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Experimental validation of an equivalent modelling strategy for clinch configurations

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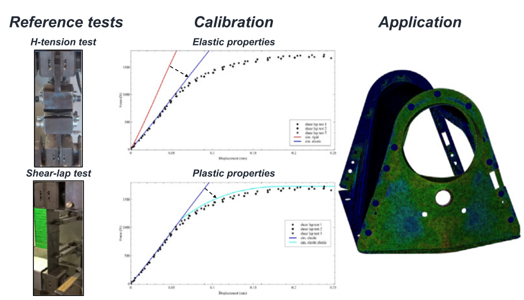
HIGHLIGHTS

- The accuracy and performance of the equivalent modelling strategy for a single clinch was validated on structures containing multiple joints.
- Lab scale tests on DC01 steel sheet under different controlled load cases were evaluated (pull-out and peel, shear and mixed mode loads).
- A structural analysis of a galvanized steel feed intake boot was performed using the proposed equivalent modelling strategy.
- Focus is on the force displacement response up to maximum force.

GRAPHICAL ABSTRACT



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ABSTRACT

Clinching is a joining technique for (dis)similar sheet(metal) parts that is realised with a permanent mechanical interlock due to local plastic deformation. In the search for lightweight and economic joining techniques, clinching is gaining interest in recent years in the domains of heating, ventilation and air conditioning (HVAC), automotive and general metal constructions. To predict the mechanical behaviour of structures containing multiple clinched joints, it is not computationally feasible to introduce detailed sub-models of these type of joints in FE simulations. In this paper, an equivalent model for a single clinched joint is applied and extended to structures which contain multiple clinched joints. It is shown that the equivalent model enables to accurately reproduce the more complex loading of clinch configurations. Finally the method is applied to an industrial feed intake boot as a test case for strength analysis of the structure.

1. Introduction

Modern mechanical design focuses on increasing performance whilst simultaneously providing environmental friendly structural solutions. This has led in recent years to an increased attention for lightweight structures. This sparked a more rapid development of novel and adapting mechanical joining techniques such as self piercing rivets(SPR), riveting and clinched joints. Clinching (also referred to as clinch joining or press joining) is a joining technique that makes use of a die and a punch to create a severe local plastic deformation of the sheet material, creating a permanent mechanical interlock.

Clinch joining has already been used for more than 35 years as a successful joining technique. Besides the fact that the joining technique itself does not add weight to the assembly, its possibility to join similar [1-3] as well as dissimilar materials [4] makes this an interesting technique for lightweight constructions. This has led to an increasing interest for the joining technique in recent years [5]. The

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Table 1
Material parameters: Thickness, Young's modulus, Fitted Swift parameters.

Material	t (mm)	Young's modulus (Mpa)	K (MPa)	ϵ_0	n
DC01	1	175 544	543.2	0.005549	0.2248
DX51D	1.5	191 509	559.4	0.2519	0.1241

Table 2
Material Lankford ratios.

Material	R0	R90	R45
DC01	1.608	2.049	1.084
DX51D	1.047	1.329	0.810

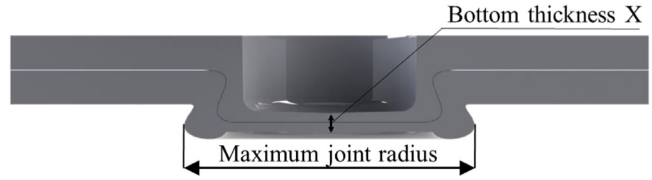

Fig. 2. Extensible die clinch joining with: a. Stripper b. punch c. Die segments d. Die anvil.

suitability of using clinching as a joining technique for high strength steels has been investigated by Varis et al. and Abe et al. [6-8]. For brittle materials, however, the formability represents a limitation for the clinch process. As the process induces large deformations, cracks potentially occur during the clinching of brittle aluminium alloys [3, 9], which might have an effect on the structural integrity of the joint. Hence, the increased attention with respect to fracture and fatigue life of clinched joints [3, 10, 11]. To improve the formability during the clinch process, heat assisted clinching was proposed [9, 12-14] in order to improve the ductility of the material during the clinching process. Clinching is mainly used in non-critically loaded constructions, because of its limited axial load or pull-out strength. In order to increase this limited strength, clinched joints are combined with adhesives [15, 16] to create hybrid joints with increased strength, new possibilities and applications.

Although the forming process, the influence of the tool geometry and the mechanical performance of a single clinched joint have been extensively investigated by finite element simulations [1, 17-22], the knowledge on the multi-joint mechanical behaviour of clinched joints is currently limited in literature. The mechanical behaviour of clinched groups in comparison with conventional joining techniques has been reported by Pedreschi et al. [23, 24] and Davies et al. [25, 26] for construction applications. For many spot joining technologies, up to thousands of joints can be present in a structure. In order to predict the mechanical behaviour of these constructions, a full scale model of the joint is not computationally feasible. Therefore, a simplified model was introduced for several joining techniques such as bolts [27], spot welds [28], rivets [29, 30] and SPR [31-34]. An equivalent modelling strategy for a single clinched joint was proposed by Breda et al. [35] enabling to reproduce the mechanical behaviour of a single clinched joint under several loading modes. The field of interest of these equivalent models, however, lies in applications were a large number of clinched joints are combined to assemble a complete structure or product. Applying multiple joints in a configuration can result in synergistic effects such as strengthening and stiffening of the structure. The key point under investigation in this paper is whether an equivalent model for a single clinched joint can be used to predict the behaviour of groups of clinched joints. Until today, limited information is available on the mechanical behaviour of clinched joints in configurations containing multiple joints, and the application of the equivalent modelling strategy for multiple joints.

In this paper the equivalent modelling strategy proposed in [35] was applied on structures containing multiple clinched joints. The accuracy and performance of the equivalent modelling strategy for a single clinched joint were validated to predict the mechanical behaviour of structures containing multiple joints. This was done using lab scale tests on DC01 steel sheet material under different controlled load cases (pull-out+peel, shear and mixed mode loads). Finally, a structural analysis of a galvanised steel feed intake boot was performed using the FEA along with the proposed equivalent modelling strategy. This FE model is validated using the force displacement behaviour captured by the tensile machine.

2. Material and joint properties

To provide the numerical models with accurate material properties, experimental material tests were performed to characterize the materials which are used in this work. For the lab scale

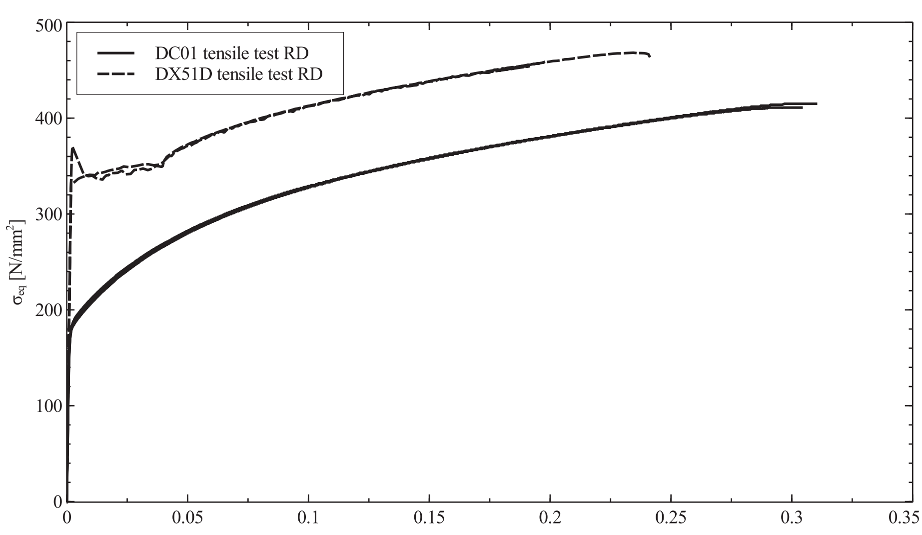

Fig. 1. Stress strain materials in the rolling direction.