A novel functionally graded impact attenuator using bonded construction

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Introduction

Automotive collisions are one of the major causes of death in the European Union, especially in childhood and adolescence. However, the enhancement on the vehicle's strength can not be achieved only by increasing the size and dimensions of the structures, as this demands more materials and longer manufacturing processes which leads to an increased resources expenditure. Moreover, the increase of the structure size raises the vehicles weight, leading to more fuel consumption, which can not be accepted due the modern environmental requirements [1]. To solve these issues, the application of bonded joints using the combination of several adherends materials such as high strength steel, aluminum alloys, and fibre reinforced polymers with crash resistant adhesives presents itself as novel solution, allowing for improvements of joint resistance, energy absorption and weight reduction provided by the combination of modern adhesives and materials. The present works introduces a novel concept of an impact absorber using the combination of functionally graded adhesives and adherends, aiming to obtain lighter and more environmentally friendly vehicles at the same time making them safer, saving resources and more important, saving lives.

Methodology

Different functionally graded adherends distributions studied in a single lap joint with an overlap of 50 mm and adhesive thickness of 0.2mm.

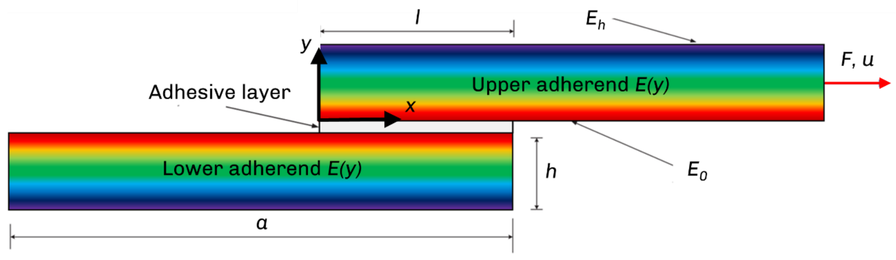
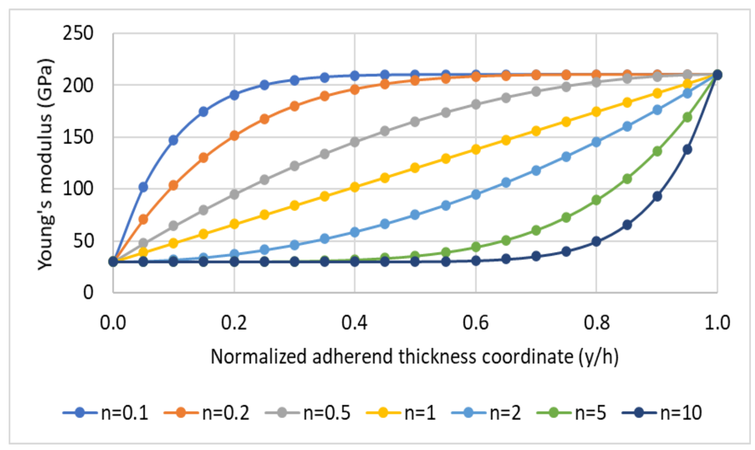


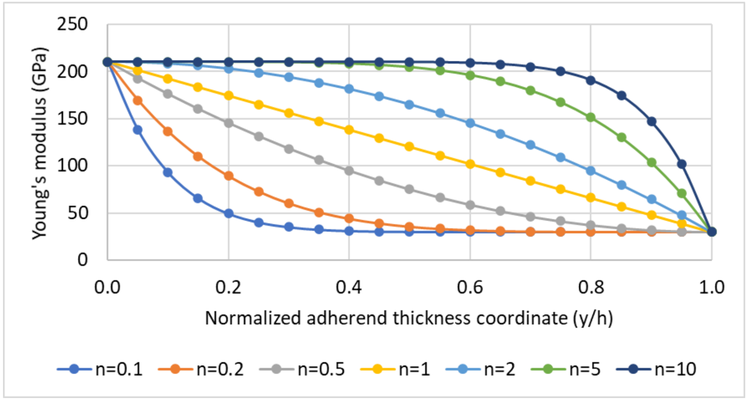
Figure 1 – Graded adherends scheme



E_0 - stiffness on internal face
E_h - stiffness at external face

$$E(y) = E_0 + (E_h - E_0) \cdot \left(\frac{y}{h}\right)^n$$

$$1 \leq n \leq \infty$$



$$E(y) = E_h + (E_0 - E_h) \cdot \left(\frac{y-h}{h}\right)^{\left(\frac{1}{n}\right)}$$

$$0 < n < 1$$

Figure 2 – Graded adherends properties distribution with flexible interface distribution

Numerical details

A numerical model was developed in Abaqus® to predict the failure load and strength on adhesive joints with functionally graded adherends.

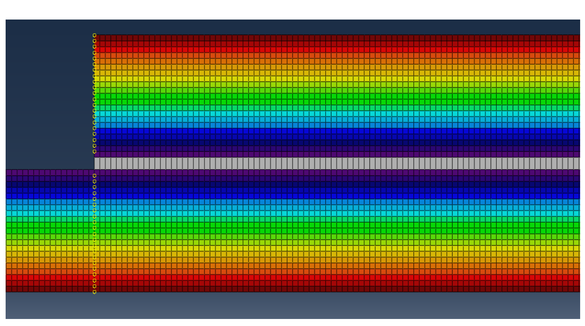
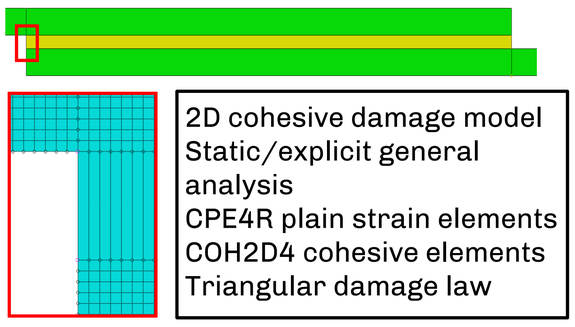


Figure 3 – Model details of layered functionally graded adherends



2D cohesive damage model
Static/explicit general analysis
CPE4R plain strain elements
COH2D4 cohesive elements
Triangular damage law

Figure 4 – Detailed parameters used in the models

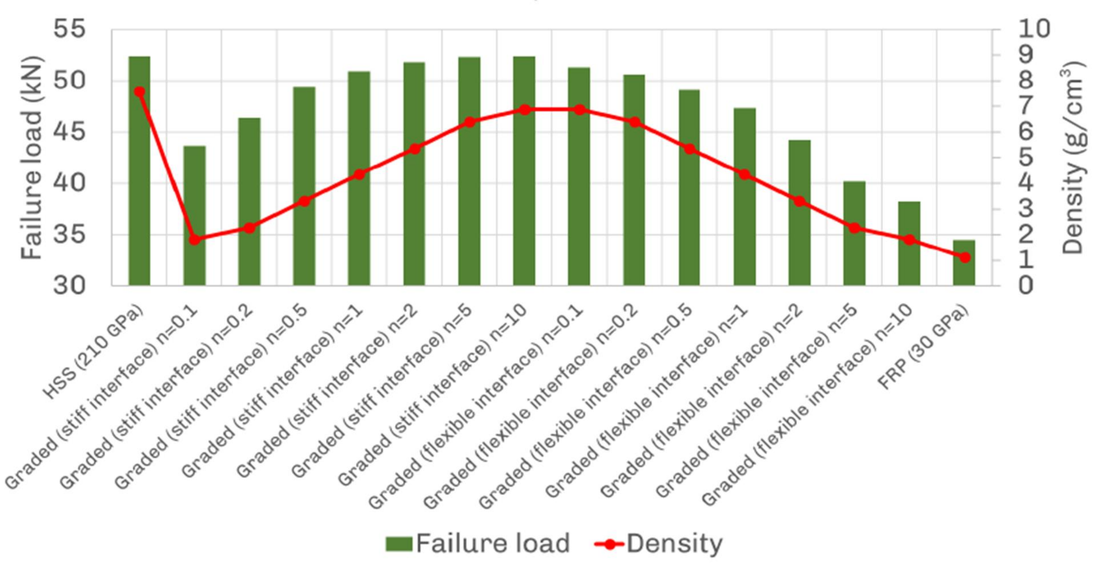


Figure 5 – Relation between the failure load and the density obtained for the homogeneous and graded adherends evaluated with adhesive 3M Scotch Weld AF 163 2K (epoxy film).

A novel functionally graded attenuator

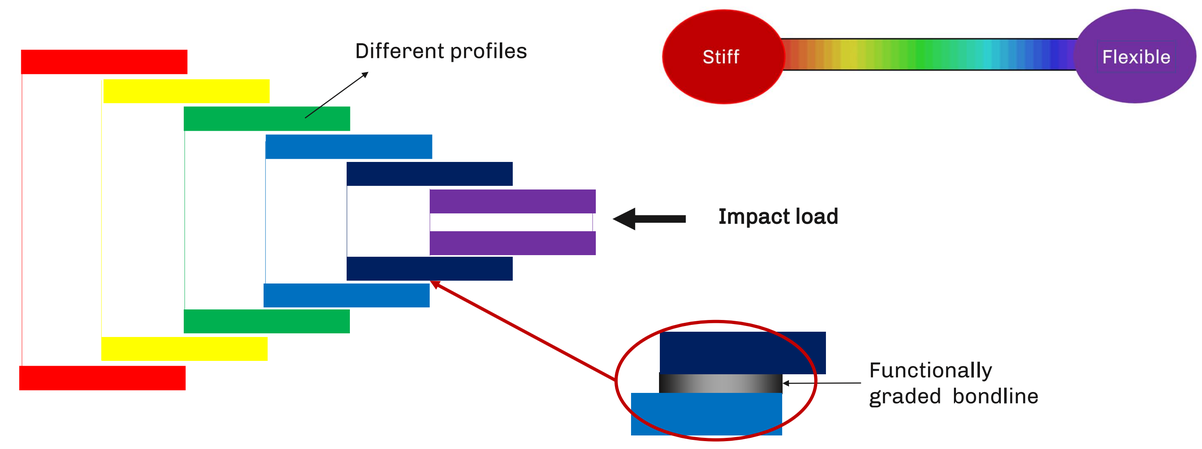


Figure 8 – Schematic representation of the second design of novel functionally graded impact attenuator using bonded construction

Conclusions

- The results obtained by the numerical analysis shows a significant difference of SLJ performance as a function of the graded adherend shape used;
- The adhesive properties play a major role on the effect of the homogeneous and graded adherends on the failure load obtained in an adhesive joint;
- The graded adherends with stiffer interfaces provided better results than the graded adherends with flexible interfaces. The best graded adherend for each case provided an improvement of 52% against 48%;
- All graded adherends evaluated provided better results than the flexible homogeneous adherends. However, only a few adherend configurations with stiffer interface provided better results than the stiffer homogeneous adherends;
- Functionally graded adherends also presented themselves as a suitable technique for weight reduction;
- The novel design attenuator was especially design with graded stiffness of the adherend but the bondline is also functionally graded that will allow to improve the joint strength.
- This attenuator concepts will be developed numerically, optimized and validated experimentally.

References

[1] L.F.M. da Silva, A. Öchsner, and R.D. Adams. *Handbook of Adhesion Technology*, (Springer-Verlag, Berlin, 2011).

[2] J.B. Marques, A.Q. Barbosa, C.I. da Silva, R.J.C. Carbas and L.F.M. da Silva (2021) An overview of manufacturing functionally graded adhesives – Challenges and prospects. *The Journal of Adhesion*, 97(2):172-206.

Acknowledgements

The authors would like to thank FCT for financially supporting this work through grants 2020.09991.BD and Nº 028473 POCI-01-0145-FEDER-028473, and Henkel Iberia for supplying the adhesive Loctite Hysol® 3422

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