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Spot Weld Model for Automotive Fem Crash Simulations

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Abstract:

This thesis deals with the finite element simulation of spot welded joint in crash analysis. Spot welding is a very common joining process in the automotive industry. It is cost effective and it provides a very fast production rate of automotive body components. Despite this advantage, spot welds are very susceptible to various types of loading conditions. Therefore they are prone to failure, if not designed properly, during their service life time. Therefore it is very important to understand the behaviour of spot welds and their failure characteristics. Generally, before the manufacturing stage, most of the automotive structural components are designed and tested in a virtual design environment. It is important to examine the crashworthiness of these body-in-white structures. To asses the crashworthiness of these structures they need to be represented correctly in virtual simulations, which necessitate the development of spot welded joint models to be included in crash analysis. Usually the models for the body-in-white structures are complicated and huge, which contains thousands of spot welded joints.Therefore a simple model for spot welded joints is desirable. Six different spot welded joint models were developed in this thesis to serve the above mentioned purpose. At the same time the simplicity issue of these developed spot weld models were also addressed, so that they can be integrated easily in a large assembly system, which consists of thousands of spot welded joints. Moreover for an effective modelling strategy, the computational costs incurred by the adopted spot weld models need also to be taken into consideration. Therefore the approach undertaken in this thesis was to study the characteristics of only one spot welded joint on a test coupon with the developed suitable spot weld nugget modelling configurations.

Introduction

Overview of Thesis Structure

The objective of this thesis was to develop simple models to represent the spot weld joint for Finite Element Analysis (FEA). These spot weld models were studied for different loading conditions. A failure criterion was implemented in the developed finite element models of this study to predict the spot weld failure responses. The predictions obtained from these simple models were compared to the actual spot weld failure results. The actual spot weld failure results were obtained through the experimental studies.

The structure of this thesis is as follows:

- Chapter – 1: Introduction

This chapter provides a general overview of the spot welding process. It also discusses the necessary background information required for the proposed study.

- Chapter – 2: Historical Background

This chapter presents the findings from the literature survey on spot weld failure characterisation. The modelling techniques presently used to represent the spot weld joints were also discussed in this chapter.

Introduction

Thus it justifies the scope of current research. It also mentions the limitation of the present work.

- Chapter – 3: Material property characterisation

This chapter presents the experimental study undertaken for the identification of the sheet metal material properties, which were used for the development of the finite element models.

- Chapter – 4: Experimental testing

This chapter presents the experimental study on spot weld failure characteristics undertaken for the current research.

- Chapter – 5: Modelling strategy

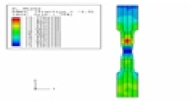
This chapter discusses the modelling strategy taken for the simulation of the spot weld joint.

- Chapter – 6: Finite element modelling of spot weld joint

Fig 3.2: Specimen dimensions for the tensile testing of sheet metal

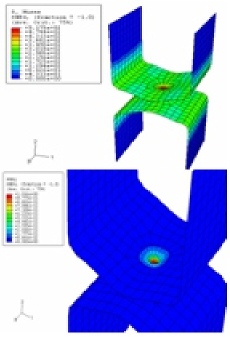
Material property Characterisation

SPOT WELD
MODEL FOR AUTOMOTIVE FEM CRASH
SIMULATIONS



Finite element modelling of spot weld joint

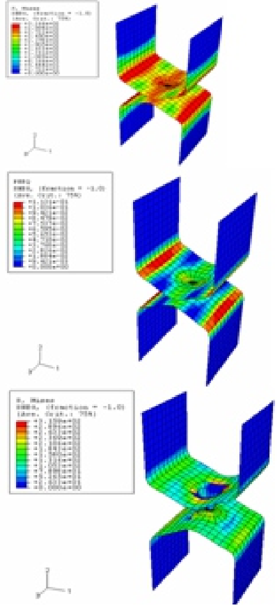
6000
Initiation of damage
or failure
5000
Propagation of
damage or failure
4000
)
Averaged Experimental(500 mm/min)
(Ne 3000
Plastic Displacement 1000mm
rcoF
Plastic displacement 2.3 mm
Complete failure or op

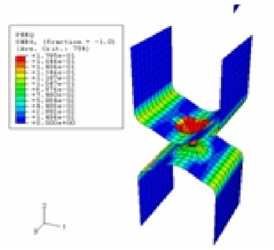


Results and Discussion

The equivalent stress and equivalent strain distribution for the failure simulations are provided only for the U tension coupon. From the equivalent stress and equivalent strain distribution of the failure simulations, the failed elements could be identified in the developed models. The failed elements around the spot weld joints are having about zero equivalent stress and the highest equivalent strain value. This is obvious because these elements were deleted (no longer affects the stiffness value of the model) from the analysis once the included failure criterion was satisfied. But at the same time they maintained the connections to the adjacent elements. It is important to point out that only the shell elements around the spot weld nugget in the Solid Element Model (SEM) failed. However, no sign of failure was observed in the solid nugget at all.

Fig 7.11: U Tension coupon with Individual Rigid Beam Model (IRB) for quasi static loading condition analysed with ABAQUS / Standard. (a) Mises equivalent stress distribution (Mpa) (b) Equivalent Strain distribution.



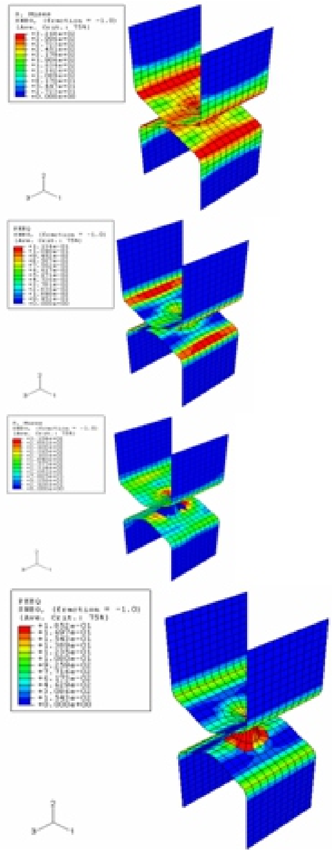


Results and Discussion

Fig 7.12: U Tension coupon with Paral el Multiple Rigid Beams Model (PMRB) for quasi static loading condition analysed with ABAQUS / Standard. (a) Mises equivalent stress distribution (Mpa) (b) Equivalent Strain distribution

Fig 7.13: U Tension coupon with Paral el Multiple Rigid Beams Model (PMRB) for failure loading condition analysed with ABAQUS / Explicit. (a) Mises equivalent stress distribution (Mpa) (b) Equivalent Strain distribution

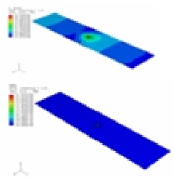
(b) Fig 7.19: U Tension coupon with Spider Configuration – 2 (SC-2) model for failure loading condition analysed with ABAQUS / Explicit. (a) Mises equivalent stress distribution (Mpa) (b) Equivalent Strain distribution



Results and Discussion

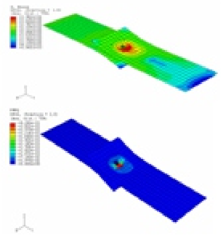
(b) Fig 7.20: U Tension coupon with Spider Configuration – 3 (SC-3) model for quasi static loading condition analysed with ABAQUS / Standard. (a) Mises equivalent stress distribution (Mpa) (b) Equivalent Strain distribution

Fig 7.27: Coach Peel coupon with Spider Configuration - 3 (SC-3) model for quasi static loading condition analysed with ABAQUS / Standard. (a) Mises equivalent stress distribution (Mpa) (b) Equivalent Strain distribution.



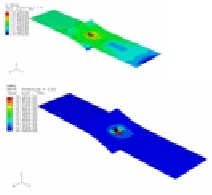
Results and Discussion

Fig 7.28: Lap Shear coupon with Individual Rigid Beams (IRB) model for quasi static loading condition analysed with ABAQUS / Standard. (a) Mises equivalent stress distribution (Mpa) (b) Equivalent Strain distribution



Results and Discussion

Fig 7.29: Lap Shear coupon with Paral el Multiple Rigid Beams (PMRB) model for quasi static loading condition analysed with ABAQUS / Standard. (a) Mises equivalent stress distribution (Mpa) (b) Equivalent Strain distribution .



Results and Discussion

Fig 7.30: Lap Shear coupon with Solid Element Model (SEM) for quasi static loading condition analysed with ABAQUS / Standard.

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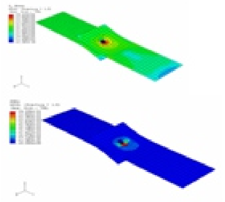
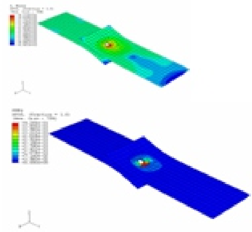
(a) Mises equivalent stress distribution (Mpa) (b) Equivalent Strain distribution



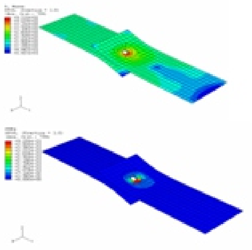
Results and Discussion

Fig 7.31: Lap Shear coupon with Spider Configuration - 1 (SC-1) model for quasi static loading condition analysed with ABAQUS / Standard. (a) Mises equivalent stress distribution (Mpa) (b) Equivalent Strain distribution



Results and Discussion

Fig 7.32: Lap Shear coupon with Spider Configuration - 2 (SC-2) model for quasi static loading condition analysed with ABAQUS / Standard. (a) Mises equivalent stress distribution (Mpa) (b) Equivalent Strain distribution .



Results and Discussion

Fig 7.33: Lap Shear coupon with Spider Configuration - 3 (SC-3) model for quasi static loading condition analysed with ABAQUS / Standard. (a) Mises equivalent stress distribution (Mpa) (b) Equivalent Strain distribution

Performance study of the developed models

The comparison of results through the characteristics responses (force displacement curve) elaborates the model performances with respect to the accuracy from a mechanics point of view.

But to clarify the complete performances of the developed spot weld models, the computational costs occurring for each model should also be considered. The computational cost is defined here as the “CPU time” which is the total approximate computation time required by the commercial code for completing the analysis. Other than the CPU time two other parameters were considered for comparison purposes. The first parameter is “Memory Used”. It is defined as the required memory value that enables the commercial code to solve the problem. The other parameter is “Required Disk Space” which is defined as the amount of disk space required for storing the scratch files during the analysis. These scratch files are deleted automatical y at the end of the analysis. This is a very important parameter for the implicit analysis procedure. But for the explicit analysis this is not required due to the numerical techniques followed by the analysis procedures. Hence they are not reported here. All the computations were performed on a WINDOWS (X – 86, 32 bit) based platform.

Conclusions :

In this thesis a strategy for developing FEM models of the spot weld joints for dynamic crash analysis and simulations was presented. Six different spot welded joint models were developed and studied for this purpose. A proper meshing strategy around the spot welded joint was also presented. The characteristics of the developed spot weld models were studied for the shear loading condition (with lap shear coupons), tensile loading condition (with U tension coupons) and the bending load condition (with Coach Peel coupons). The developed model performances were evaluated from two perspectives. First with respect to the experimental results (force displacement response) obtained through the spot welded test coupons. Second perspective was with respect to the computational costs incurred by each of the models.

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