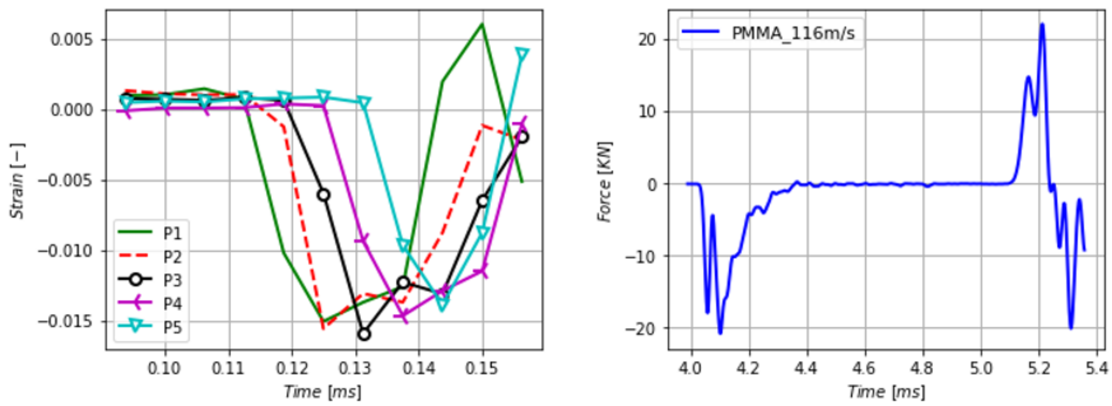

Fig. 3. a) PMMA Compressive strains at different points in the strain field and **b)** Impact Force in the Hopkinson Bar with the PMMA fragment launched at 116m/s

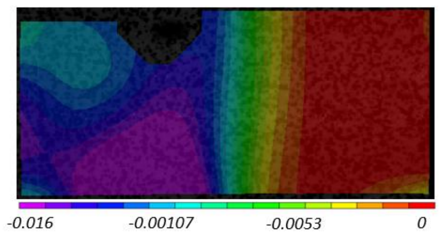

Fig. 4. Strain field of PMMA fragment launched at 116m/s

Figure 3 b shows a first compressive pulse induced by the impact with a maximum of 20.62kN and a pulse duration 0.3ms. A second tensile pulse can be seen about 1ms after produced by the reflection of the pulse at its end. Finally, the impulse is calculated performing the integral of the force, obtaining a value of 2.1N·s.

Since the theoretical impulse is 2.32N·s, it can be considered that experimental Hopkinson Bar data is valid. PMMA is a quasibrittle material whose failure mode at this impact condition is the total breakage, and therefore almost all impulse is transmitted to the bar during the impact. In the Figure 5 it can be observed the strain distribution during the impact, and how the compression pulse is almost flat (along the width of the projectile) in the specimen, showing the appropriate orientation of the impact. As it is shown in Figure 6, the damage pattern is the completely breakage of the specimen. The maximum compressive strain observed in the specimen is 1.5%. The fragment reaches that value in a period of 0.01ms (Fig 5).

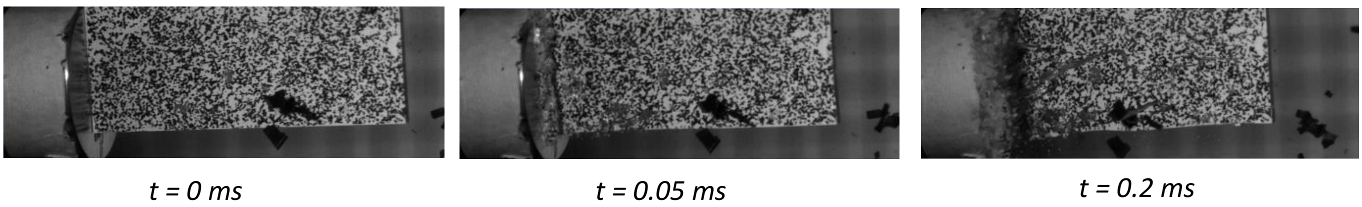

Fig. 5. Impact experiment of PMMA fragment launched at 116m/s

3.2 CFRP fragment impact results v=113m/s

In this section an analysis of the impact process for the woven composite specimen is performed. The impact analyzed was performed at 113m/s, which is the test with a closer kinetic energy to the PMMA case from the previous section.

Figure 6 shows the strain field obtained using the VIC-3D software. The Photron SA-Z parameters are the same performed in the PMMA experiment, described in the previous section. Since the damage failure mode is different, and the composite specimen does not totally break like the polymer, it can be observed how the compressive pulse evolves. Two compressive pulses before the breakage can be observed, reaching a value of compressive strain of 1.1% in a period of 0.017ms.

Moreover, the Figure 6 shown the impact force induced obtained thanks to the semiconductor strain gages. Compared to the PMMA strain pulse, the composite specimen applies an impact force almost 6 times higher (concretely, it reaches a value of 112KN) and consequently the impact duration is much smaller.

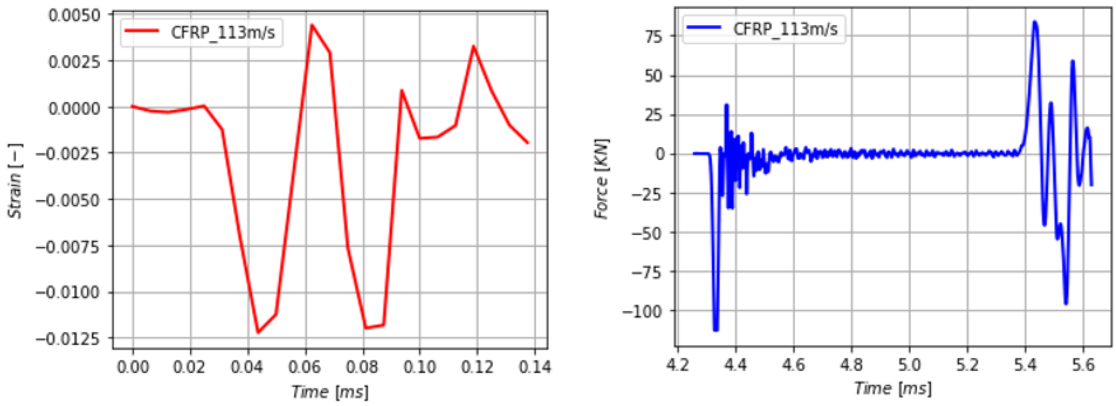

Fig. 6. a) CFRP compressive strain field and **b)** Impact force in the Hopkinson Bar with the CFRP fragment launched at 113 m/s

The Figure 7 shows the strain field analysed thanks to the VIC-3D software in the CFRP fragment. It can be observed how the compressive front pulse is not completely perpendicular to the edge of the fragment. Basing on the ratio between the impact velocity and the compressive pulse velocity (which is closer to 50) and the angle of the compressive front pulse measured thanks to the software, it can be concluded that the loss of perpendicularity in the impact is less than 1 degree.

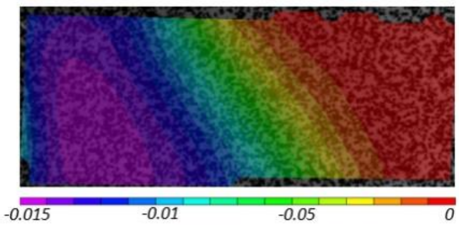

Fig. 7. Strain field of CFRP launched at 113m/s

The Figure 8 shows the impact process at different time instants. Figure 9 present the specimen after the impact process. As it can be seen two main damage can be observed: specimen erosion in the impacted face and delamination between plies. Also, some breakage between plies among the epoxy matrix can be seen. The water-slide paper used for the DIC slides detached once the breakage and delamination occur, which does not interfere in the different data obtained in the VIC-3D system.

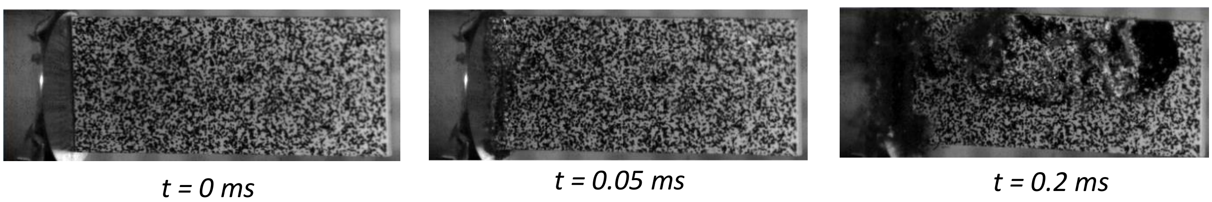

Fig. 8. Impact experiment of CFRP launched at 113m/s

Fig. 9. Damage patterns of CFRP specimen at 113m/s **a)** Delamination **b)** Erosion **c)** Matrix Breakage

4 Conclusions

In this work the high velocity impact of Poly Methacrylate Methyl Amide (PMMA) and Carbon Fiber Reinforced Polymer (CFRP) have been analyzed against a Hopkinson Bar. Experimental tests have been performed using a gas gun while it has been recorded with 2 Photron SA-Z High Speed Cameras. The specimen compressive strains have been observed with the VIC-3D software, allowing to observe the strain field as the and an approximation to the failure strain. Semiconductor strain gages are implemented to increase the sensibility of the procedure to obtain the compressive pulses in the Hopkinson Bar, which are needed to analyze the impact force. The water-slide paper technique for the DIC have been successfully used. From the presented results, the main conclusions extracted are:

- The CFRP fragment presents an impact force almost 6 times higher than the PMMA fragment.
- Different compressive pulses have been observed in the CFRP fragment before failure, the two of them reaching a maximum compressive strain of 1.1%.
- The damage pattern is very different comparing quasibrittle materials. PMMA fragments presents a totally breackage, while CFRP fragment shows different failure modes such as delamination, erosion, and matrix breackage.

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