Deliverable n°T.4.7.1

TECHNICAL REPORT ON THE IMPACT RESISTANCE OF BIOBASED COMPOSITES

03/2023

UoP

European Regional Development Fund

Partners

PP Leader : University of Portsmouth

Partners involved : Kairos, EcoTechnilin

Content

1. Introduction

Fibre reinforced composite materials have been increasingly used in various industries. This trend is mainly due to their superior properties over conventional metallic materials. In addition to their cost, the extensive use of composite materials with non-recyclable constituents has also brought serious environmental problem.

Development of natural plant fibre composites (NPFCs) is considered as a greener alternative to composites with synthetic reinforcement. Apart from being sustainable and biodegradable, NPFCs offer several advantages such as low cost, light weight, low density, high specific strength and low abrasiveness compared to their conventional counterparts such as glass and carbon fibre reinforced composites.

The application of the NPFCs in structural components requires a thorough understanding of their material properties and mechanical performance. Various aspects of natural fibre reinforced composites are available in the published literature.

Flax fibres (FF) are one the most common natural fibres used in composite applications. The mechanical properties of FF are generally not as comparable as the synthetic ones. However, their specific mechanical properties are reported to be comparable to or even better than those of glass fibres [1]. Various aspects of flax fibre-reinforced composites are investigated by researchers and some reviews of these studies can be found in [2-4].

Impact resistance is one of the key properties of a material. The key objectives of this report are to evaluate the impact behaviour of flax fibre-based composites by employing low velocity impact tests. For this purpose, the response of five types materials provided by Kairos, under low velocity impact (LVI) is presented in this report. Force-displacement, force-time and energy-time traces obtained from LVI tests are utilized to quantify and compare the impact response of these materials.

2. Materials

The LVI tests are carried out for five different types of materials, namely, Conventional Non- Woven (CNW), New Non-Woven, (NNW), Kairlin Brown (KB), Kairlin White (KW) and Kairlin White with filler 2 (KW-F2) are Used. The composition of each material is provided in previous reports. Four specimens are tested for each material. The length and width are 65 mm × 65 mm. The thickness and weight of the samples are measured before the experiment and are shown in *Table.1*.

Table 1. Dimensions of samples

	Thickness (mm)	*Length (mm)*	*Width (mm)*
CNW	*2.7*	*65*	*65*
NNW	*1.8*	*65*	*65*
KB	*1.8*	*65*	*65*
KW	*2*	*65*	*65*
KW-F2	*2*	*65*	*65*

3. Experimental procedure

The LVI experiments are carried out using Instron CEAST 9340 drop weight machine. The testing machine set-up is shown in Figure 1. The experiments were carried out in room temperature and was tried to do all the tests in identical conditions.

The experiments started by applying 7J of impact energy on all materials. The results for each material are presented in terms of force-displacement, force-time and energy- time graphs. Since the thickness of each material are different, the results normalised by the thinness of each material are also presented.

In order to investigate the response of materials for various impact energies, two materials with identical thickness are selected. For this purpose, impact energies of 3J, 5J and 7J were applied on KW and KW-F2.

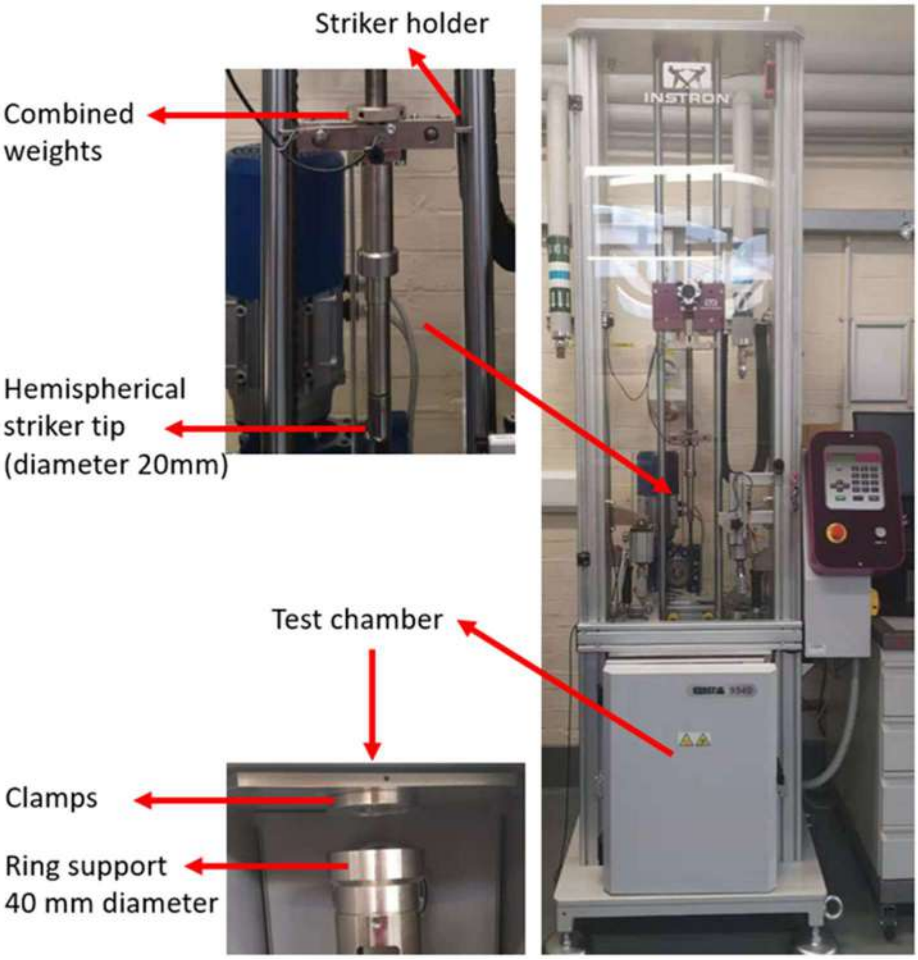

Fig 1. Impact test machine, Instron CEAST 9340

4. Results and discussion

4.1 Impact behaviour

The results for each material are presented in terms of force-displacement, force-time and energy- time graphs. The specimens in each material group show very similar response. This implies an appropriate repeatability of the experiments. Then, one sample representing the average behaviour in each group is used to make the comparison between the materials. In addition to comparing the results, the force and energy values are normalized by the thickness of each material.

The impact test results for all materials are presented in Figure 2 to Figure 4. As shown in Figure 2, all materials are fully penetrated by an impact energy of 7J. considering the normalised values, CNW shows the best impact resistance while Kairlin white with filler 2 has the least impact resistance.

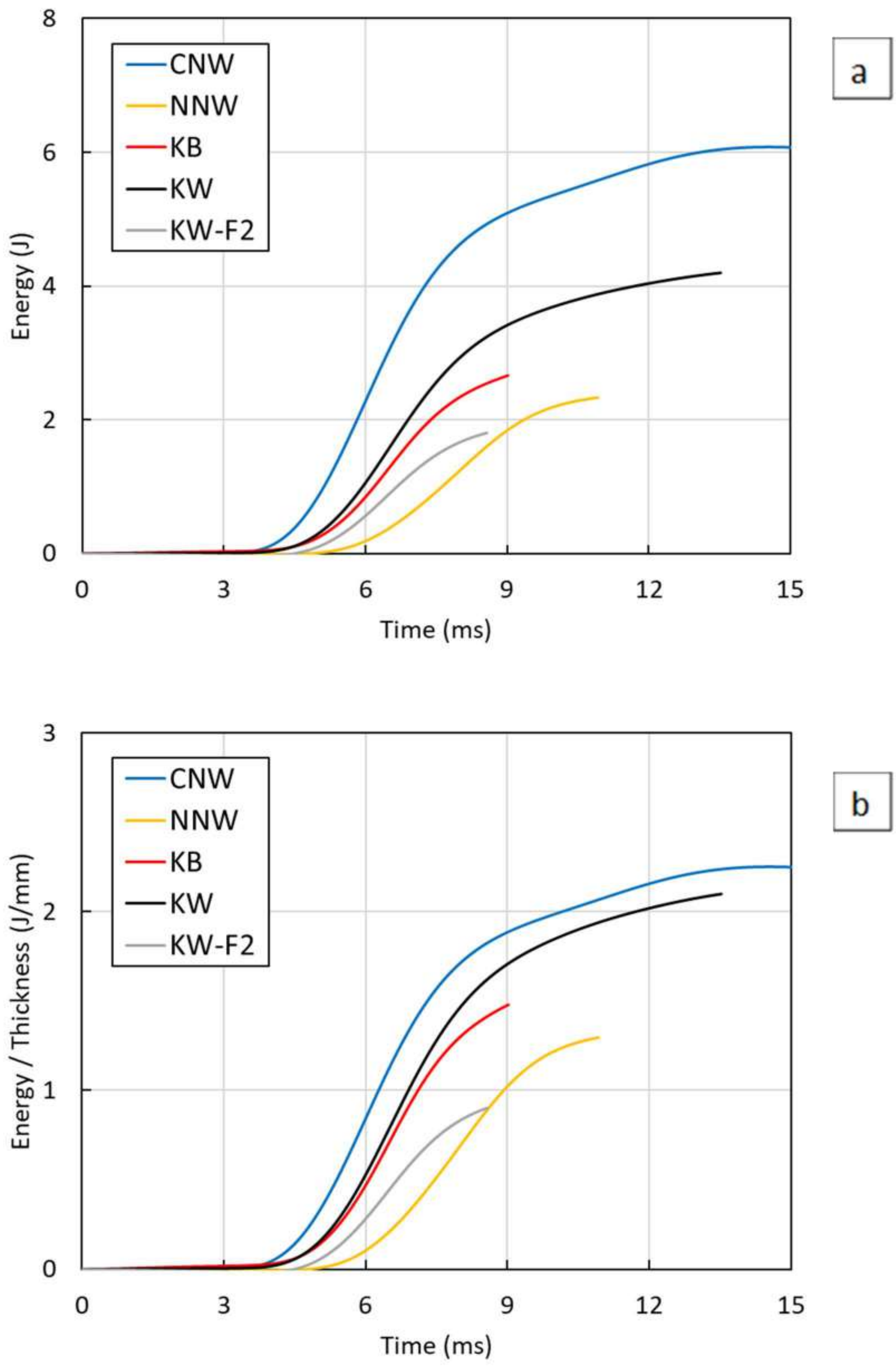

Fig 2. Comparison of impact test results for all materials (a) energy- time response, (b) Normalised energy- time response

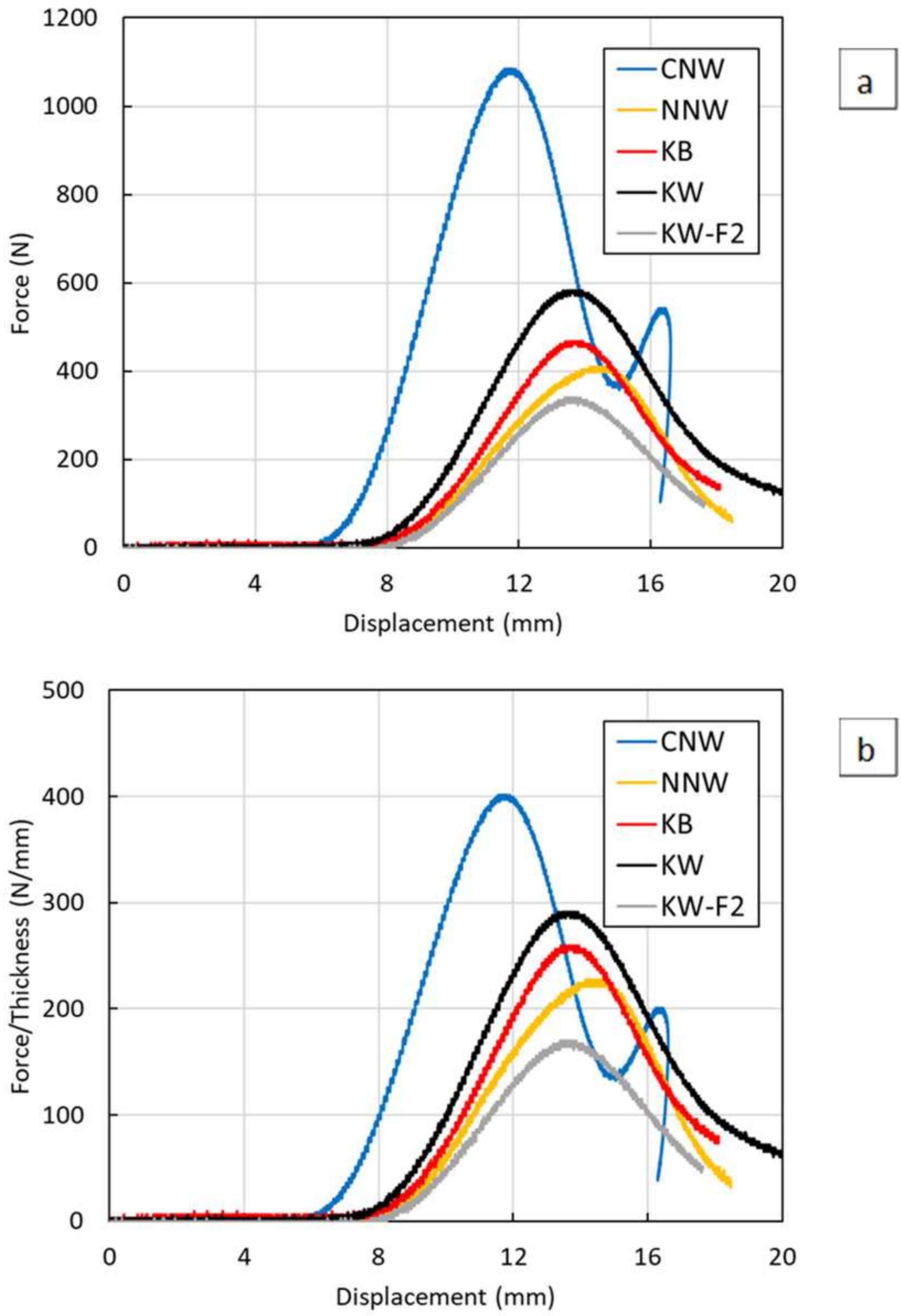

Fig 3. Comparison of impact test results for all materials (a) Force- displacement response, (b) Normalised force- displacement response

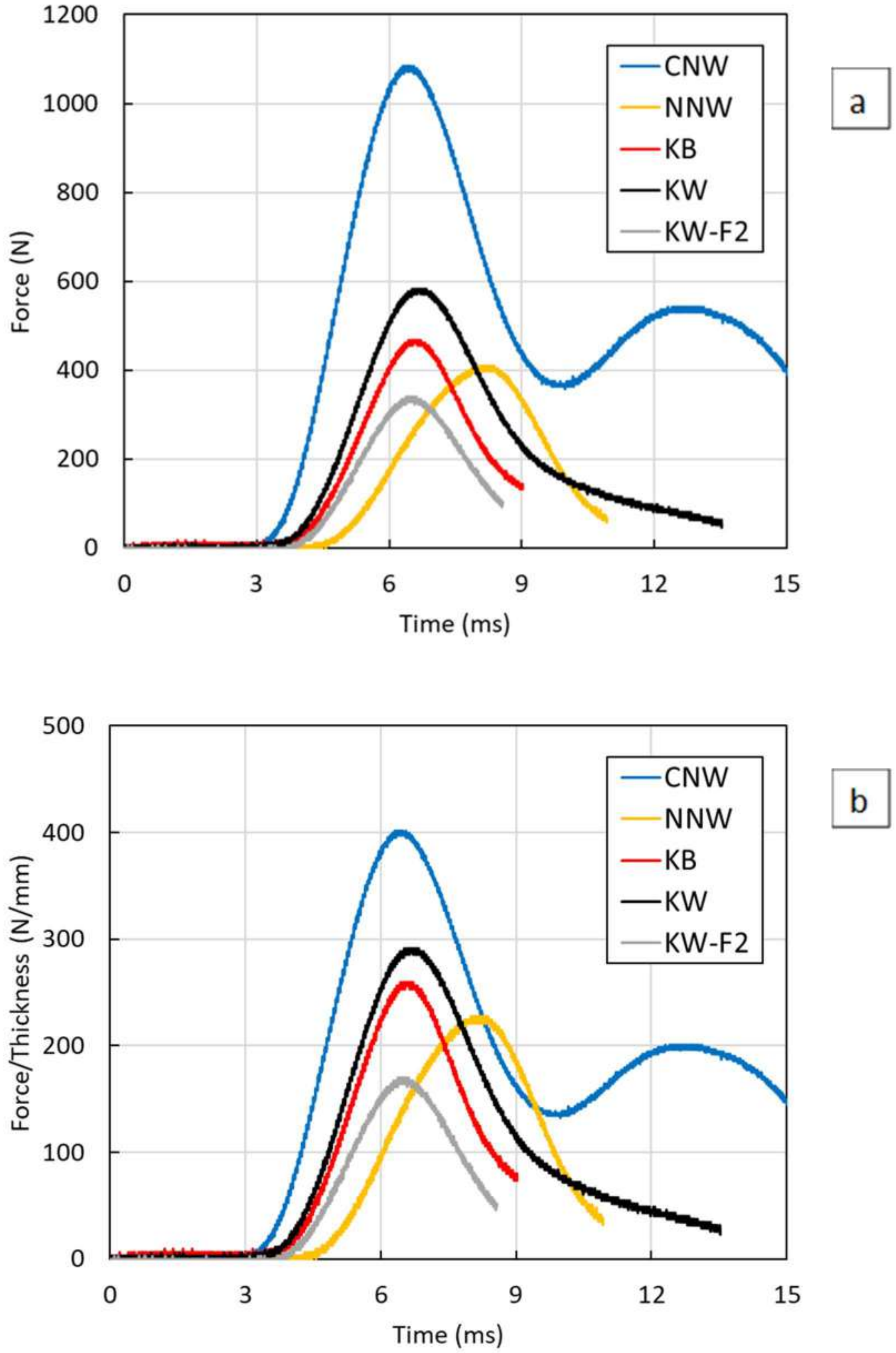

Fig 4. Comparison of impact test results for all materials (a) Force- time response, (b) Normalised force- time response

The force-displacement and force-time graphs of the impact testing for all materials are shown in Figure 4 and Figure 3. The results suggest that CNW experiences the highest force during the impact.

4.2 Damage behaviour

In this part of the report the specimens are compared ion terms of differences in appearance after the impact. For this purpose, the front side, rear side view of impact zones for each material are presented in Figure 5 to Figure 7.

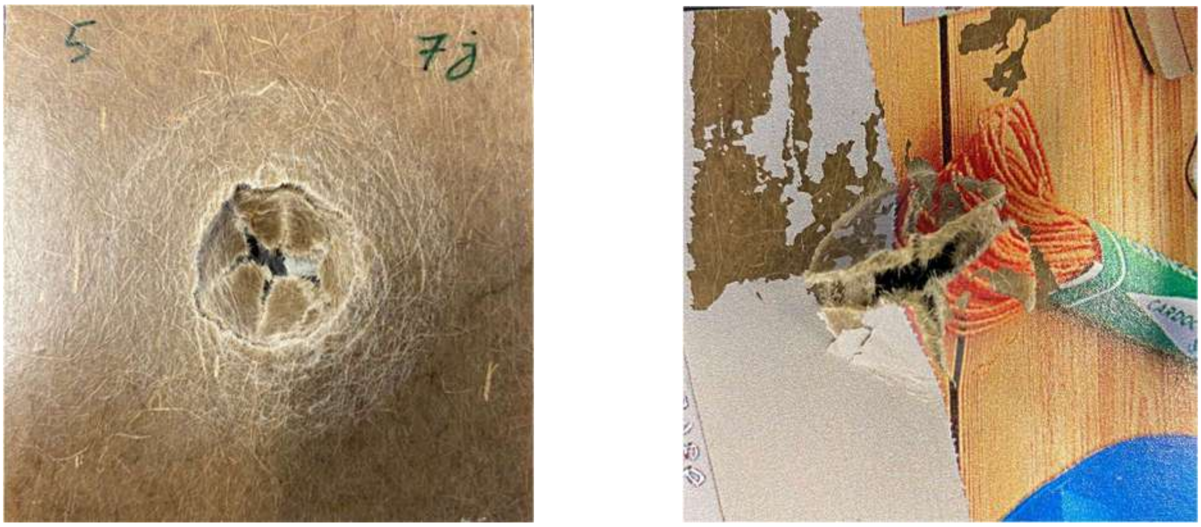

Fig 5. Appearance of CNW samples after impact test

Fig 6. Appearance of NNW samples after impact test

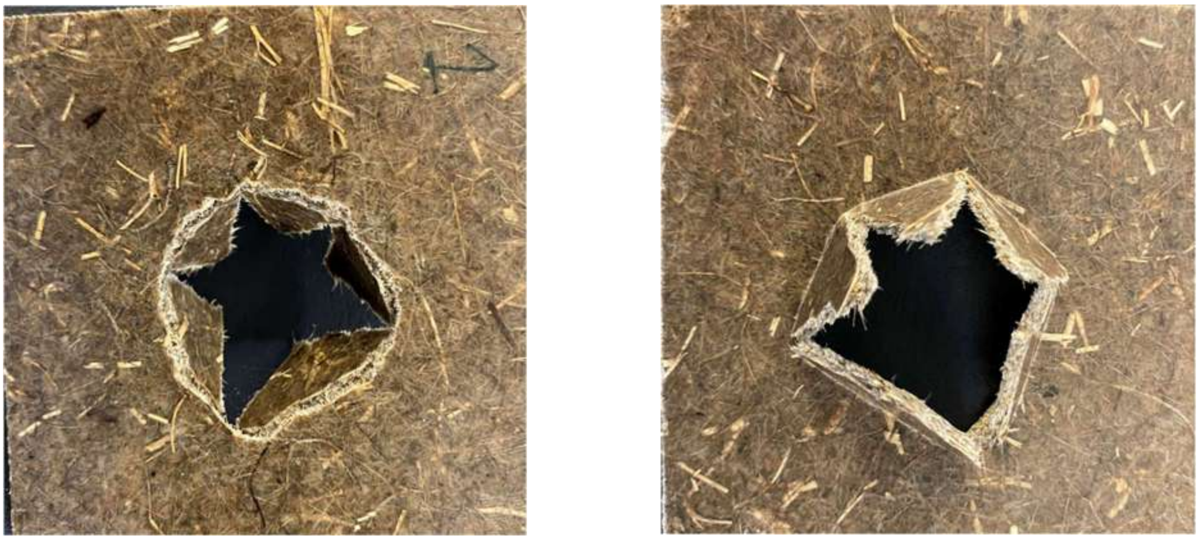

Fig 7. Appearance of Kairlin brown samples after impact test

Since additional experiments with different energy levels are carried out for Kairlin white and Kairlin white with filler 2, the results for these materials are discussed in more details in the following section.

4.3 Impact behaviour KW and KW-F2 under 3J, 5J and 7J impact energy

Although the results from previous section revealed the better impact resistance of KW over KW-F2, in order to have a better understanding the effect of fillers in impact behaviour, additional experiments with lower impact energies of 3J and 5J were carried on for these to materials.

The energy-time, energy displacement, force-time and force-displacements graphs for KW and KW-F2 under 3J, 5J and 7J are presented in Figure 8 to Figure 11. Since the thickness of the two materials are the same (2mm) the normalised energy and force values are not considered in this section. The impact energy response results in Figure 8 and Figure 9, show that the impact resistance of KW-F2 is even below 3J.

The appearance of KW and KW-F2 after impact under impact energy of 3J, 5J and 7J are shown in Figure 12. As shown in this figure, except KW in 3J, all other specimens were fully penetrated. For KW-F2 all the material in impact region is fully removed after impact. This might imply that, adding filler, not only has deteriorated the impact resistance, but also makes the composite more brittle.

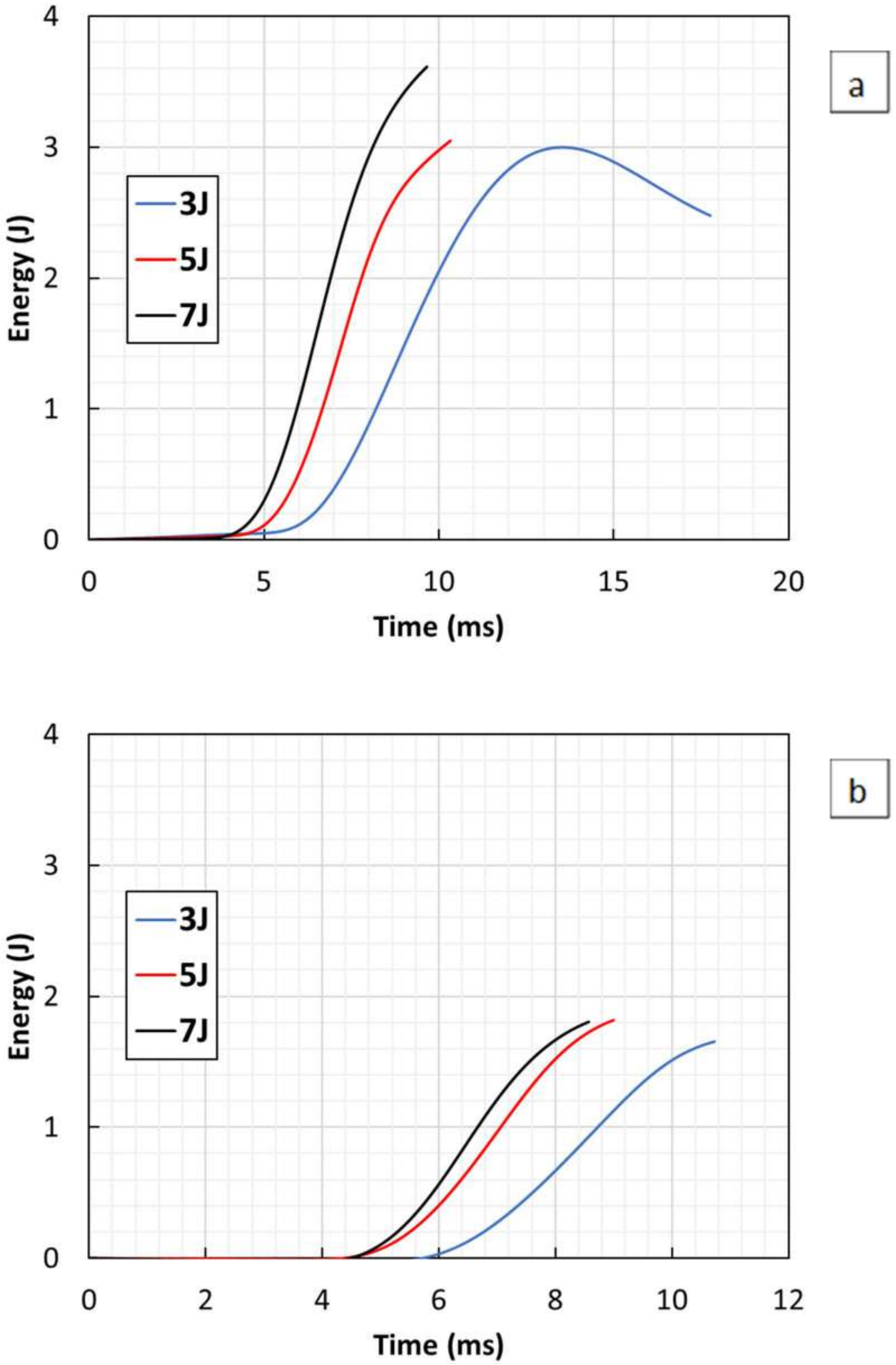

Fig 8. Energy-time graphs under three different impact energy level for: (a) KW, (b) KW-F2

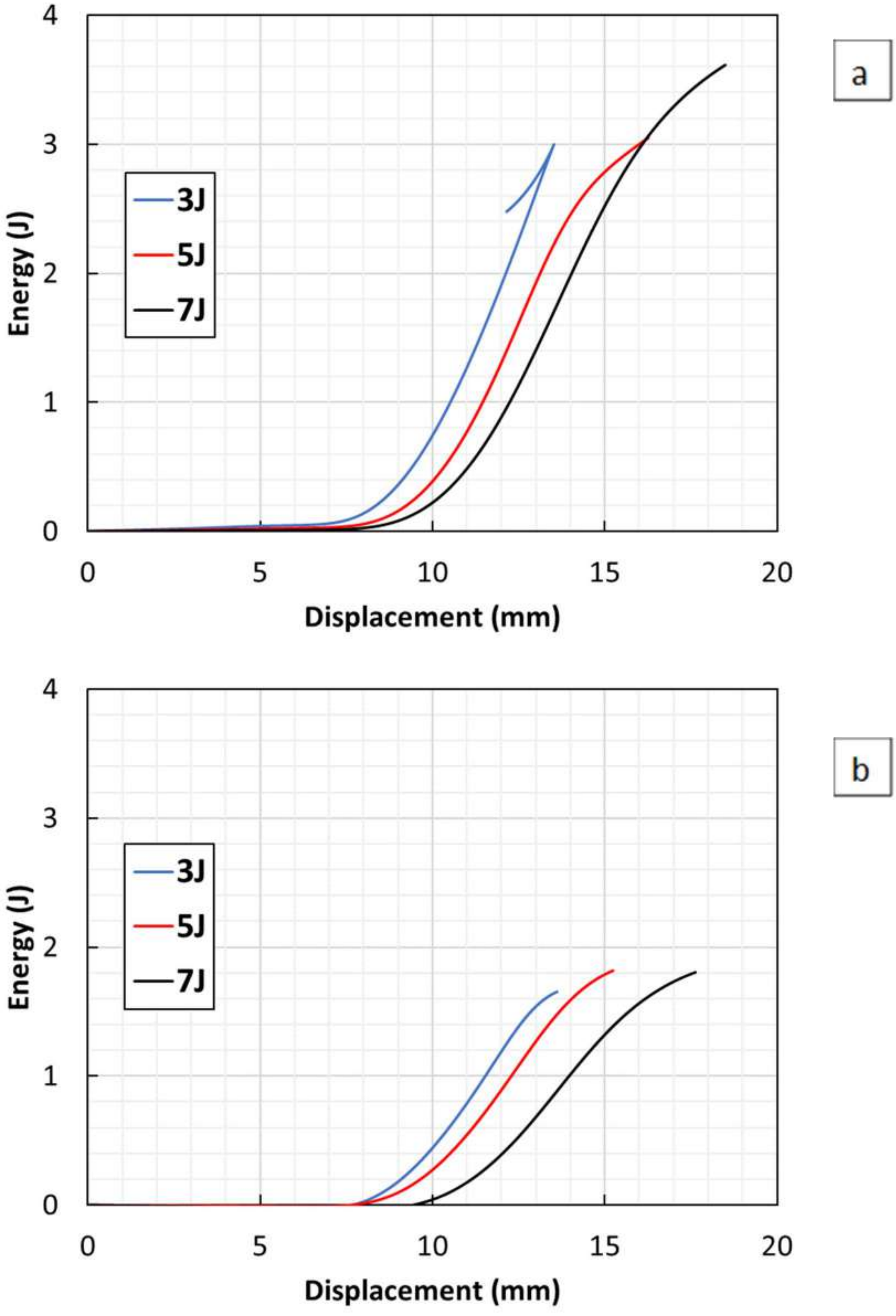

Fig 9. Energy-displacement traces under three impact energy level for: (a) KW, (b) KW-F2

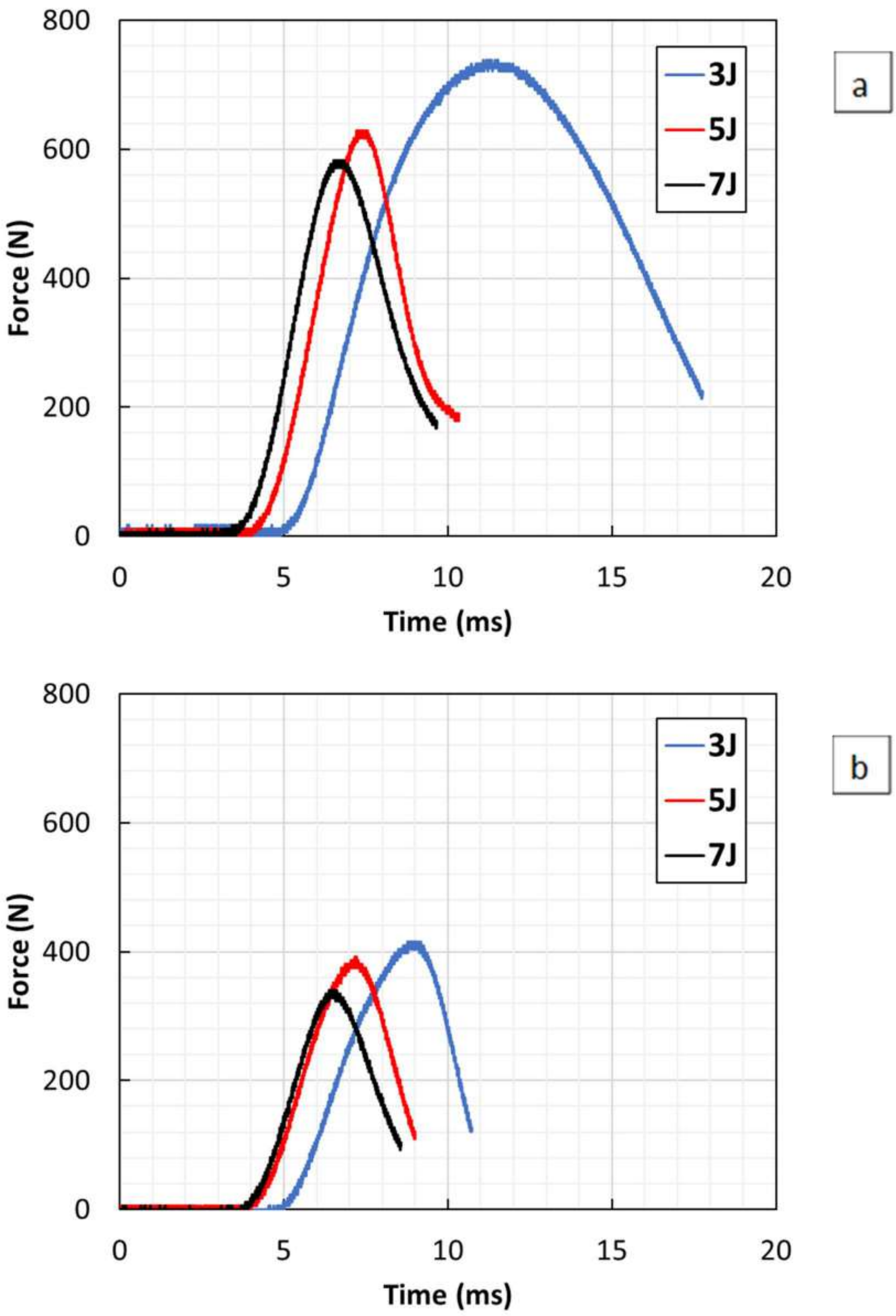

Fig 10. Force-time traces under three impact energy level for: (a) KW, (b) KW-F2

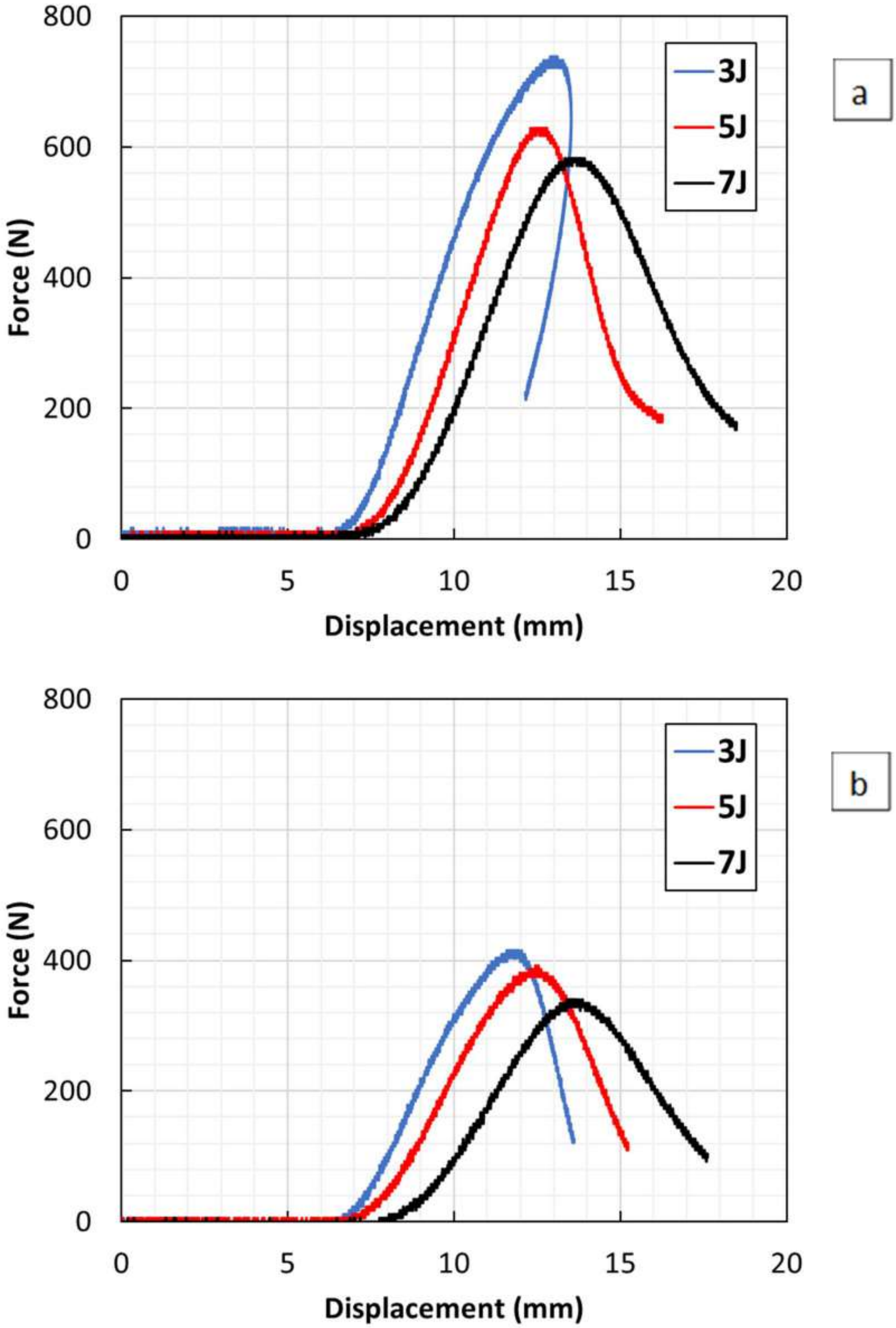

Fig 11. Force-displacement traces under three impact energy level for: (a) KW, (b) KW-F2

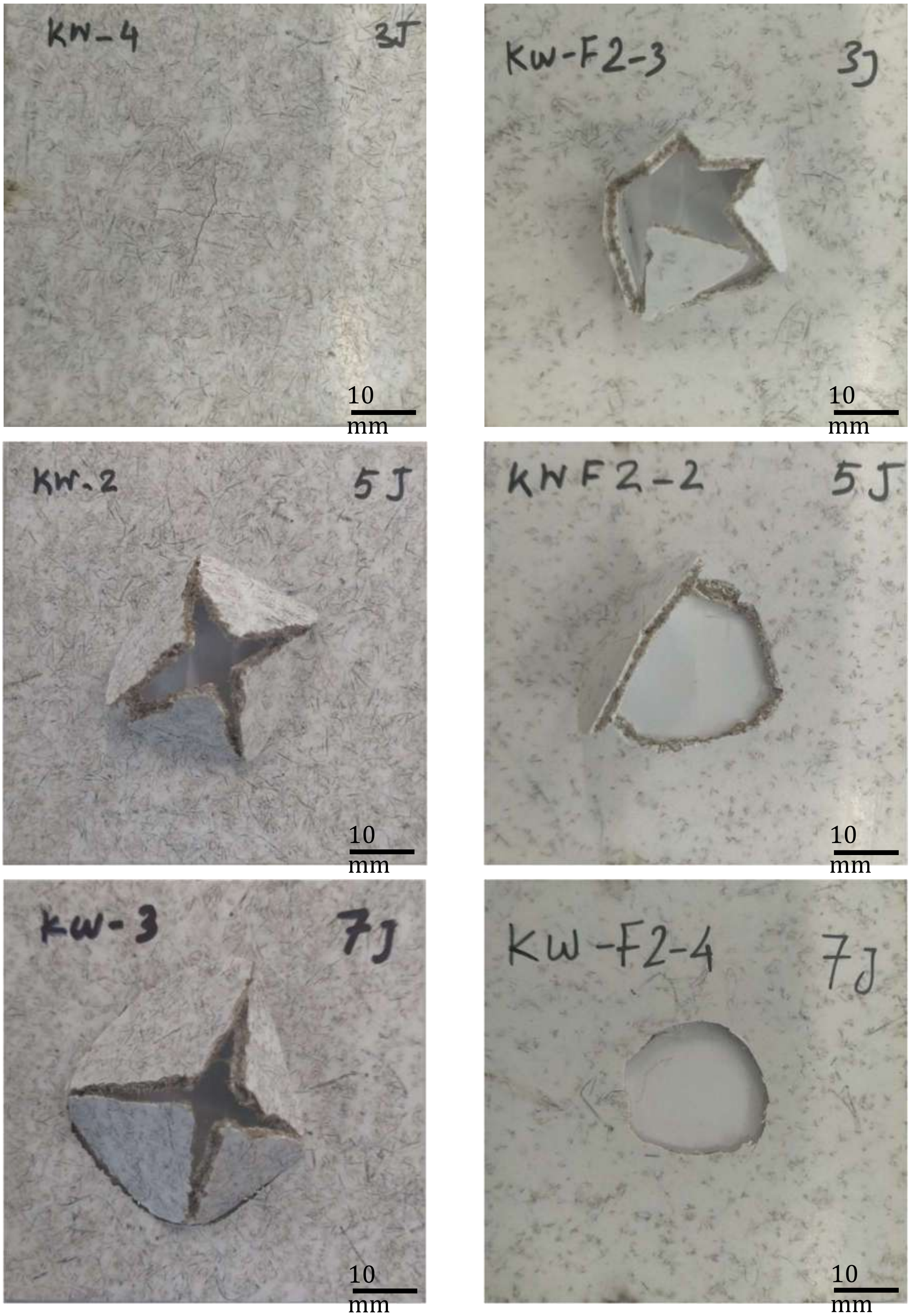

Fig 12. Comparison of appearance after impact test for KW (right) and KW-F2 (left) under 3J, 5J and 7J impact enegy

5. Conclusions

The impact resistance of five different biobased flax composites namely, CNW, NNW, KB, KW and KW-F2 are presented and compared in this report. The low velocity impact tests were carried out in two stages. In first the stage, all materials were subjected to an impact energy of 7J. The results indicated that CNW shows the best impact performance while KW-F2 showed the poorest performance.

In the second stage, additional impact tests with impact energies of 3J, 5J were carried out on KW and KW-F2. The results showed in addition to decreasing the impact resistance, the fillers make the composite material more brittle.

The tests were carried on EcoTechnilin and Kairos materials as it is relevant for these subjects since POS are manipulated really often.
These results will be useful for the fridge truck panel and wind turbine blades as the ne non woven is used to produce these parts.

References

[1] Ku, H., Wang, H., Pattarachaiyakoop, N., & Trada, M. (2011). A review on the tensile properties of natural fiber reinforced polymer composites. Composites Part B: Engineering, 42(4), 856–873. https://doi.org/10.1016/j.compositesb.2011.01.010
[2] Yan, L., Chouw, N., & Jayaraman, K. (2014). Flax fibre and its composites - A review. Composites Part B: Engineering, 56, 296–317. https://doi.org/10.1016/j.compositesb.2013.08.014
[3] Rahman, M. Z. (2021). Mechanical and damping performances of flax fibre composites – A review. Composites Part C: Open Access, 4(December 2020), 100081. https://doi.org/10.1016/j.jcomc.2020.100081
[4] Baley, C., Bourmaud, A., & Davies, P. (2021). Eighty years of composites reinforced by flax fibres: A historical review. Composites Part A: Applied Science and Manufacturing, 144, 106333. https://doi.org/10.1016/j.compositesa.2021.106333