Challenges in developing a generalized idealized fastener method

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ABSTRACT

The evolution of Computer Aided Engineering has engendered the need to perform assembly level analysis. Parts interact with each other through: a) Interface contact b) Fastened attachments. Fasteners are rarely modeled in their entirety (complete geometry) in assembly models since it is a) Computationally expensive b) Exhibits convergence problems. Consequently, it is essential to have an accurate but simplified modeling method that idealizes fasteners.

Weight and cost efficient structures with high strength to weight ratios can be designed using composite materials. However the methods to analyze composites are often significantly more complex than metals. Closed form solutions are more an exception than the norm. Hence attributes like load share in a composite joint with a 2-D fastener pattern are often analyzed with Finite Element models. A corollary requirement is the need to model fasteners accurately and efficiently.

This presentation aims to explain some of the challenges encountered during the development of generalized methods that are applicable to most structural bolted joint types.

There are a handful of industry accepted methods today. However, the applicability of such methods is often very restrictive. Engineers need to be aware and understand the limitation of each method in question. Idealizing actual physics of a joint requires a system of springs to simulate certain stiffness terms such as translational and rotational bearing stiffness. Many existing methods rely on the stiffness calculations based on theoretical or semi-empirical equations that do not account for the inherent flexibility of finite elements. Utilizing these stiffnesses directly without factoring in the mesh flexibility can render the joint artificially soft and the load share un-conservative.

The difficulty of coming up a generalized method is due to variability present in a joint design. There are two main sources of variability, linked to: 1) Physical joint configurations and 2) Finite Element Analysis specific parameters.

Physical joint types vary depending on the number of joined members and the loading condition: single, double shear, multiple strap or hard point joint configuration. Certain design parameter such as the T/D (total joint stack thickness over fastener diameter) ratio can produce vastly distinct joint behavior. For example, a thick joint has more shear/bending interaction compared to a thin joint.

There are many finite element analysis specific parameters that can influence the joint response. Some of these parameters are highly dependent on the user's experience and input. Generalized methods should provide consistent results independent of the user's choice of the following parameters: a) Element topology (2D or 3D), b) Element type (hexagonal, tetrahedral and other element types) and c) Mesh density (in-plane and through thickness). Further, the fastener idealization has to be general enough to produce a consistent response across the numerous combinations generated by the individual joint members possessing a 2-D or 3D element topology.

In order to cover all physical aspects of a joint behavior, it is conceivable that the fastener idealization architecture (a system of beams and springs) will become complex. The automated creation of complicated idealized fasteners capturing major load paths promotes a) Standardization b) Reduced engineering cost and time c) Reduction or elimination of errors d) Ease of use e) Seamless adoption of method. Hence it becomes imperative to develop a tool that facilitates creation and post-processing of idealized fasteners.