 release agents:

- Loctite Frekote 770-NC, FMS, PMC
- Zyxax Enviroshield
- Zyxax Nano
- Zyxax Flex Z1
- Mequiars Mirror Glaze 87 Wax.

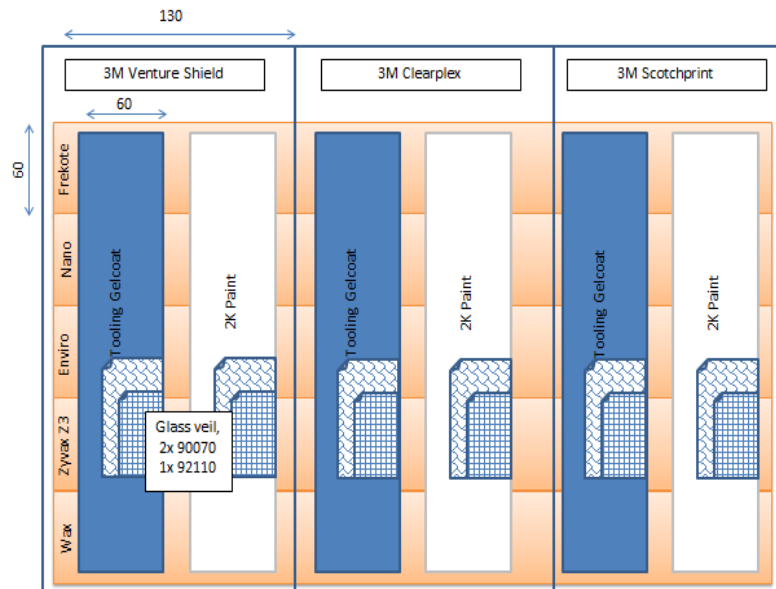


Figure 4-14: Test layout of non-conventional tests

GC1150 Tooling gelcoat and 2K paint were applied as surface layers and reinforced with one layer of glass veil, two layers of 90070 and one layer of 92110.

4.5.2 TEST 4: MANUFACTURING OF SAMPLES

A surface was covered with each of the materials. The materials were then treated with the five different release agents according to their datasheets. Tooling gelcoat and 2K paint was then applied to the surfaces. Two hours after the application of the surface layers, the reinforcement was applied. The samples were then cured for three days at 23°C and were demoulded. Figure 4-15 shows the demoulded samples.

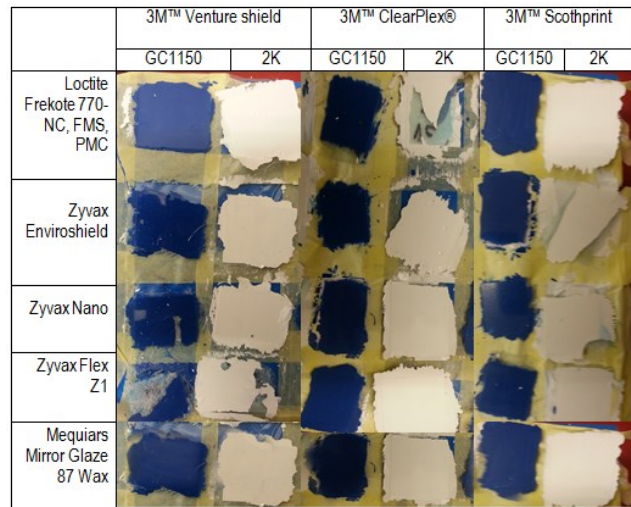


Figure 4-15: Demoulded non-conventional material samples

4.5.3 TEST 4.1: DATA AND RESULTS

The samples revealed difficulty in demoulding and showed a number of surface discrepancies, as illustrated in Figure 4-15. The wax release agent showed the best demoulding properties for all of the materials. The Frekote release agent showed difficulty demoulding 2K paint with the ClearPlex. The Enviroshield showed difficulty demoulding with the 2K Scotchprint. Zyvox Nano and Zyvox Z1 both showed difficulty with demoulding the samples from the Ventureshield. From this test the best release agent to use with any of these materials was therefore found to be Meguiars wax.

4.5.4 TEST 4.2: DATA AND RESULTS

Table 4-6 lists the data points collected from the three non-conventional materials and the influence that the various release agents had on them. Only two data points for each sample were taken, which means that the average value is a very rough estimate.

Table 4-6: Surface roughnesses created by non-conventional plug materials

Release agents		3M venture shield		Clear vinyl		White vinyl	
		gelcoat (Ra)[um]	2k (Ra)[um]	gelcoat (Ra)[um]	2k (Ra)[um]	gelcoat (Ra)[um]	2k (Ra)[um]
Loctite Frekote 770- NC	1	0.285	0.244	0.380	3.047	0.688	1.477
	2	0.359	0.568	0.364	2.115	1.097	1.505
	Ave	0.322	0.406	0.372	2.581	0.893	1.491
Zyvox Nano	1	0.780	0.588	0.395	1.570	0.282	2.961
	2	0.850	0.649	0.537	2.084	0.645	2.247
	Ave	0.815	0.619	0.466	1.827	0.464	2.604
Zyvox Enviroshield	1	1.523	0.285	0.618	2.075	0.757	2.655
	2	1.315	0.925	0.294	1.560	0.750	2.816
	Ave	1.419	0.605	0.456	1.818	0.754	2.736
Zyvox Flex Z3	1	1.374	1.402	0.808	2.393	1.206	2.318
	2	1.877	1.104	0.694	1.824	0.813	1.904
	Ave	1.626	1.253	0.751	2.109	1.010	2.111
Meguiars wax	1	0.385	0.485	0.281	0.874	0.364	0.429
	2	0.554	0.295	0.724	0.247	0.341	0.471
	Ave	0.738	0.390	0.683	0.561	0.856	0.450

The average surface roughness values of the 2K surfaces and the gelcoat surfaces were plotted on Figure 4-16 and 4-17. The graph shows the different non-conventional materials and the applicable release agent used.

In Figure 4-16, it can be observed that the 3M Ventureshield provided the best surface finish for 2K with any of the release agents used, with the highest 1.200 um. The Meguiars wax release agent showed the best average values, namely around 0.400 um. The surface finish obtained from any of the

samples was 0.400 um on the lowest, which was equal to a P400 grit sanding paper, but not even Class B surface finish (which is 0.250 um). Therefore these materials are not usable for obtaining a 2K painted Class A finished part.

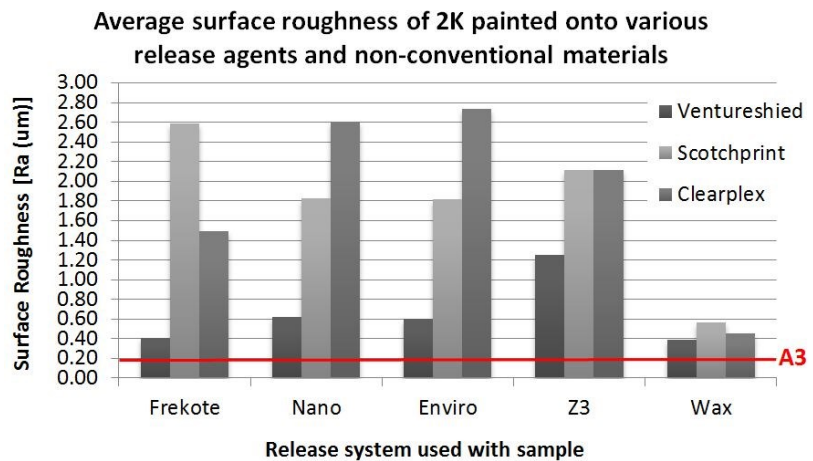


Figure 4-16: Average surface roughness of 2K surfaces on non-conventional materials versus various release agents

Figure 4-17 shows the results for using these materials as possible plug surfaces. The tooling gelcoat samples obtained from the materials yielded a surface roughness, obtained with the Meguiars wax, of the lowest 0.680 μm (which has not even been finished to a P400 grit). The surfaces obtained from these materials were therefore not usable for obtaining Class A finished mould surfaces.

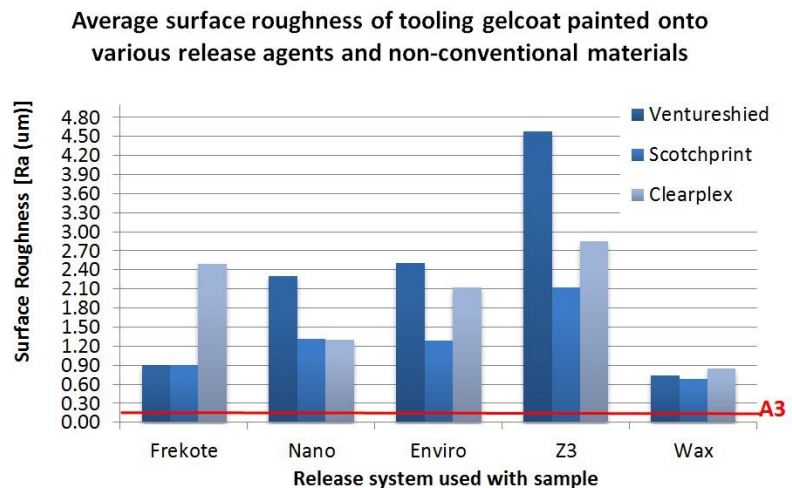


Figure 4-17: Average surface roughness of gelcoat surfaces on non-conventional materials versus various release agents

4.5.5 TEST 4.3: DATA AND RESULTS

The surface roughness obtained from the tooling gelcoat and wax release agent, described in Figure 4-18, was then compared to the values obtained in Test 3.2, when the acrylic and 2K surfaces were used as plug materials. From the Graph it can be seen that the acrylic and 2K paint both yielded tooling surfaces of below 0.120 μm , which means they are Class A2 surfaces.

The other three materials, however, yielded tooling gelcoat surfaces of higher than 0.600 μm , which is not even a P400 grit surface finish. From Figure 4-18 it is thus clear that the best plug surfaces to use would be 2K paint or acrylic sheets.

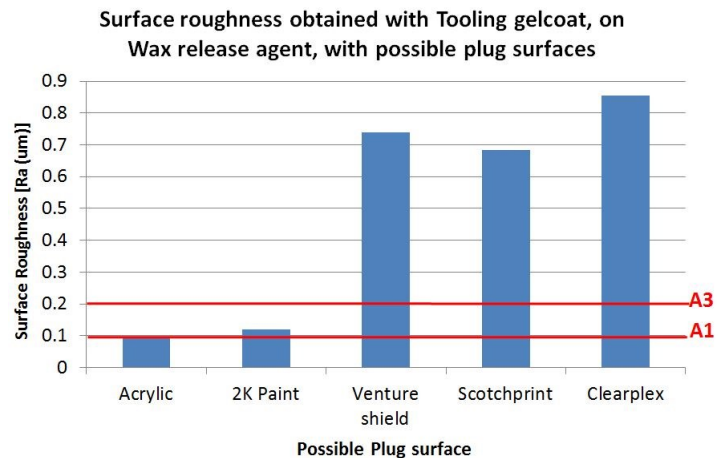


Figure 4-18: Surface roughness obtained with tooling gelcoat, on wax release agent, with possible plug surfaces

From Figure 4-18 it can also be gleaned that even the lowest values obtained from any of the non-conventional materials does not nearly compare to the surfaces obtained from acrylic sheet or a 2K finished plug surface.

4.5.6 TEST 4: CONCLUSION

From the test results obtained here, the conclusion was drawn that the use of non-conventional materials actually worsens the surface roughness projected onto the mould surfaces. These materials were also revealed to be largely incompatible with most of the release agents used in the mould-making process and have demoulding problems, with all of the release agents except Meguiars wax. From this test it can be concluded that using conventional 2K finishing of plugs and possibly split surfaces from acrylics will provide the best tooling gelcoat mould surfaces, with a minimum of Class A2 surface finish.

4.6 TEST 5: PRINT THROUGH BARRIER OF THE MOULD SURFACE

Composite surfaces can appear perfectly smooth directly after demoulding, but can develop small print-through after the post-curing cycles. Print-through is a small surface defect where the weave pattern of the first structural layer is imprinted on the surface due to shrinkage of the surface. This test created a matrix of time of application against the surface layers applied.

4.6.1 TEST 5: DESCRIPTION

The test was constructed using an acrylic surface. The surface was divided into a matrix of the different print barriers and waiting periods for curing of the gelcoat before applying the print barriers and structural reinforcement. The time frames used was 10 minutes, 30

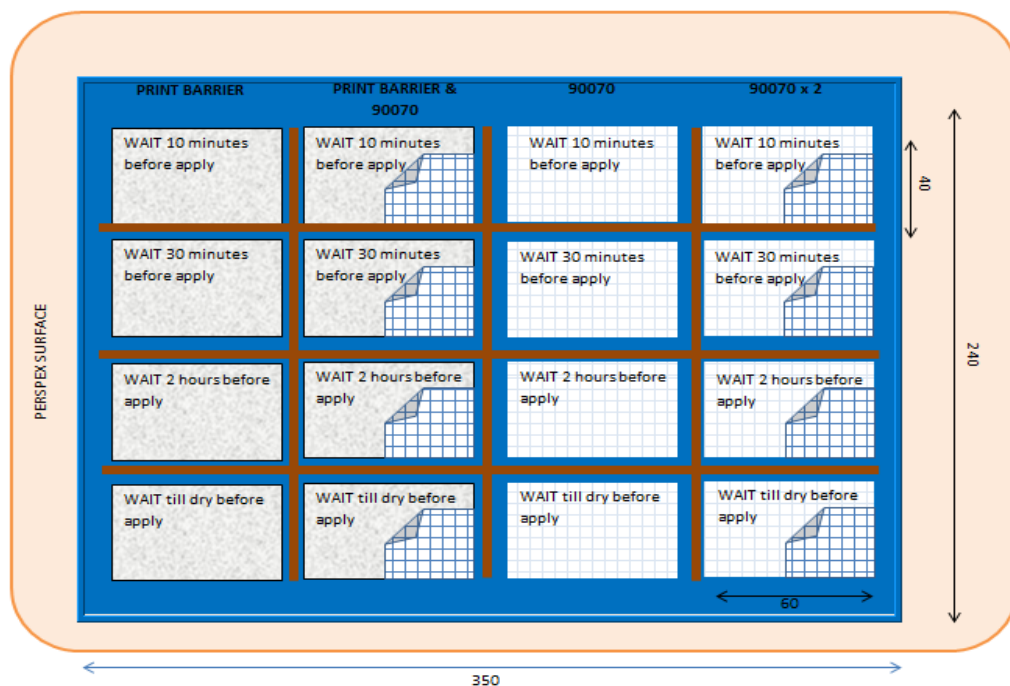


Figure 4-19: Print-through barrier test layout for various print barriers and time schedules.

minutes, 2 hours and 8 hours. Glass 92125 was used as a structural layer for all of the samples. The four print barrier methods tested were:

- Glass veil
- Glass veil and glass 90070
- Glass 90070
- Glass 90070 on 90° and 45°

Figure 4-19 illustrates the test layout matrix

4.6.2 TEST 5: MANUFACTURING OF THE SAMPLES

The acrylic surface was treated with Mequiars Mirror Glaze 87 Wax and divided into the matrix with masking tape. The materials were prepared and the gelcoat layer was applied.

After the gelcoat layer has been applied (Figure 4-20b), small layups of the different reinforcements (Figure 4-20c) were created a few minutes before expiration of each waiting period. A ten minute time-lapse was allowed before the first application of the surface layers (top row of Figure 4-20d) followed by 30 minutes, 2 hours' and 8 hours' time-frames. After the samples have been fully cured, they were demoulded and underwent 36 hours of post curing at 45 degrees before they were inspected for post-curing.

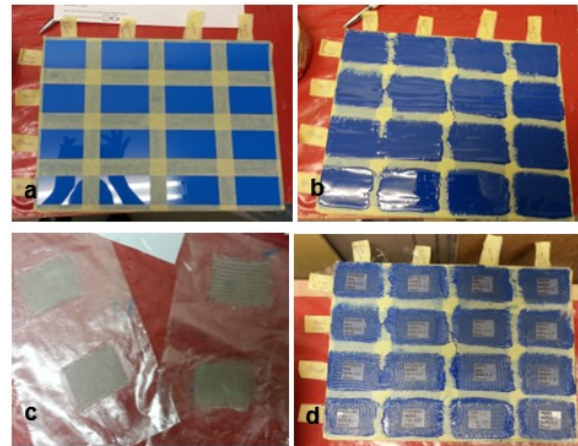


Figure 4-20: Manufacturing the print barrier samples.
(a) The mould (b) Applying the gelcoat (c) Preparing layups (d) Applying the structural layers

4.6.3 TEST 5: DATA AND RESULTS

Because it is difficult to capture print through on pictures and measurable quantities, this test was evaluated by means of inspection and the results are therefore qualitative in nature. A three-point scale was developed for evaluating the print-through. A “0” was awarded for a good surface with minimum print-through, a “1” for a surface with visible print-through and a “2” for a surface with severe print-through that is completely unacceptable.

Table 4-7 categorises the samples into a 0, 1, 2 category. A sample was rewarded a 0 if it revealed a clear print-through, it was awarded a 1 one if a slight print-through was visible, or if it was not clear whether there was a print-through or not. It only recieved a 2 if there was absolutely no print-through visible.

Table 4-7: Print-through test analyses

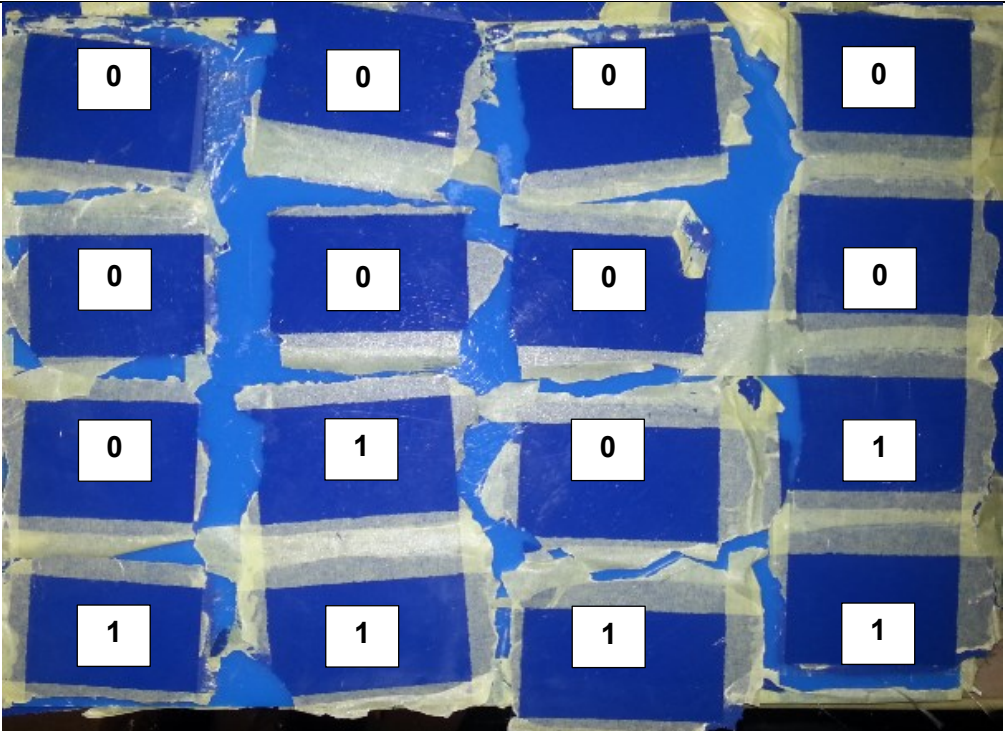
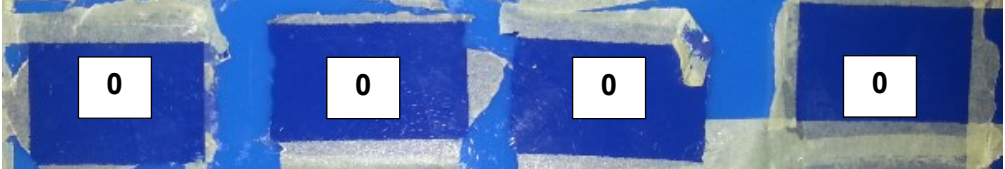
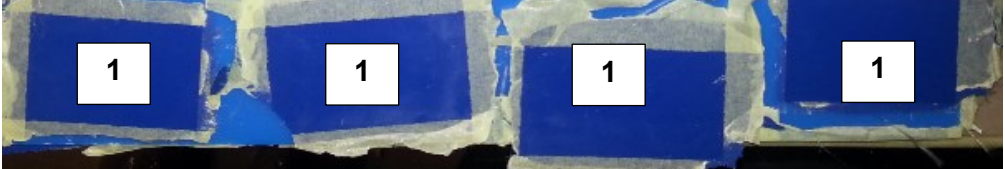
10 min before layup				
20 min before layup				
2 hours before layup				
8 hours before layup				
	Glass veil only	Glass veil & 90070	90070 only	2 x 90070
0 – print-through, 1 – vaguely print-through, 2 – no print-through				

Table 4-7 indicates that using all of the materials showed either a lot or a small measure of print-through. This meant that none of these materials on their own would be suitable as a print barrier. However, the test did reveal that curing of the tooling gelcoat, before applying the print barriers, did have a fairly significant influence on the print-through. All the samples with a time frame of 2 hours and 8 hours were found to yield less print-through than those samples of which the reinforcement was applied at 10 minutes and 30 minutes. The test also indicated that using a singular print barrier is not as good as using a double layer of print barrier.

4.6.4 TEST 5: CONCLUSION

The test results were not clear in terms of indicating the exact surface layers that one should use, but it could be concluded that the gelcoat layer should at least cure 2 hours to 8 hours before application of the layers.

4.7 TEST 6: APPLICATION OF TOOLING GELCOAT WITH A HEATGUN AND TOOLING GELCOAT VERSUS THE USAGE OF EPOXY SURFACES

After the completion of Test 5, it was still unclear which print barrier method one should use. What was still unclear was the influence of the application method of the tooling gelcoat, and a possible alternative surface layer for a composite mould; these have not yet been tested. Test 6 was then conducted with a view to answer these questions.

4.7.1 TEST 6: DESCRIPTION, MANUFACTURING AND RESULTS

The first two samples were manufactured to compare the usage of Epoxy filler mixture, illustrated in Figure 4-21. The filler used was Carb-o-sil, with a ratio of 3:2 Carb-o-sil to LR 25/287 Epoxy mixed. The other sample was tooling gelcoat, heated whilst applying. A small amount of tooling gelcoat was applied on another mould without heating. (Appendix B.2 provides more information on the manufacturing of these samples.)

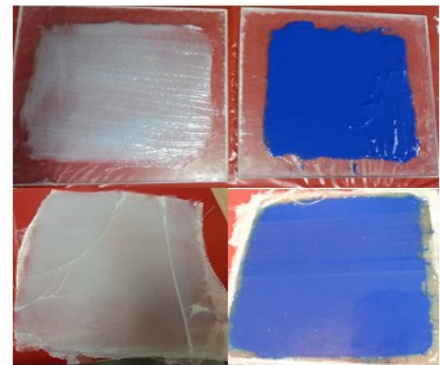


Figure 4-21: Manufacturing of Epoxy filler and gelcoat test samples

The sample with the epoxy filler showed difficulty in demoulding and was brittle, with a few surface discrepancies. It was concluded that this method is not suitable as a surface layer for composite tooling. It was also noticed that the heated tooling gelcoat became tacky in 20 minutes, thus increasing the gel time. This resulted in earlier application of the reinforcement layers. Both the gelcoat samples demoulded easily, and were trimmed to reveal a sectional view of the gelcoat layers.

The section view, Figure 4-22, reveals that when the gelcoat was not heated, it was automatically thicker and had more bubbles in the surface. These bubbles were not necessarily noticeable on the surface but if the surface were to be sanded, they would have appeared. The heated sample did not have these discrepancies and was automatically thinner. The thickness was 0.5mm on average. A good bond between the structural layers and the gelcoat was also noted.

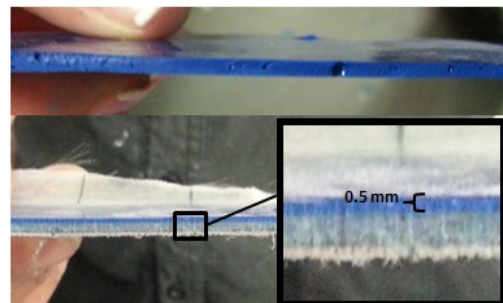


Figure 4-22: Sectioned view of tooling gelcoat samples.

The next test samples were manufactured the same way as described for the first test, but with different print barrier layers. One sample had four glass veil layers and the other sample two glass veil layers. Both samples were structurally reinforced with two layers on 90° and 45°, of

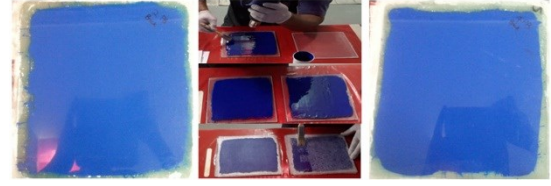


Figure 4-23: Print barrier layers applied onto cured, heated tooling gelcoat

90070, 92110, 92125 and 450 GSM, plain weave glass fibre. These samples were subjected to 48 hours of post curing at 45°C and then inspected for print through. Both the samples revealed to have no print through. The samples are shown in Figure 4-23. Thus, from the results of Test 4, it was concluded that two layers of glass veil and an increasing build-up of small to large fibre GSM, in both directions, eliminate print-through.

4.7.2 TEST 6: CONCLUSION

After Test 6 has been completed, it could be concluded that tooling gelcoat is a good surface layer for composite tooling. It should be applied whilst being heated and backed with at least two layers of glass veil and a steady increase of GSM of structural glass fibres to prevent print-through.

4.8 TEST 7: RELEASE AGENT VERSUS THE SPRAY OF PART SURFACE LAYERS

It was mentioned previously that JS uses gelcoat in the moulds for most products. The demoulded product is then finished with a 2K paint system. This is done to correct the moulded finish to the required A1 finish. It is, however, desirable to finish the component directly from the mould and for many parts a 2K finish is also required by the customer.

This section will therefore investigate the effect of the release system on the surface finish and as a second step evaluate the possibility of using 2K paint in the mould instead of gelcoat.

4.8.1 TEST 7: DESCRIPTION

The test was conducted on a tooling gelcoat flat mould surface. The surface was divided into the different release agents. The 2K paint and tooling gelcoat were then applied over all the release agents, as illustrated in Figure 4-24. The surface layers were first applied in a mist coat layer, then two full layers followed, after which the reinforcement materials were applied.

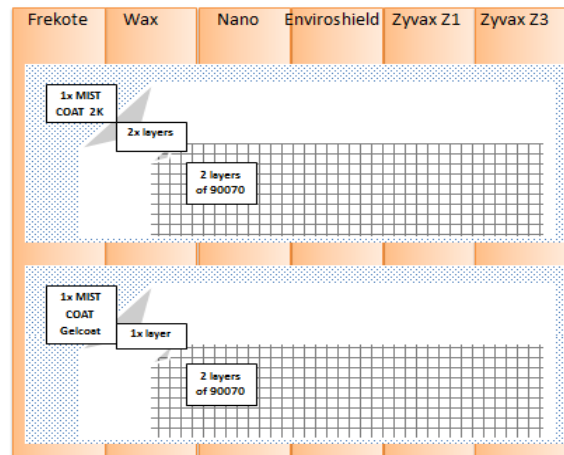


Figure 4-24: Test 7 layout

4.8.2 TEST 7: MANUFACTURING

The samples were manufactured on a moulded composite tooling gelcoat surface with an average surface roughness of 0.230 μm . The first step in the process was to treat the surface with all the particular release systems, according to each system's datasheet, Appendix H, as illustrated in Figure 4-25.



Figure 4-25: Test layout of the release agent test

The next step was the spraying. A 2K Standox paint and gelcoat were mixed and sprayed onto the surfaces with an initial mist coat. Five minutes after the application of the initial mist coat layer, the next layer was applied. Five minutes after the application of the second layer, a third layer was applied. These layers showed yet potential for pinholes with the Zyxax Enviroshield, as illustrated in Table 4-8.

After the application of the paint layers, 30 minutes had elapsed before the surface layers and structural layers was applied. The layers comprises of two layers of print barrier, two layers of 90070 glass fibre on 90° and 0°, two layers of 92110 glass fibre on -45° and +45° and two layers of 92125 glass, on 90° and 0°.

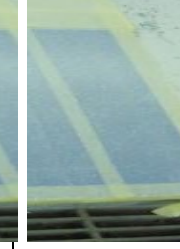
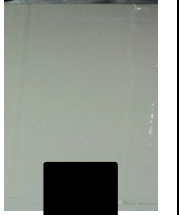
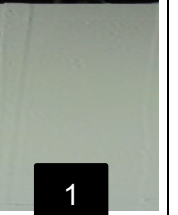
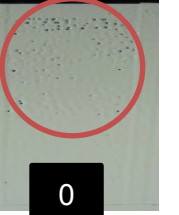
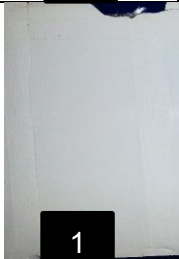
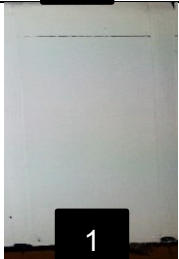
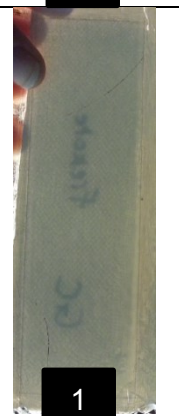
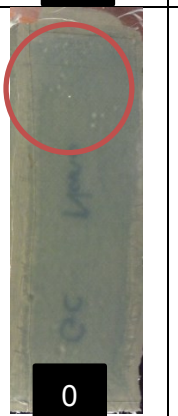
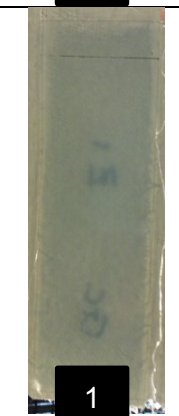
4.8.3 TEST 7: DATA AND RESULTS

Tables 4-8 and 4-9 were drawn up with a scoring system to decide on the best possible release system to use. The criteria were potential pinholes during spraying, demoulding failure and surface discrepancies after demoulding. A mark of 0 was allocated if the sample failed the criteria and 1 if the sample passed the criteria. The samples with the highest score were chosen as the release agents to be used.

4.8.3.1 TEST 7.1: DATA AND RESULTS

From Table 4-8 it is clear that Enviroshield revealed discrepancies already from the time when the spraying layers was applied. The other samples seemed to have no discrepancies during spraying or after demoulding. However, when held against a light, all the samples except for the Zyxax Z1 and Meguiars Wax revealed discrepancies. The number of discrepancies with the Frekote was, however, very minor, and less than those found with the Zyxax Nano, Enviroshield and Z3. For spraying gelcoat with IMC, the best release agent to thus use is Meguiars wax, but if a semi-permanent release is desired, Frekote can be used.

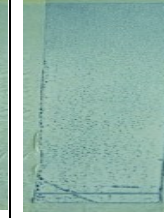
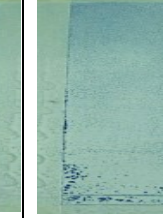
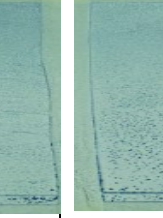
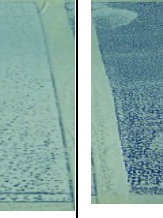
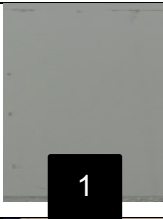
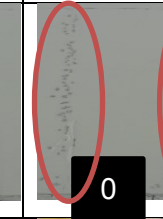
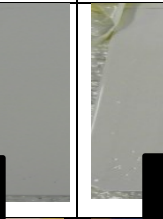
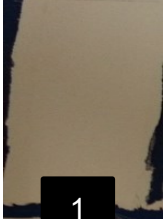
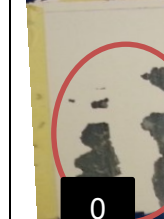
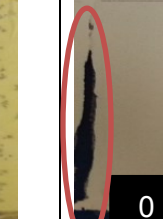
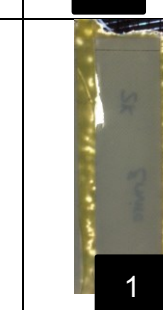
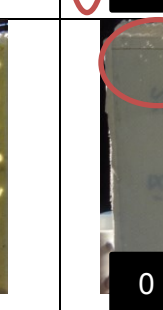
Table 4-8: Gelcoat paint with various release agents results

Mist coat						
Third full layer						
Ease of demoulding						
With a back light, after demoulding						
	Loctite Frekote 770-NC	Meguiars mirror glaze 87 wax	Zyxax Nano	Zyxax Enviroshield	Zyxax Flex Z1	Zyxax Flex Z3
	3	2	2	0	3	2

4.8.3.2 TEST 7.2: DATA AND RESULTS

Test 7.2 tested the IMC of 2K paints with various release agents. This test also revealed potential problems with the Zyxax Enviroshield, as illustrated in Table 4-9. The Enviroshield did not have pinholes on the core of the sample, but it did show a large number of pinholes on the sides of the sample. The Zyxax Nano was very difficult to demould and the Zyxax Enviroshield and Zyxax Z1 revealed minor demoulding difficulties. The Zyxax Z1 and Z3, however, were found to have a great many pinholes when held against the light, with Frekote again showing a very minor presence of pinholes. From Table 4-9, it can be seen that the Meguiars wax is again the best IMC release agent to use, but if one required a semi-permanent release agent, the Frekote is the best choice.

Table 4-9: 2K with various release agents results

mist coat						
Third full layer	 1	 1	 1	 0	 1	 1
Ease of demoulding	 1	 1	 0	 0	 0	 1
With a back light, after demoulding	 2	 1	 1	 1	 0	 0
	Loctite Frekote 770- NC	Meguiars mirror glaze wax 87	Zyxax Nano	Zyxax Enviroshield	Zyxax Flex Z1	Zyxax Flex Z3
	2	3	2	1	1	2

4.8.4 TEST 7: CONCLUSION

The test showed that Loctite Frekote 770-NC and Meguiars Mirror Glaze 87 wax scored the highest, with a total of 5. The numbers of pinholes created by the Loctite Frekote 770-NC release system and Meguiars Mirror Glaze 87 Wax are also much smaller than the number of pinholes created by the other release agents. Loctite Frekote 770-NC release system and Meguiars Mirror Glaze 87 Wax also demoulded easily, without any damage. This shows that Meguiars Mirror Glaze 87 Wax or Loctite Frekote 770-NC release system can be used with the application of either 2K paint or gelcoat.

4.9 TESTING SUMMARY

Seven tests were completed, which revealed the information required to compile the proposed methodology for the manufacturing of Class A finished parts.

Test 1 revealed that a Class A surface finish is between 0.200um and 0.050 um, which could be used to verify demoulded parts. Test 2 revealed guideline settings to be used with the CNC manufacturing of Nuceron651, with the most significant parameter the step over with a value of 0.5 being most suitable for the finishing processes. Test 3.1, 3.2 and 4 revealed that acrylic and 2K paint can be used as a possible solution for split surfaces; however, the use of the tested non-conventional materials is not advised.

Test 3.3 revealed that best method for strengthening mould small radii and sharp corners is the use of rovings. Test 5 did not provide a clear answer on the use of print barriers, but this test was followed with Test 6 which revealed that a tooling gelcoat is a good surface layer for composite tooling, provided that it is applied whilst heating. Print-through can be minimised by the use of glass veil as print barrier with a steady increase of GSM of structural glass fibres.

Finally Test 7 revealed that Meguiars wax release agent or Loctite Frekote 770-NC release system can be used when 2K paint or gelcoat is sprayed directly into the mould.