Modelling of Industrial Hybrid Bonding Processes considering Fluid-Structure-Interaction

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ABSTRACT

Typically, adhesive joint manufacturing starts in a first step with the application of the liquid adhesive on one of the adherends to join. In a second step, the remaining adherend is placed such to achieve an adhesive bonded gap between the parts to be bonded. The last step consists on curing the adhesive until final strength is achieved, a process which in some industrial is being accelerated by appropriate heating. In recent years, in the automotive industry, bonding is increasingly being used to achieve lightweight structures with high crash performance. Adhesively bonded joints usually ensure a much smother load transfer, higher joint capacities, and stiffer connection; they however, are more process intensive, and curing times are long. In the automotive industry, amongst others, bonding complements–connections in the car main body, doors and hoods–with traditional mechanical fastening, as for example clinching, hamming and riveting; their main advantage lie in short process times, although with lower joints strengths. Specific advantages of adhesively bonded joints and mechanical fastening can be combined in form of hybrid joints, which yield in synergies of manufacturing, strength, crash behaviour, and durability performance.

In a specific hybrid bonding process increasingly used in industry, the so called “fixation method”, fluid adhesive is applied between two metal sheets, then mechanical joining is performed while the adhesive is yet uncured, after which the adhesive is cured. Depending on the type of mechanical fastener, e.g. considering hamming or rivets, the hybrid joint can take different designations. The hybrid adhesive-hamming process includes large plastic deformation of the metal sheets, in presence of the pasty liquid adhesives. The hybrid adhesive-riveting process additionally includes the fracture of the upper metal sheet, influenced by the presence of a pasty fluid. Critical issues in such hybrid joining processes are the formation of adhesive pockets in the region of the mechanical junctions, the potential presence of air bubbles in the adhesive, and the usually large global deformations of the metal sheets between the mechanical joints.

Numerical modelling of such hybrid joining processes makes it necessary to consider various physics: all effects related to the uncured–thus liquid–adhesive are associated to fluid dynamics, while solid mechanics is needed for the mechanical fasteners and metal sheets. Since both effects act simultaneously, taking into account the Fluid-Structure-Interaction (FSI) is fundamental. In hybrid bonding processes hydrostatic pressures inside the adhesive pockets can reach very high values, such to lead to plastic deformations of the metal sheets. When transferring high pressures, the exchange process of boundary conditions between the software for the solid metal forming process and the code for simulation of the fluid flow of the liquid adhesive is limited by the stability of the FSI simulation. This requires a careful selection of an adequate code coupling module. On the basis of experimental studies the authors present simulations for the numerical descriptions of hybrid joining processes. Different examples of simulations of hybrid adhesive-hemming, and adhesive-riveting, processes will be presented; from simple–academic–geometries to industry-relevant structures. The elaborated FSI simulations are able to shed additional light on the insights, and on the influence of several key parameters on the process.

REFERENCES

[1] H. Fricke and T. Vallée, “Numerical Modeling of Hybrid-bonded Joints”, *The Journal of Adhesion*, Vol. **92**, pp. 652-664, (2016).

[2] D. Landgrebe, B. Mayer, S. Niese, H. Fricke, et al., “Adhesive distribution and global deformation between hybrid joints”, *Key Engineering Materials*, Vol **651,** pp. 1465-1471, (2015).

[3] R. Neugebauer, M. Israel, B. Mayer and H. Fricke, “Numerical and Experimental Studies on the Clinch-bonding and Riv-bonding Process”, *Key Engineering Materials*, Vol. **504,** pp 771-776, (2012).