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Several seam weld finite element idealizations challenged in fatigue within a French industrial collaborative workgroup.

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Abstract

In industry with fatigue strengthening concern, there are as many ways to make an FE seam weld idealization as factories involved in these types of simulations. Tens of ways to model a seam weld are available as soon as it is necessary to get out of direct connection assumption and if it is needed to take into account local weld stiffness and secondary bending effect of the fillet weld. Then it becomes mandatory to be able to discriminate such idealization processes while evaluating associated life prediction accuracy and industrial idealization efficiency (automation). This concern leads the idea to create a French industrial workgroup including CETIM and about 20 industrial companies, members of the "Mobile Machinery Program Committee". The main goal of this collaborative project being to challenge well documented and most promising seam weld idealization models (with associated methods) to converge at the end towards the most capacitive ones (with better results on given fatigue metrics).
As a first part of the multi-partner project work, a complete and precise technical review was achieved, giving a state of the art of the idealization models and methods available. Then the workgroup started extensive comparisons between well documented fatigue tests on seam welded components and associated FEA for some retained models and methods (Fayard, Lohr, IIW Hot Spot Stress, Notch Stress). Several components were considered, with more than 100 fatigue test results. This paper presents most of the obtained results, the Round Robin being still on-going. Preliminary results comparisons demonstrate general applicability of classical methods introduced in the standards or recommendations, these being also in most cases conservative. Results of this work aim to help choosing the right methodology, depending of the seam weld configuration and the in service loadings. It is also intended to try building partnerships with FE software editors to include most efficient methodologies in an automated way, making less tedious the seam weld modelling task on huge chassis frames. Small and medium factories should then reach an efficiency gain and improved accuracy level when building their virtual seam welded frames with new automated scripts integrated in their own FEA solutions.

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1. Introduction

1.1. Context

Industries from Public Works, Mining-Drilling, Handling-Lifting-Storage and Agricultural Machinery committees design and manufacture large and heavy metallic structures that must meet high requirement levels of reliability and safety. These structures often consist of components shaped and assembled mainly by welding. Although this process is widely used in industry, offering the possibility to produce structures with complex geometries, it appears however that the welded zones represent weak points with respect to fatigue resistance, due to geometric and/or structural discontinuities and residual stresses induced.

It is established that the fatigue strength of welded joints mainly depends on:

- The weld's geometry, introducing stress and strain concentrations at the toe and the root,

- Residual stresses associated with temperature gradients and phase changes due to the welding operation and overall average stress level in the structure,

Several fatigue design methodologies for welded joints are now available. They allow designers to evaluate the risk of fatigue failure by comparing different damage parameters, usually obtained by a structural calculation with an appropriate fatigue criterion. From a numerical point of view, these methods are implemented through different modeling strategies. Manufacturers need to have a panorama of these methods and techniques especially in finite element modeling and particularly in the case of shell models. This type of modeling is commonly used in industry, particularly for the advantage in model size and time calculations. However it relies on many simplifying assumptions that require a matching between the computed stresses and strains (not necessarily realistic) and associated analysis criteria in static and fatigue loading.

In addition, the designer rarely models the seam weld details (size, penetration, local geometry…), considering often the welded joint by coincident nodes, whereas this can have a significant influence on the transfer of loads.

1.2. Objectives of the study

The French multi-partner project aims to:

- Realize a state of the art on methods and techniques of modeling seam welded joints usable in an industrial context,
- Select some of these methods considered as most relevant and propose application cases to compare predicted fatigue lives to test ones,
- Allow, through the working group, exchanges between manufacturers on this theme of modeling welded joints and share experiences,
- Point out methodologies compatible with industrial constraints and tools, which can be recognized by the standard and legal authorities,
- Build partnership with FE and fatigue software editors in order to implement identified methodologies in an efficient industrial process.

This paper presents part of the results obtained during this still on-going project. It gives first a brief and non-exhaustive overview of the literature on seam welds modeling techniques and fatigue damage calculation methods, then comparisons of predicted lives to fatigue test lives are made for some selected approaches.

2. Fatigue assessment methods and welds idealization techniques

2.1. Background

Taking into account fatigue of materials in design of components or structures is a complex task, made even more complex when it comes to welded parts where the assembly process introduces factors influencing drastically the

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