EXPERIMENTAL EVALUATION FOR CFRP STRENGTH AFTER VARIOUS PAINT STRIPING METHODS

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Abstract

Paint strip technology is one of the fundamental processes for aircraft maintenance operations. This paper shows an experimental evaluation of mechanical properties of paint-stripped CFRP laminates. Tensile and compressive strength tests were conducted on CFRP laminates which had gone through paint strip by various paint strip methods, including sanding, chemical strip (methylene chloride type), plastic media blast (PMB) strip, and TEA-CO_2 laser coating removal method. The surface observations of the paint stripped CFRP laminates were conducted by optical microscope. The TEA-CO_2 laser coating removal methods were also demonstrated in sectional cut observation of the surface. In tension strength test results, obvious mechanical properties (strength and elastic modulus) changes were not obtained, except for the fact that the chemical-stripped CFRP laminates showed large coefficient variation in tensile strength. Compressive strength results also did not show much difference in their mechanical properties. On the other hand, matrix damage and/or fiber breakages were observed on the surface of paint-stripped CFRP laminates which methods were sanding strip (complete), chemical strip, PMB strip (complete), and laser carting removal method (complete and further strip).

1 Introduction

Paint strip technology is one of the fundamental processes for aircraft maintenance operations. At present, aircraft structures are mainly made of metallic materials. Several mechanical and chemical paint stripping methods, such as sanding by hand, plastic media blasting (PMB), and chemical paint remover, are applied during aircraft structural maintenance. Recently, proportions of composite structures to the aircraft have increased including main structures of the aircraft. It will be a major concern about what paint stripping methods are safe and economical for such composite aircraft structures. This report shows an experimental evaluation of strength effects for CFRP laminates on which several paint stripping methods were applied. Sanding by hand, plastic media blasting (PMB), paint remover (chemical stripping), and TEA-CO_2 laser coating removal system by SLCR, were employed. Painted CFRP laminates were dried, then the paint of these CFRP laminates were removed via several paint stripping methods and different stripping conditions. Surface observation and sectional cut observations were conducted on the CFRP laminates after paint removal. Moreover, tension strength and compression strength tests were conducted before and after the paint had been stripped from the CFRP laminates.

2 Test Method

The CFRP laminates were made of 180-degree cure type epoxy and T300 woven fabric system, BMS-256. Eight-ply and 16-ply quasi-isotropic CFRP laminates were prepared for tension and compression strength evaluation, respectively. These CFRP laminates were painted with a primer (Epora 3000) and a topcoat (V-100) after surface treatment. An epoxy type of primer (Epora 3000) was painted one time, and a polyurethane type of topcoat for aircraft (V-100) was painted two times on the CFRP laminates surface. After a drying process, the paint was stripped by different types of paint-stripping methods and conditions. The paint stripping condition matrix is shown in Table 1. After paint stripping, these CFRP laminates surfaces were observed by optical microscope. Tension and compression test specimens were also prepared and tested.

Table 1 Paint stripping condition matrix

Stripping method			Conditions
8 ply 12 ply	1	No paint removal	-
	2	Sanding 1	Complete removal
	3	Sanding 2	3 times paint and remove
	4	Chemical removal	-
	5	PMB 1	Complete removal
	6	PMB 2	3 times paint and remove
	7	Laser	3 level irradiations

2.1 Paint process

Masking and lightly sanding were applied to the CFRP laminates. An epoxy primer (Epora 3000S) was applied to the CFRP laminates surface as undercoating. After undercoating, polyurethane enamel paint (V-100) was painted on the undercoated CFRP laminates. The total thickness of painted CFRP laminates was 30-50 micrometer. Figure 1 shows an example of a painting process picture in a field.

Fig. 1 Paint process

2.2 Paint stripping

2.2.1 Sanding

The sanding method is the most common paint stripping method for composite aircraft structures. The topcoat and undercoat were removed from these specimens and referred to as Sanding 1 (complete). Those with only the topcoat removed were prepared as Sanding 2. In the Sanding 2 case, the painting and stripping of the topcoat were repeated three times. Figure 2 shows a picture of the paint stripping by the sanding method.

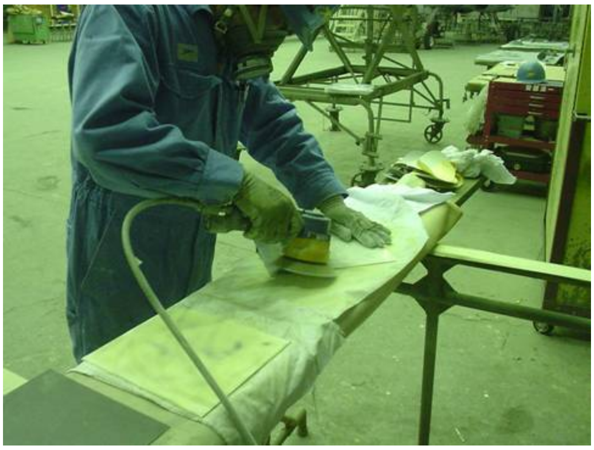
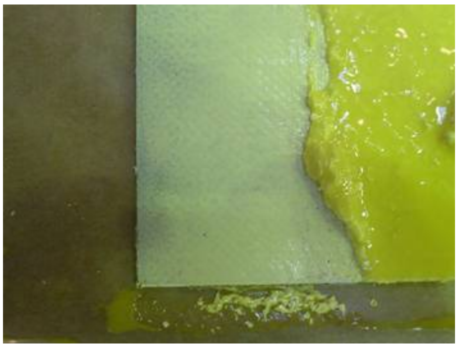


Fig. 2 Paint stripping by sanding

2.2.2 Chemical paint stripping

A chemical stripping method, methylene chloride type paint remover, was used for paint removal on the CFRP laminates, deliberately. Normally, the methylene chloride type of paint remover is not applied on the paint stripping of CFRP laminates and bonded structures. Using the paint remover, after 55 minutes, the topcoat and undercoat were completely removed from the CFRP laminates. Figure 3 shows a picture of a paint stripping operation by the paint remover and paint stripping surface of the CFRP laminates.

(a)



(b)

Fig. 3 Paint stripping by chemical paint remover
(a) Paint stripping, (b) Surface of stripping CFRP laminates.

2.2.3 Plastic media blasting(PMB)

The PMB method was employed to the CFRP laminates, deliberately. This method also is not used on composite aircraft structures, in general. The size of PMB was 30/40 mesh. The pressure of blasting was set to 30 psi for complete paint removal as PMB 1 and 20 psi for the topcoat only removal as PMB 2. In PMB 2, the painting and removal process were repeated 3 times in the same CFRP laminates. Figure 4 shows a picture of PMB operation in the PMB work space.

Fig. 4 Paint stripping by PMB.

2.2.4 TEA-CO_2 Laser coating removal method

A TEA-CO_2 laser coating removal system was developed by SLCR in Germany. Figure 5 shows a picture of the SLCR machine which equipped a robot hand for paint stripping aircraft parts. Three levels of the laser strength were set in this study: complete, selective, and further. The complete level can remove the topcoat and undercoat on the CFRP laminates at the same time, the selective level only removes the topcoat, and the further level is a stronger level of laser beam condition than the complete level. Figure 6 shows the paint stripping on the CFRP laminate surface by laser coating removal method in which levels were complete, selective, and further.

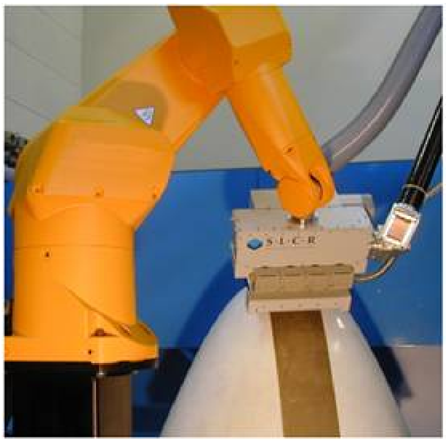


Fig. 5 Paint stripping by TEA-CO_2 coating removal method.

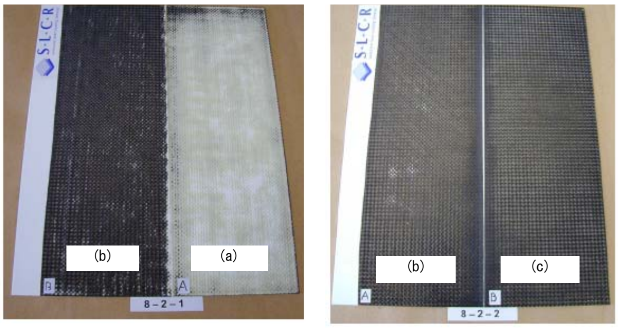
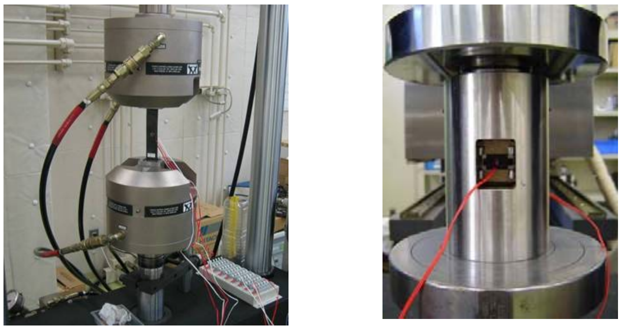


Fig. 6 After paint stripping CFRP laminates.
(a) Selective, (b) Complete, (c) Further

2.3 Specimen of static tests

After various paint-stripping methods were applied, static test specimens were cut from the CFRP laminates. Eight-ply specimens were for tension, 12-ply specimens were for compression. The tension test specimen size was 250 mm (length) and 25.4 mm (width). Compression test specimen size was 80 mm (l) and 15 mm (w). Figure 7 shows pictures of tension and compression test setups.



(a) (b)

Fig. 7 Test setups.
(a) Tension, (b) Compression

3 Results

3.1 Surface observation

Figure 8 shows the surfaces of applying several paint stripping methods for CFRP laminates, including the no paint case. An optical fiber digital microscope (Keyence VHX-200) was used for the observations. The magnification is 40. Figure 8(a) is the no-paint CFRP laminates. Figure 8(b) is the surface after paint stripping by chemical remover. The undercoat remained a little in the textures of the fabric. Figure 8(c) is the surface after paint stripping by sanding (complete). The undercoat remained a little on the surface, and it was observed that the surface was flat in comparison to other stripping methods. Figure 8(d) is the surface after paint stripping by PMB (complete). Many pits were observed and the surface was uneven. Figure 8(e) and (f) were using TAE-CO_2 laser coating removal method, selective and complete. A white surface was observed in figure 8(e), because the undercoat remained by using the selective level of the laser beam. On the other hand, the undercoat did not remain by using the complete level.

From these surface observations, obvious fiber breakage and resin starvation on the CFRP surface by microscope observations was not observed.

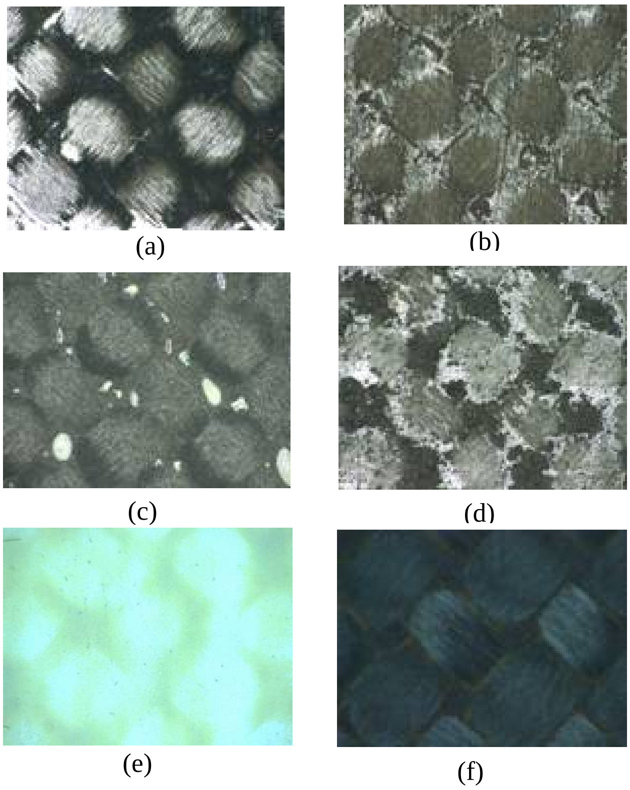


Fig. 8 Surface observation results.
(a) No paint, (b) Chemical remover, (c) Sanding (complete), (d) PMB (complete), (e) Laser coating removal method (Selective), (f) Laser coating removal method (complete).

3.2 Tension strength test

Tension strength tests were conducted after various paint stripping methods of CFRP laminates. Figure 9 shows the averaged static strength and modulus of tension tests. The number of the test specimens was 5. It was found that the tension strength of several paint stripping methods were not much different in strength and modulus. The only difference was that the chemical stripping CFRP laminates strength had larger coefficient of variation (Cv) than other stripping methods.

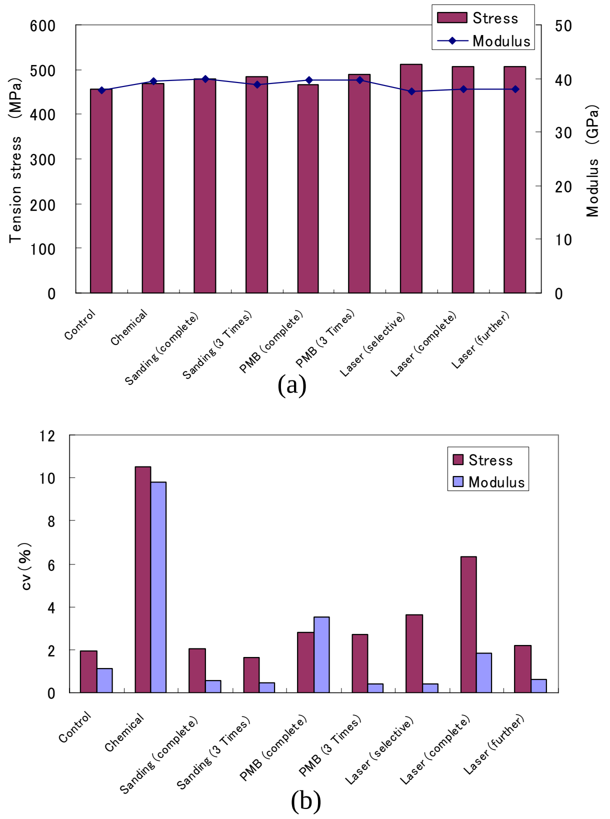
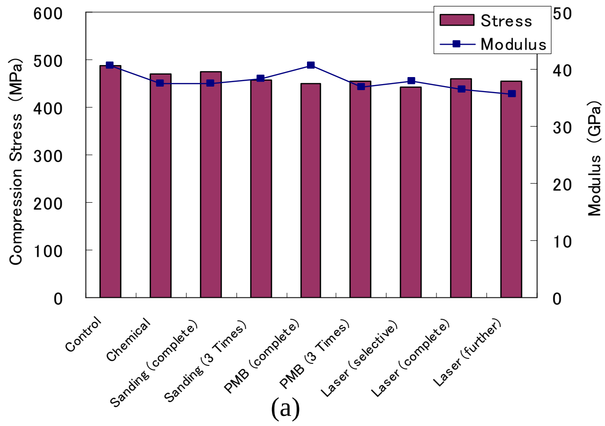


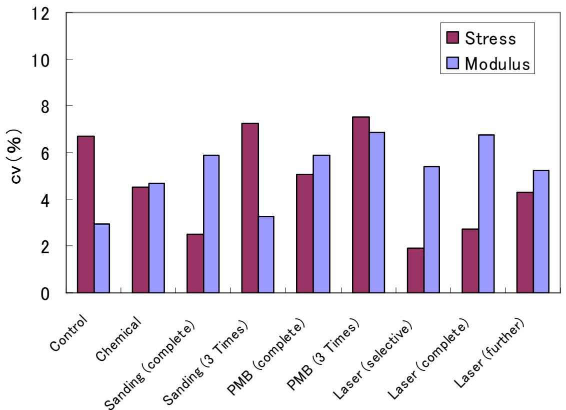
Fig. 9 Tension test results.
(a) Tension strength, (b) Coefficient of variation (Cv)

3.3 Compression strength test

Compression strength tests were conducted after various paint-stripping methods on the CFRP laminates. Figure 10 shows the averaged static strength and modulus of compression tests. Small strength deteriorations were observed in the PMB (complete) and laser stripping (selective) case. However, it was not determined that those of deteriorations were caused by paint stripping effects. There were no obvious differences in compression strengths, modulus, and coefficient of variation.



(a)

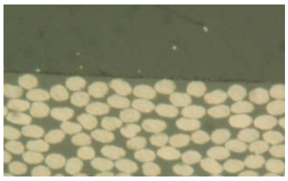


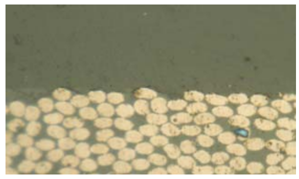
(b)

Fig. 10 Compression test results.
(a) Compression strength, (b) Coefficient of variation (Cv)

3.4 Sectional cut observation

Sectional cut observations by microscope were conducted near the CFRP surface after paint stripping. An optical fiber digital microscope (Keyence VHX-1000) was used for the observations, and the magnification was 500 or 1000. Figure 11 shows various paint stripping methods-applied CFRP laminates surfaces: no paint (a), chemical stripping (b), sanding (complete)(c), PMB (complete)(d), and laser coating removal methods (selective (e) and complete (f)).
The no-paint CFRP surface (a) was observed that the resin layer remained on the CFRP surface and carbon fibers were ordered precisely. In the chemical remover stripping (b), there was no resin layer on the surface and carbon fibers were exposed of the CFRP laminates. In the sanding method, there was not only resin layer disappearance but also the carbon fiber was worn out (c). This means that the carbon fiber and resin are damaged by the sanding method. In the PMB method (d), there was resin layer disappearance and an uneven surface, caused by media hit, on the CFRP laminates surface. In the laser method (selective)(e), a remaining layer of the undercoat was observed. There was a slight uneven surface on the undercoat surface. Though, it was suggested that the laser coating removal method could be carried out for precise paint removal, such as only topcoat removal, without CFRP surface damages. In the laser (complete and further) case (e and f), all of the paint was removed and carbon fibers exposure on the CFRP surface and uneven surface were observed, as with the PMB case.


(a)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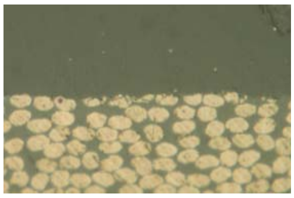
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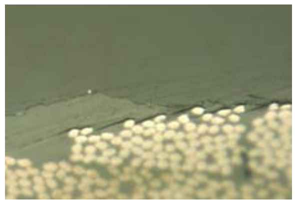
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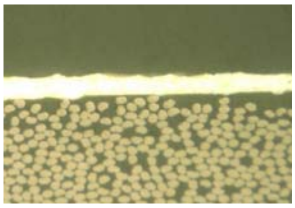
(e)

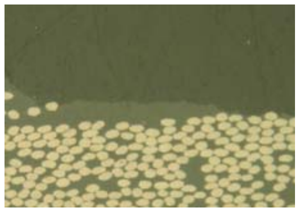
(f)

Fig. 11 Sectional cut observation results.
(a) No paint, (b) Chemical remover, (c) Sanding (complete), (d) PMB (complete), (e) Laser coating removal method (Selective), (f) Laser coating removal method (complete).

4 Discussion

4.1 Strength and paint stripping methods

The strength effect on several paint stripping methods were investigated for CFRP laminates. These paint-stripping methods include those used for metal aircraft structures. The result that tension and compression strength and modulus were almost equivalent even after paint stripping the CFRP laminates. Only one case of tension strength coefficient of variation was larger than others in the chemical stripping method. It was suspected that the CFRP surface resin was damaged by chemical attack and there was no resin layer near the CFRP surface in this method. The sanding method also had observed damage of fiber and resin by sanding operation. It is suggested that special attention be paid by the operator to remove the undercoat without damage to the CFRP laminates. An uneven resin layer on the CFRP surface was observed on the PMB method. Some disappearance of the resin layers was also observed. Figure 12 shows a sectional observation result as a comparison of the surface after the PMB (complete) and laser coating removal method (complete and further). All of the methods give an uneven resin layer and fiber exposure after paint stripping the CFRP laminates, though there was not much effect on the static strength and modulus in this test results. However, there is not evidence of strength effects by fatigue or environmental effect. These strength effects must be considered in future works.

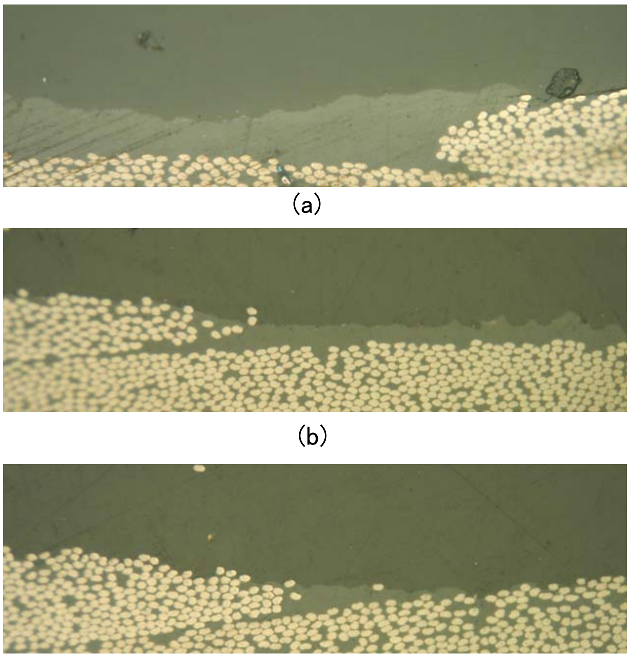

Fig. 12 The comparison of CFRP surfaces, PMB and laser coating removal method.
(a) PMB (complete), (b) Laser coating removal method (Complete), (c) Laser coating removal method (further).

4.2 Time of paint removal

Table 2 shows an estimation result of paint removal time of one side of the CFRP surface, where area size is 200 mm and 200 mm (The time of the laser methods were estimated from catalogue data). It does not include preparation time for equipments or machines.

It takes more time for only topcoat paint stripping by sanding, because that is a hand operation, and the operator needs to pay additional attention when undertaking only topcoat paint stripping without undercoat removal. The chemical paint stripping method was not applicable composite structures and bonding area. It is not difficult to remove the paint completely, though control of the paint stripping thickness must be difficult in the paint stripping operation, such as only topcoat removal. The PMB is a relatively short operation in spending time, though it is difficult to set conditions of the paint stripping, appropriate distance of structure, blast pressure and media size etc. The PMB is not approved for utilization on a CFRP laminate structure right now. It is suspected that further blasting causes resin cracking, fiber damage, and resin disappearance of the CFRP laminates surface. Those damages on the surface affected decrease of fatigue strength or environment resistance of the composite structures in estimation. The laser coating removal method is the fastest of all other methods in this study. Moreover, this method can control precise paint removal to the thickness direction. As shown in Figure 5, this method has applicability to the complex shape surface or relatively wide area of a structure when the laser head attached to a robot controlled arm or special equipment.

Table 2 Estimation of the paint stripping time

Methods	0.05m^2
Sanding	Top coat only : 30 min. Complete : 15 min.
Chemical	Top coat only : - Complete : 55 min.
PMB	Top coat only : 5 min. Complete : 5 min. (pressure change)
TEA-Co2 Laser (HL100)	Top coat only : 1.1 min Complete : 2.3 min.

4.3 Future works

The paint stripping on composite structures will be required for next generation aircraft maintenance technique. This study conducted strength evaluation and observation of CFRP laminates surfaces after paint stripping, by using metal structure paint

stripping methods, consciously. It was found that static mechanical properties were not affected by these paint-stripping methods, though surface conditions were different in various paint stripping methods. It was not taken into account about fatigue life and environmental effect on the mechanical properties on CFRP laminates in this study. The relationship between the unevenness of the CFRP laminates surface and fatigue life or environmental effect on the CFRP laminates should be a concern.
In general, mechanical paint stripping methods, sanding, and PMB, required looking into acquiring more speed and stripping thickness control. Chemical methods are also required to be able to strip the paint without chemical attack and damages to the CFRP laminates surface. And the environmental pollution and working condition are also considered at the same time in chemical method improvement. The thermal damage effects on the CFRP laminates must also be considered. Research and development of the pain-removal systems must be continued.

5 Conclusions

Experimental investigations were conducted for paint-stripped CFRP laminates on which several paint-stripping methods were applied. The following conclusions were obtained:

- There was not much difference in the averaged tension and compression modulus and strengths by different paint stripping method in this study.
- Large C_v values were observed in the static tension strength results of the chemical stripping case.
- Uneven surface conditions were observed in the PMB (complete) and laser stripping method.
- The TEA-CO_2 laser coating removal system is one of the very effective tools for composite paint stripping operation. However, it was suggested that matrix damages were observed by this method, complete and further exposure of the CO_2 laser beam strength case.

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References

[1] Catalogue of the selective laser coating removal by SLCR in Germany.