Evaluation of Polypropylene Fibre Reinforced Composites for use in Accident Debris Retention

Gary Savage
Honda Racing F1 Team

**This paper may not be published at this time. It is a report of Honda F1's findings only. It is, in no way, a recommendation or endorsement by F1 for Innegrity's products since it has not yet been fully reviewed or ruled upon by the FIA Rules Committee.

Introduction

Carbon fibre reinforced composites are used extensively in Formula 1 motor racing to enhance performance as a consequence of their high strength and stiffness per unit mass. Composite chassis and crash structures have also contributed greatly to the crashworthiness and survivability of the vehicles. One area of concern however arises from some of the thin-skinned composite components which make up many of the aerodynamic parts of the car (wing end plates, barge boards and other deflectors etc). Such components have been observed to disintegrate during impact scenarios producing sharp debris. The so-called "chards of carbon fibre" have the potential to damage the tyres of other vehicles thus worsening the affects of any incident. In order to address this issue FIA introduced Article 3.4.3 into the Formula 1 Technical Regulations: "In order to avoid the spread of debris on the track following an accident, the outer skins of the front wing end plates and any turning vanes in the vicinity of the front wheels (and any similarly vulnerable bodywork parts in this area), must be made predominantly from materials which are included for the specific purpose of containing debris. The FIA must be satisfied that all such parts are constructed in order to achieve the stated objective."

At present the material of choice to comply with Article 3.4.3 is a lightweight Kevlar weave impregnated with a 135^{o}C curing toughened epoxy resin. Recently FIA have been approached by an American Company, Innegrity from Greenville South Carolina, with a proposed alternative to Kevlar. The new fibre is a high strength polypropylene known as "Innegra" which is being applied in the ballistics market in competition with polyaramids (Kevlar and Twaron). This fibre is attractive for this application for a number of reasons; in addition to high strength and stiffness it has a strain to failure of 8% which is double that of Kevlar. This means that components are more likely to stretch and tear rather than snap under impact load. Innegra is lighter than Kevlar (density of 0.8gcm^{-3} rather than 1.4gcm^{-3}) and is significantly cheaper due to its simple melt processing rather than the complex chemical reaction used to produce Kevlar. Furthermore it contains no unsaturated chemical bonds and is thus not susceptible to ultra-violet degradation unlike Kevlar and PBO (Zylon). It was decided therefore to evaluate components made using Innegra to see if it met expectation.

Materials and components

Three different Innegra fabrics were supplied for evaluation, a 130gsm plain weave, 120gsm 4-harness satin and a 170gsm plain weave carbon (T300)/Innegra hybrid, the latter being chosen to provide increased stiffness and afford improved structural capability. The materials were prepregged using Cytec 2020 epoxy resin (Figure 1). 2020 is a "work horse" aerospace grade toughened epoxy and is one of the two systems qualified for the mandatory Zylon "anti-penetration appliqué panels" used on all F1 chassis. The new fabrics were taped to existing carbon fabrics and solution prepregged during a standard production run. This was the first time Innegra has been prepregged with epoxy and required no special conditions.

A front wing endplate was made from each of the prepregs by replacing the Kevlar in each using our standard manufacturing processes. A Kevlar endplate was used as a control.

Test procedure

Testing was carried out using an instrumented falling weight impact test machine and more crudely by clamping the component in a vice and hitting it multiple times with a hammer. The instrumented test involved clamping the component in the test rig and impacting with a 10mm diameter hemispherical tup with a mass of 10kg at a velocity of 5ms^{-1}. The test pieces were hit on the top, at the front and rear as this was believed

to have the potential to cause the most damage (Figure 3). The second test involved hitting the parts at random using a mallet to simulate the randomness of impact situations.

Figure 1: *Innegra prepreg samples.*

Results and observations

The falling weight impact tests and the mallet tests both showed the Innegra material to be equal to and generally superior to the Kevlar equivalent. This was manifested both in terms of resistance to damage and minimising the size and quantity of debris (please see video files which will be sent under separate cover on DVD). The Kevlar end plates were completely destroyed by three hits from the mallet (Figure 2) whereas the Innegra equivalent remained relatively unscathed (Figure 3).

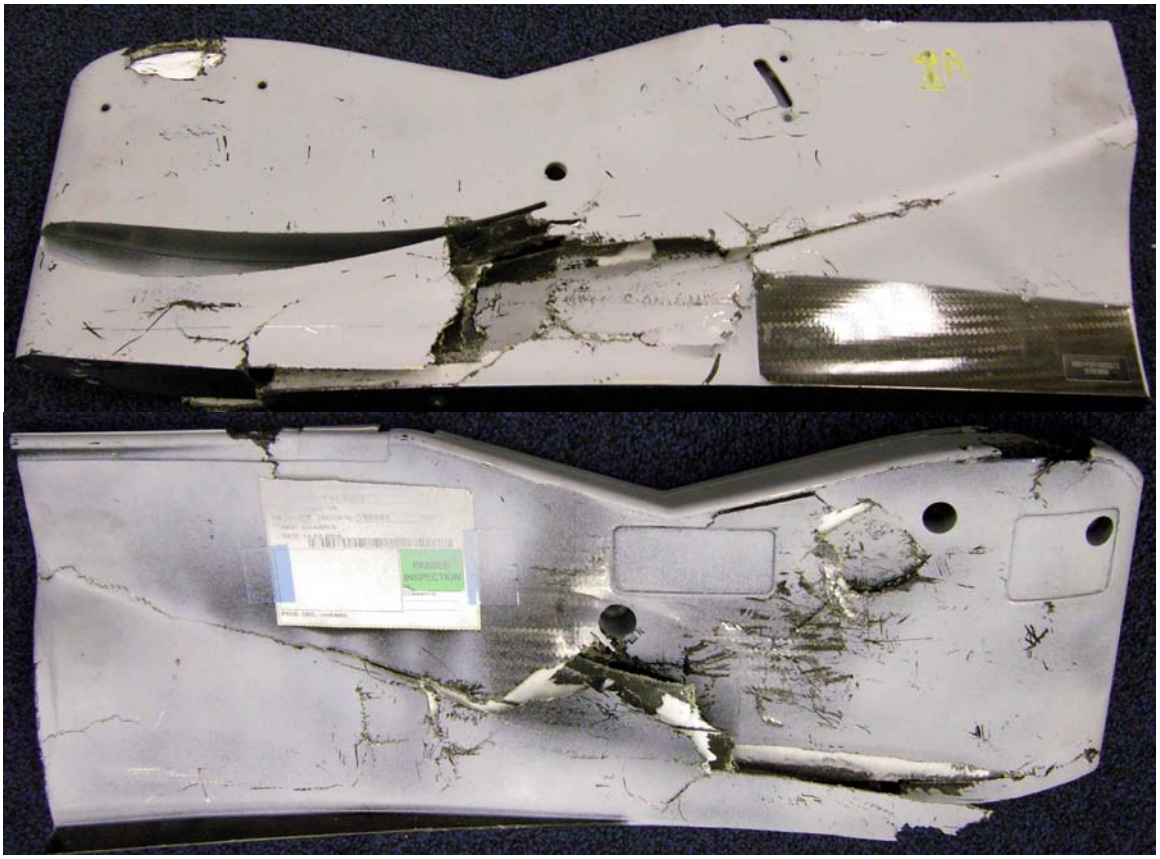

Figure 2: *Front and rear views of a Kevlar/carbon front wing endplate destroyed by instrumented impact testing and a "madman with a mallet"!*

It was further observed that, when the Innegra composite was damaged, the tendency was for the fibres to tear and pull out of the matrix rather than forming sharp debris. There did not seem to be any advantage of one type of weave over the other, but the hybrid was more likely to form “chards” than the pure Innegra and is therefore preferred for safety.

Figure 3: *Despite suffering the same fate as the specimen in Figure 2, the Innegra/Carbon front wing endplate remained intact and relatively unscathed.*

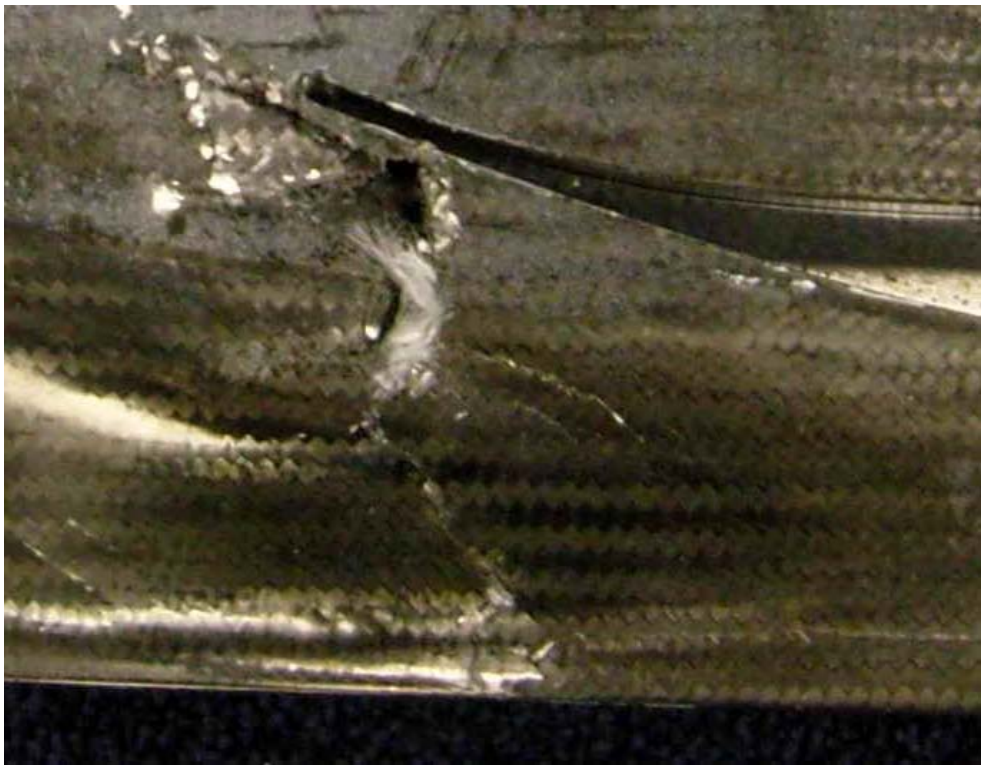

Figure 4: *When Innegra composite is damaged there is a tendency to tear and pull out fibres from the matrix rather than form sharp debris.*

Conclusions and recommendations

This rather simple but effective evaluation has proved conclusively that not only are Innegra reinforced composites able to satisfy Article 3.4.3, they are superior to those materials presently selected for this task. Furthermore they are considerably cheaper (around $^{1}/_{3}$ to ½ the price of Kevlar); inert to environmental damage; electrically insulating and the fibres are easily recycled. Although ours was the first attempt to prepreg Innegra fabric it was, using Cytec's expertise, achieved with ease at the first attempt requiring no special processing conditions and could be integrated into existing production runs at no extra cost. It is recommended therefore that Innegra is given FIA approval for use on Formula 1 cars.