Numerical modeling of the strength and failure of point-to-point joints in impact-loaded structures

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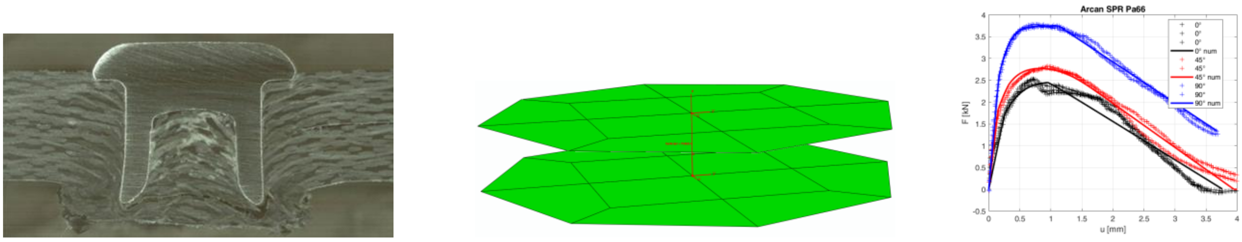
The structure of automotive vehicles is designed to undergo programmed deformation during road accidents (passive safety). Explicit computations of impact-loaded full-scale automotive structures are performed to this end using commercial finite element softwares such as Abaqus. A difficulty in this modeling relies on the different scales of the computation: that of the full-scale structure (a few meters), and that of the joints (a few millimeters), which play a major role in the deformation process. For the cost-efficiency of explicit structural computations, connector elements need to be used in the modeling of point-to-point joints such as Resistance Spot Welds (RSW) and Self Piercing Rivets (SPR) [1-4]. Connector elements are expected to dissipate the same amount of energy as the physical assembly, in order to obtain a good agreement between impact-loaded full-scale structure experiments and computations.



Modeling of a SPR joint in structural computations [1].
(a) Physical joint. (b) Joint model. (c) Behavior & dissipated energy.

The connector elements feature modular elastic, plastic, viscous, damage material behaviors and multiple plastic, damage initiation, failure criteria to model the energy dissipated in various assembly types. Indeed, new material types were assembled in a context of light-weighting of ground transportation vehicles. The connector models are thus expected to allow the modeling of RSW joining multiple High Strength Steel (HSS) sheets [2, 3] or of composite-aluminum SPR joints [1], for example. Quite promising results were obtained in the modeling of the strength and failure of these new assembly types [1, 3]. However, the connector models can still be enhanced by generalizing the material behavior and criteria models employed. The formulation and identification of new material models and criteria would allow:

- (i) a better modeling of the post-peak energy associated with the plate tearing failure mode [4],
- (ii) a definition of a connector model that takes into account the RSW quality obtained by non-destructive (acoustic) means [2].

Moreover, the joints featuring multiple sheets involve multiple loading configurations. The analysis of the new assembly models proposed [3] can still be deepened.

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The PhD work will thus aim at enhancing the material models and criteria of connector elements for a better point-to-point joints strength and failure representativeness in the computations of impact-loaded structures. To this end, various point-to-point joints tested at LAMIH and others available in the literature could be modeled to evaluate the reliability of the models proposed. The models will most likely be built using Abaqus commercial Finite Element software, and may involve some programming of user finite element subroutines. The results obtained will be compared to that of the literature or experiments performed. The non-destructive and destructive tests performed on multiple sheet RSW at LAMIH could be analyzed to build models including RSW quality parameters.

[1] LECONTE N., BOUREL B., LAURO F., BADULESCU C., MARKIEWICZ É. (**2020**). Strength and failure of an aluminum/PA66 self-piercing riveted assembly at low and moderate loading rates: experiments and modeling. *International Journal of Impact Engineering*. [IF=3.173] [DOI=10.1016/j.ijimpeng.2020.103587]

[2] TOUNSI R., HAUGOU G., CHAARI F., LECONTE N., MARKIEWICZ É. (**2019**). Experimental characterization of the mechanical behaviour and the failure of multi-sheet and multi-material spot welded assembly. *International Journal of Impact Engineering*, 130, pp. 226-238.

[3] CHTOUROU R., LECONTE N., CHAARI F., HAUGOU G., MARKIEWICZ É., ZOUARI B. (**2017**). Macro-modeling of the strength and failure of multi-layer multi-steel grade spot welds: Connector formulation, assembly model and identification procedure. *Thin-Walled Structures*, 113, pp. 228– 239. [DOI=http://dx.doi.org/10.1016/j.tws.2017.01.023]

[4] CHTOUROU R., LECONTE N., ZOUARI B., CHAARI F., MARKIEWICZ É., LANGRAND B. (**2017**). Macro-modeling of spot weld strength and failure: formulation and identification procedure based on pure and mixed modes of loading. *Engineering Computations*, 34 (3), pp. 941-959. [DOI=http://dx.doi.org/10.1108/EC-03-2016-0081]]