# THE QUALITITATIVE EFFECT OF VARIOUS PREFORMING RELATED DEFECTS WITHIN AS MOULDED PREPREG CARBON FIBRE LAMINATES

Richard Russell, Composite Manufacturing Engineer, Rolls-Royce Plc

*Richard.Russell@rolls-royce.com*

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**Abstract**

In order to study the resulting defects in laminates various preforming related contaminant and features were introduced into carbon fibre composite panels prior to cure. The panels were subsequently non-destructively tested in the post cured condition to determine if they could be detected. Furthermore the samples were sectioned and inspected via microscopy to understand the relationship between defects prior to cure and how they manifest themselves after cure. From this study it has been possible to determine the most severe types of contaminants in terms of the resulting defects as well as the characteristics of those defects.

## 1. Introduction

When manufacturing composite parts in industrial production facilities, where the processing can be numerous and complex, it can become difficult to eliminate all sources of contamination. Contaminants can come from the manual or automated processes in the plant and can include fluids (such as water, acetone and grease) or solids (such as ply cuttings and dust). It then becomes a challenge to determine which contaminants need to be priorities over others.

Prior to carrying out this investigation it was noted that little evidence was documented in the publically available literature into the effect of various preforming related defects on the cured component. It was deemed necessary to investigate further into such like defect / features during the preforming stage to understand which defects maybe more critical than others and therefore require close manufacturing control and safe guarding during preforming operations.

The author was aware that various pieces of work have been ongoing using modelling techniques and verification into the effects of various preforming related defect types, namely gaps and overlaps between plies and tows, in plane and out of plane wrinkling and de-laminations [1 to 4]. However little work was found to investigate into various preforming related threats such as the various foreign objectives that may eventually become cured into the part.

## 2. Experimental Setup

To help understand the relationship between defects and features which may be introduced into a carbon fibre reinforced composite structure during preforming and how they manifest themselves in the as-moulded state, various samples were manufactured.

Eight different defect / feature types were introduced into three panels, which would represent common contaminants during typical manufacturing processes. Each defect type was graded as low, medium and high 'severity' based on the size introduced into the panel during lay-up. Each defect / feature was introduced into the central ply of each panel to help determine and trace the location for post cure inspection work.

Each panel was de-bulked under vacuum at ambient temperature, autoclave cured and then inspected using through transmission and pulse echo inspected prior to micro structural evaluations via cut ups.

Figures 1 to 3 show the position and type of defects, which were introduced into the mid ply of each panel.

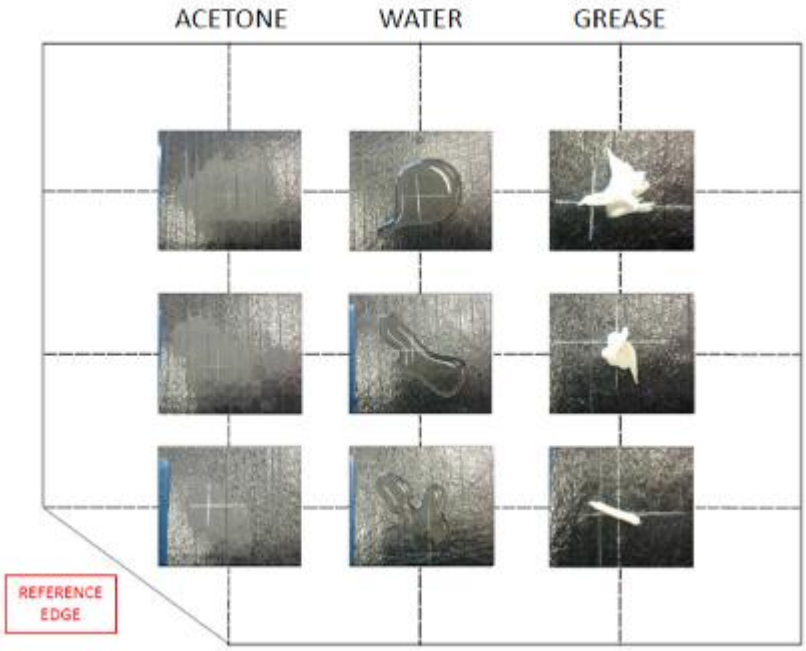


Figure 1. Defect / feature type identification and location in panel 1.

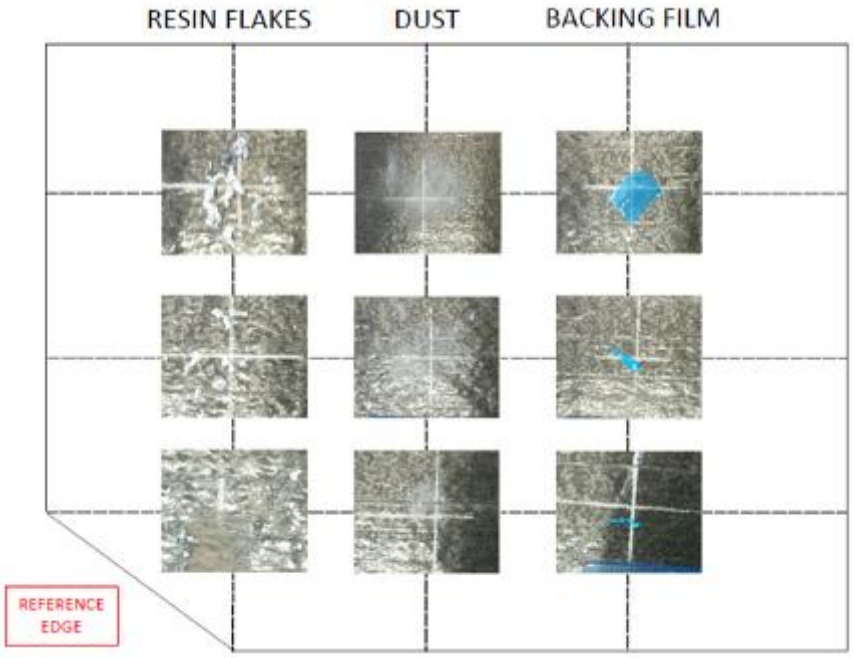


Figure 2. Defect / feature type identification and location in panel 2.

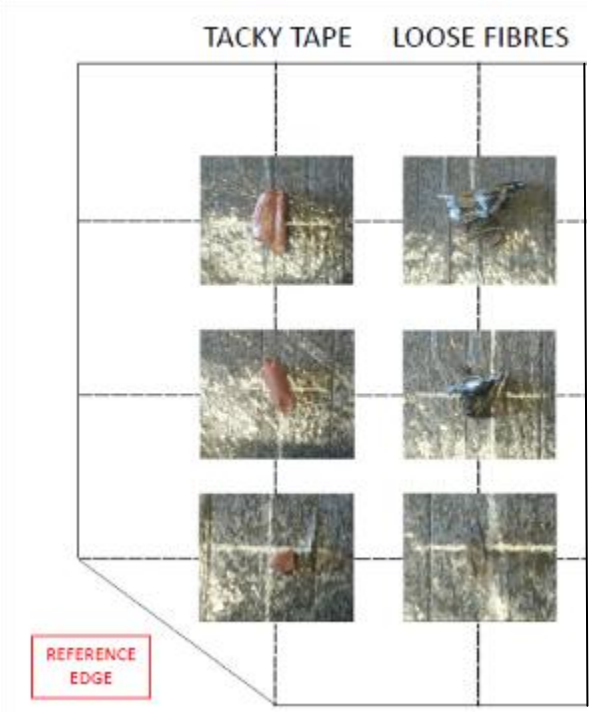


Figure 3. Defect / feature type identification and location in panel 3

## 3. Results and Discussion

Following the curing process each panel was inspected using through transmission and pulse-echo ultrasonic NDE methods to help determine what can be detected for the given sizes / severities of each defect type.

Table 1 below gives a summary of NDE findings for each defect type and their sizes (measured pre cure) to indicate what were detected (indicated by a tick) and those which had not.

| Defect | Size | T/ Trans | Pulse Echo |
|---|---|---|---|
| ACETONE | Small (38.5mm x 29.5mm) | | |
| | Medium (62.5mm x 59mm) | | ✓ |
| | Large (71mm x 66mm) | ✓ | ✓ |
| WATER | Small (40mm x 30.2mm) | | |
| | Medium (47.8mm x 47.5mm) | | ✓ |
| | Large (52.1mm x 52.5mm) | ✓ | ✓ |
| GREASE | Small (4.2mm x 13.9mm) | ✓ | ✓ |
| | Medium (15.8mm x 9.8mm) | ✓ | ✓ |
| | Large (19.2mm x 18.9mm) | ✓ | ✓ |
| RESIN FLAKES | Small (2mm x 1mm) | | |
| | Medium (8.5mm x 7mm) | | ✓ |
| | Large (20mm x 14.5mm) | | ✓ |
| DUST | Small (10.8mm x 10mm) | | |
| | Medium (20.5mm x 23mm) | | |
| | Large (36.5mm x 37.8mm) | | |
| BACK FILM | Small (1mm x 6mm) | ✓ | |
| | Medium (9.2mm x 8.9mm) | ✓ | ✓ |
| | Large (14.5mm x 14.4mm) | ✓ | ✓ |
| Tacky Tape | Small (2.5mm x 2.5mm) | ✓ | ✓ |
| | Medium (7.8mm x 4mm) | ✓ | ✓ |
| | Large (14.5mm x 7mm) | ✓ | ✓ |
| Loose Fibres | Small (5.9mm x 2mm) | | |
| | Medium (9.7mm x 11mm) | | ✓ |
| | Large (13.5mm x 15.2mm) | | ✓ |

Table 1. A summary of NDE findings by defect / feature type and their sizes.

Following NDE inspection work, the panels were sectioned at the defect location and examined using optical microscopy. Each sample was ground flat and polished to a 6 micron metre finish.

The following conclusions have been taken from the evaluations of the defects / features taken from the 'large' defect sizes intentionally added into the panels.

### 3.1 Acetone damage

As expected, the addition of acetone to the preform caused significant delamination and absence of resin in between the affected plies. The images of the acetone damage in Figure 1 show the instantaneous damage of the uncured prepreg ply which corresponds well with the through thickness as moulded cross sectional damage and delamination in between plies as per Figure 4.

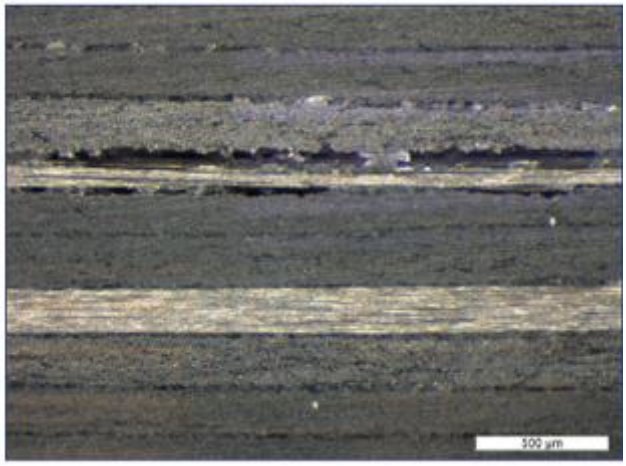


Figure 4. Acetone damage in between post cured plies.

### 3.2 Autoclave grease damage

The autoclave grease was the most aggressive and damaging defect / feature introduced into this package of work. It was seen that the grease, as expected, had flowed and spread itself to a much greater area than the initial addition and also spread in between affected through thickness plies during cure. The grease appeared to have taken away resin matrix in between the affected plies and also caused some apparent heat damage / scorching affects on the surrounding regions indicating that there may have been a local exothermic reaction in the region affected. This is shown below in figure 5.

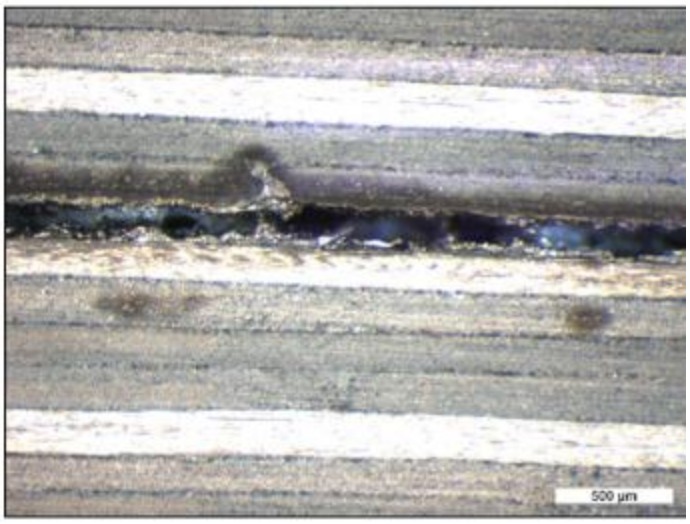


Figure 5. Autoclave grease damage in between post cured plies, showing significant damage and heat damage / discolouration within surrounding affected plies.

### 3.3 Water damage

No significantly discernable difference between the plies with water sprayed onto them and those without was seen post cure. Arguably local regions of slightly higher porosity in between affected plies may be deduced and further image analysis work would be required to make a more firm conclusion, however little effect was found in this work.

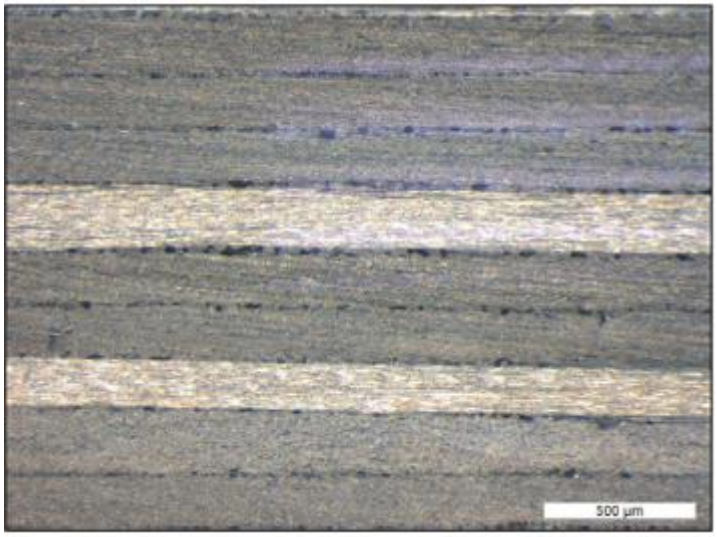


Figure 6. Water damage, showing little effect in between affected cured plies.

### 3.4 Resin flakes

Similarly to water additions, no significant differences between affected plies with local additions of resin flakes (from parent material system) was found. Small regions of resin richness were occasionally seen on close examination of the ply affected across the panel, however this was very minute differences to the unaffected parent material and therefore was deemed insignificant.

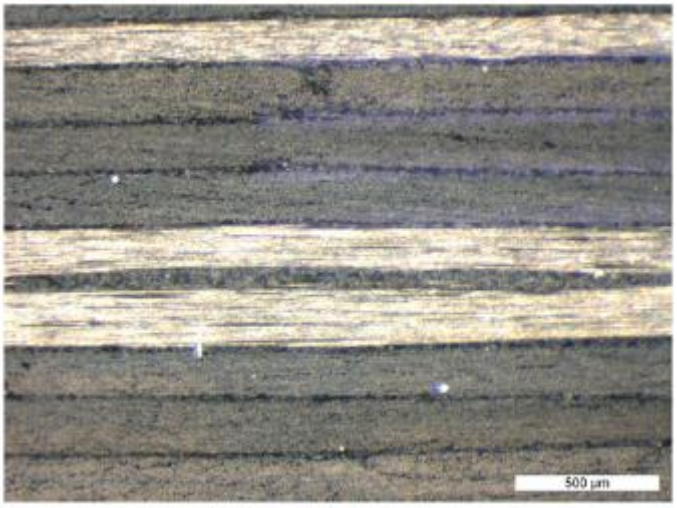


Figure 7. Local resin flake additions, showing little effect in between affected cured plies.

### 3.5 Backing film

As expected the addition of the prepreg backer film showed a clear delamination and dis-bond between affected ply zones post cure. The dis-bond did not appear to extend past the edge of the backing film.

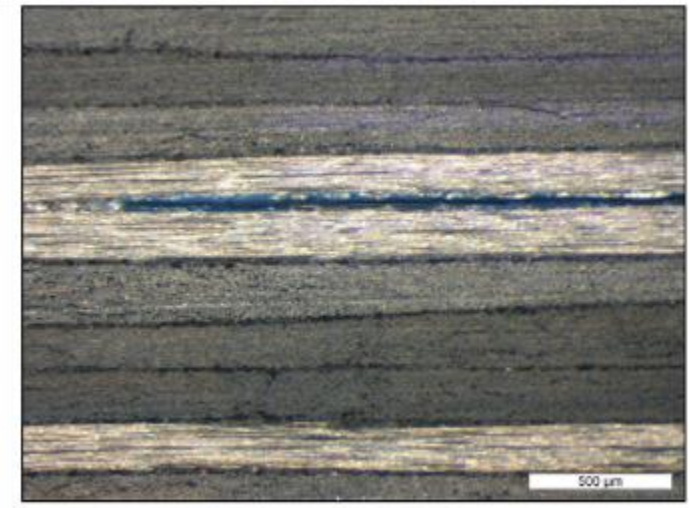


Figure 8. Backing film showing clear delamination / dis-bond between affected plies.

### 3.6 Dust

Dust from surrounding areas outside of the preforming cleanroom was added into the central ply of the panel also. However little effect of the dust was found in the post cured laminate panel. A very local region was found, however no significant affect in the samples taken could be concluded.

### 3.7 Tacky tape from vacuum bag

Unfortunately the tacky tape was not found during microscopic evaluation at the time of writing and further work is required to detect this defect type and assess its effect on the cured laminate. It can however be determined that through the NDE test work on the panel that significant delamination and dis-bond between plies was caused, as expected. The NDE, ultrasonic through transmission scan work is shown in Figure 9.

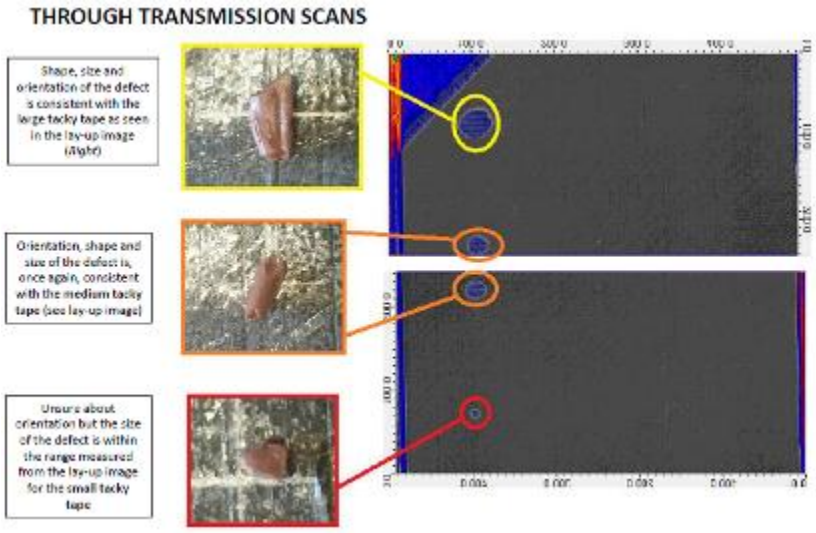


Figure 9. Through transmission assessment work carried out on tacky tape defects within cured laminate.

### 3.8 Loose fibres

Loose / stray fibres were shown to have some effect on the NDE test work performed and on the microscopy work they were also detected as local regions of out of plane deviations as shown in Figure 10.

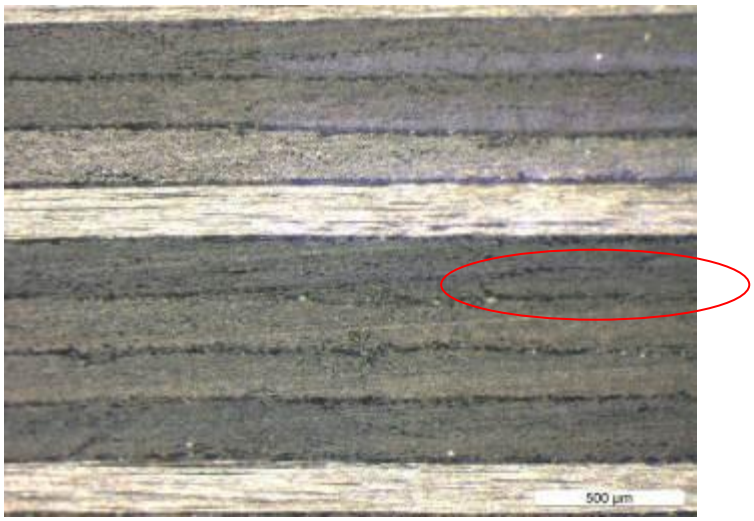


Figure 10. Loose fibres detected through thickness as moulded condition.

## 4. Conclusions

It was concluded that all defect feature types were found to have some effect on the as moulded laminate, this was deemed through both NDE and microscopy work. Further work is required to more firmly conclude the effects of dust, tacky tape, water and loose fibres on the laminate in the cured condition.

It was determined that autoclave grease lubrication and acetone were the most aggressive foreign materials which were seeded into the preform prior to cure, as not only did the former cause significant delamination but they also caused evidence of heat damage to surrounding plies. Other defects such as water damage and loose fibres showed little effect on the cured panel, however further sectioning and investigation need to be carried out to understand these defects / features.

Within the production environment this study has provided useful information in prioritizing which contaminants would need to be controlled more rigorously than others. It also highlights areas where further research can provide value through quantifying the effects of the most severe contaminants on the resulting composite structures.

## References

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