The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM)
ISSN: 2602-3199

The Eurasia Proceedings of Science, Technology, Engineering and Mathematics (EPSTEM), 2025

Volume 38, Pages 115-120

IConTES 2025: International Conference on Technology, Engineering and Science

Numerical Analysis of Weld Spot Spacing Effects on Shear Tensile Behavior of TRIP 800 Steel

Cherfi Mohamed
University of Sidi Bel Abbes

Reffas Sid Ahmad
University of Sidi Bel Abbes

Sahli Abderahmane
University of Sidi Bel Abbes

Moulgada Abdelmajıd
University of Sidi Bel Abbes

Ghermaoui Mohammed Ilyes
University of Sidi Bel Abbes

Abstract: The global TRIP 800 steel industry is a dynamic and constantly evolving sector, requiring innovative technologies and robust materials to meet performance and safety standards. Among the techniques used for assembling metallic materials, resistance welding—and more specifically, spot welding is widely employed for joining high-quality metal parts. This method enables the creation of sealed and durable joints, which are essential for applications in the aerospace, automotive, shipbuilding, and other industrial sectors. The variations in temperature and pressure can influence the metallurgical structure of the joint, potentially compromising its strength and durability. The objective of our study is to model a shear tensile test to visualize the influence of spot welding parameters, such as the spacing between weld points, the dimensions of the weld joints, and the effect of TRIP 800 steel plates. This study covers the various welding methods, with a particular focus on resistance spot welding. We discuss the welding principle, the different stages of the process, the geometry and microstructure of the weld nugget, as well as the heat-affected zone (HAZ) and weldability considerations, and we explore the general concepts related to TRIP 800 steel. Secondly we interpret the equivalent stress results (VON MISES and MAX PRINCIPAL) and analyze stress histograms representing the molten metal and the heat-affected zone across four different geometric models to illustrate the influence of weld point spacing, finally, we focused on the behavior of the joint in the event of failure (spot welding), by creating a model that includes a crack.This crack occurs in the base metal with identical size, in order to parameterize the study and visualize the fracture behavior of the joint while interpreting the J-integral contour.

Keywords: Spot welding, FEM, TRIP 800 Max principal stress, J-integral contour

Introduction

The global TRIP 800 steel industry is a dynamic and constantly evolving sector that demands innovative technologies and robust materials to meet performance and safety requirements. Among the various techniques used for joining metallic materials, resistance welding-and more specifically spot welding-is widely employed to assemble high-quality metal components. This method enables the creation of tight and durable joints, which are essential for applications in the aerospace, automotive, shipbuilding, and other industrial sectors.

Spot resistance welding is an innovative joining technique, particularly widespread in the automotive industry. It does not require any filler material, as the weld nugget is formed by the fusion of the metal itself (Joule effect) between the sheets to be joined. Generally, this technique is used to assemble two thin sheets (ranging from 0.1 to 3 mm) through the formation of a weld nugget. The sheets in contact are subjected to pressure by two electrodes and traversed by a high-intensity alternating current at low voltage.

However, spot welding presents several challenges, notably the need for precise control of welding parameters to ensure high-quality results. Variations in temperature and pressure can affect the metallographic structure of the joint, potentially compromising its strength and durability. The objective of our study is to model the shear-tensile test in order to visualize the influence of spot welding parameters, such as the spacing between weld spots, the dimensions of the weld joints, and the effect of TRIP 800 steel plates.

Method and Analysis

Mechanical Properties and Model

In this study, we will create a numerical model of two spot-welded plates using physical, mechanical, or thermal data obtained from previous studies in the field in which we aim to develop this model. Many books focus on this area, such as those by Sylvain DANCETTE and Habib LEBBAL, who use different types of stainless steel to represent the behavior of welded plates. We conducted a comparison between two spot-welded plates in this study. These two plates have the same dimensions, as shown in Figure 1.

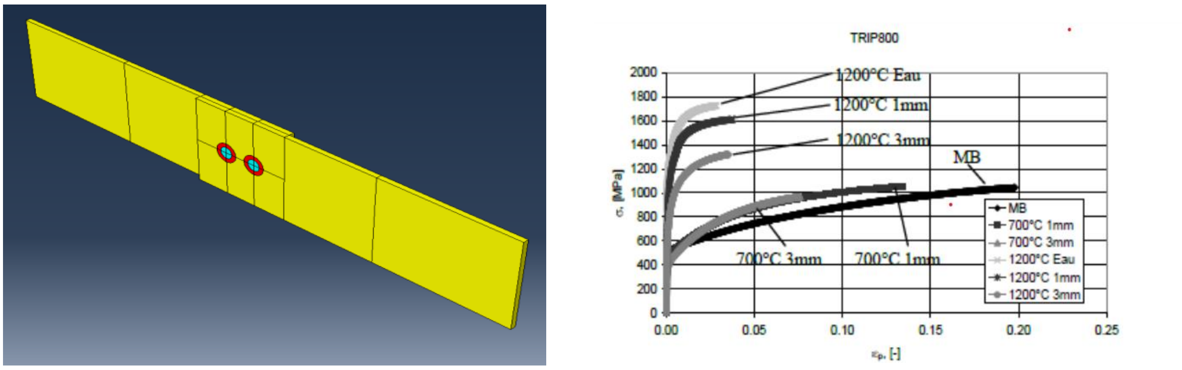

Figure 1. Spot welding model and tensile behavior law as a function of the thermal cycle for TRIP 800

Boundary Conditions and Mesh Model

The boundary conditions include all the forces or constraints that affect the mechanical behavior of the plate during the tensile test. The boundary conditions may include stress, concentric force, displacement, strain, and so on. During a tensile test, the boundary conditions are generally defined as two tensile forces applied on both sides of the sheets, one being equal and opposite to the other, or as a simplified case with one side fixed and a load applied on the other.

The Figure 2 shows the boundary conditions used in this simulation:

- An applied load in MPa.
- A fixed (encastrement) constraint.
- Zero displacement along the Y and Z axes.
- Allowed displacement along the X axis.

Obtaining reliable results requires an extremely sophisticated mesh. Indeed, it is essential to refine the mesh by studying the interaction between the base metal, the heat-affected zone (HAZ), and the molten metal in order to analyze the overall structure. The graphical representation illustrates the structure of the different parts of the welded plate. By applying the concept of convergence and accuracy of the results in this study, we improved the mesh in the various regions of the plate. The ABAQUS computational code allows us to perform this refinement in all zones and directions. In this study, we created a linear quadratic element, and the global model generated 23,082 elements of type C3D8R.

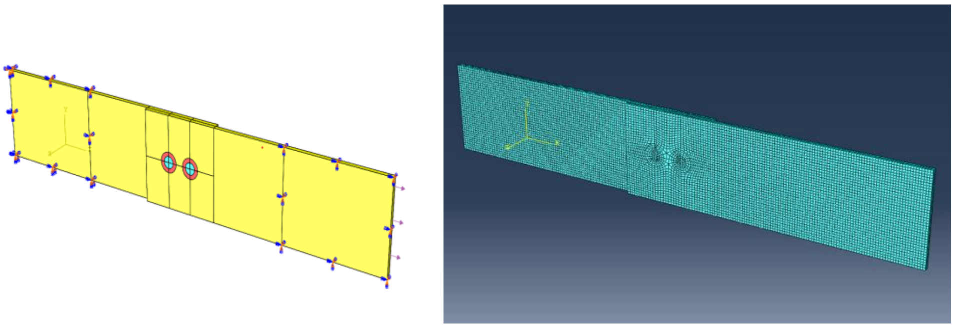

Figure 2. Boundary conditions and mesh model

Results and Discussion

The Graphs below illustrate the variation of the equivalent stress for the TRIP 800 material as a function of the overlap (38 mm) for six loading modes, ranging from 20 MPa to 200 MPa, for X1, X2, X3, and X4 in the longitudinal direction. The analysis of these four graphs shows that the effect of the applied load on the stress intensity is significant, far exceeding the stresses recorded in the transverse direction. Each point corresponding to X1, X2, X3, and X4 is highly stressed and exhibits a peak in the maximum principal stress. This peak value is similar for the first three positions (X1, X2, and X3), which show the same behavior, whereas X4 presents a different pattern. It is also observed that the graphs display a non-symmetrical and stochastic profile that increases in the loading direction, with stress peaks along the overlap. This behavior is due to the transition from one zone to another (variable stiffness). The highest stress values are recorded for X1, X2, and X3, reaching levels around 1000 MPa-close to the yield strength of the molten metal. In contrast, X4 shows a stress value around 600 MPa, which largely exceeds the yield strength of the base metal and the heat-affected zone, yet remains below that of the molten metal.

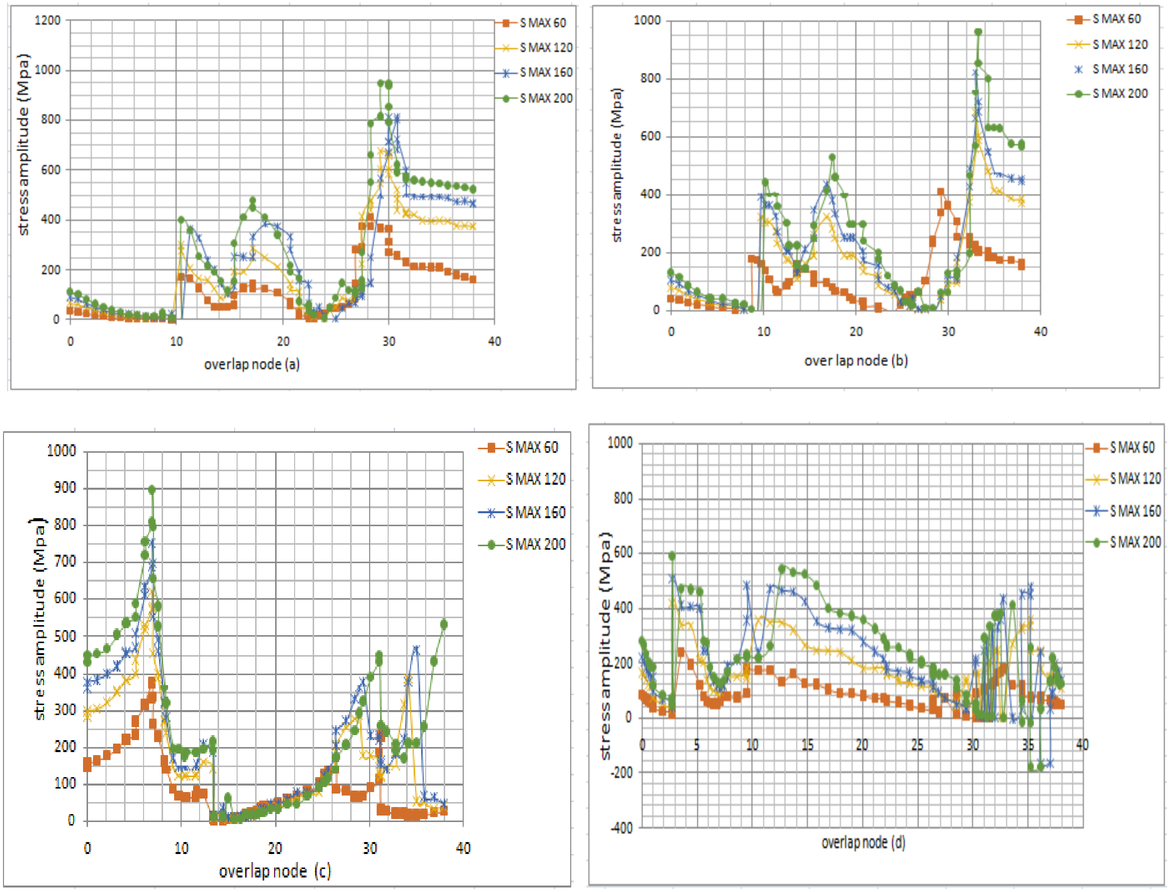

Figure 3. Evolution of the maximum principal stress as a function of the longitudinal overlap nodes for TRIP 800: (a) (x = 120), (b) (x = 155), (c) (x = 195), (d) (x = 275).

To clearly understand the effect of the applied load and study its influence on the behavior of the TRIP 800 welded plate, we conducted an analysis of the variation of the equivalent stress (maximum principal stress) in the direction perpendicular to the loading (transverse direction) for different load amplitudes: 20, 60, 100, 120, 160, and 200 MPa. The figure illustrates the schematic representation of the transverse direction considered in our study. This axis passes through the midline between the two sheets at the overlap region and crosses both the heat-affected zone and the weld nugget (molten metal). The purpose of creating this axis was to visualize the evolution of the equivalent stress at the contact points between the two plates.

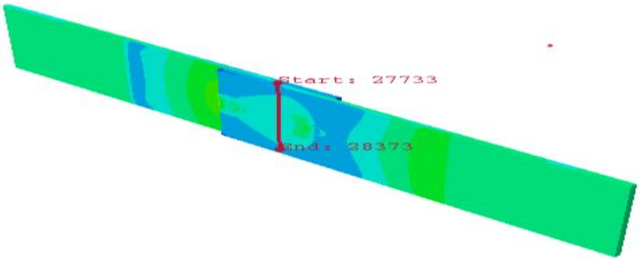

Figure 4. Schematic representation of the transverse direction

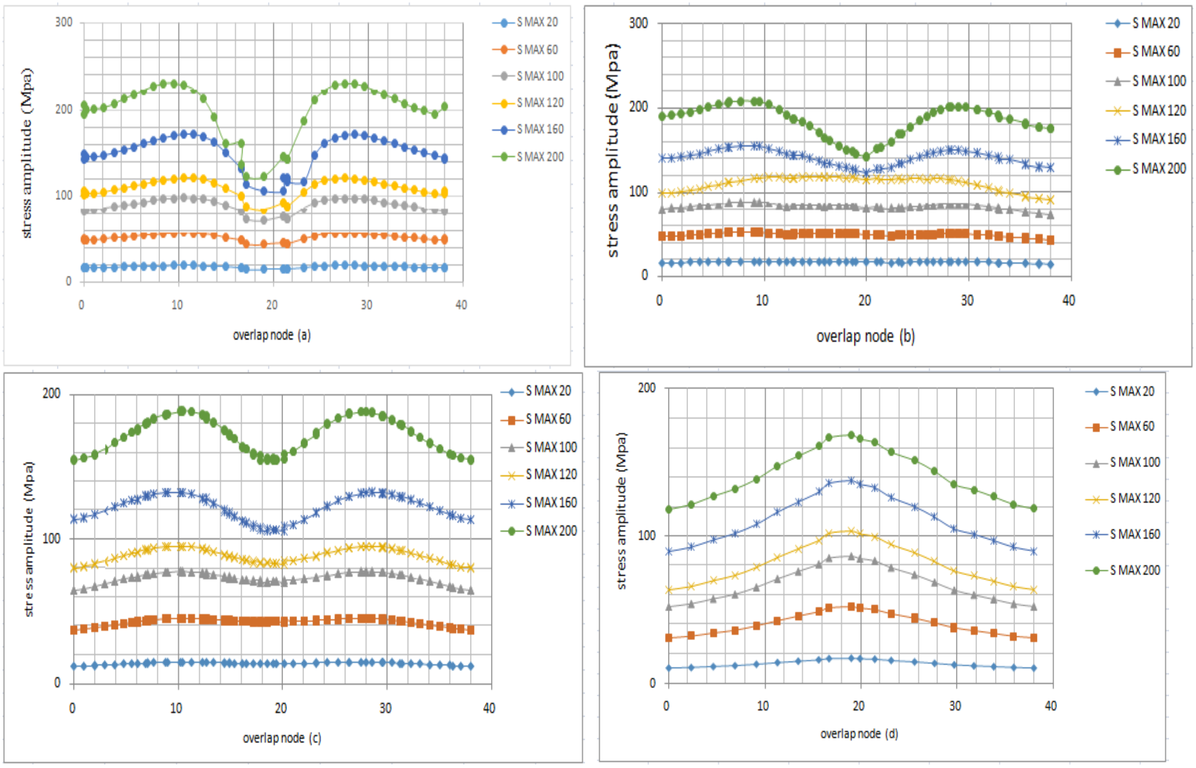

Figure 5. Evolution of the maximum principal stress as a function of the transverse overlap nodes for TRIP 800: (a) (x = 120), (b) (x = 155), (c) (x = 195), (d) (x = 275).

Conclusion

To evaluate the mechanical strength of spot welds in steels used in the automotive industry, we conducted one of the most thorough tests - the shear-tensile test - in order to observe how resistance spot-welded sheets behave as they approach the point of failure. Accordingly, a detailed numerical model was developed using the ABAQUS software, which accurately reproduces the geometric model used in the tensile test. It should be noted that this research focused on studying the behavior of DP450 and DP980 steels in the elastoplastic domain, providing valuable data on their strength and performance when subjected to mechanical stresses. The combination of experimental testing and numerical modeling allows for a more precise estimation of the strength of steel spot welds, contributing to the continuous improvement of vehicle safety and durability. The results obtained allow us to conclude that:

- The stresses increase with the applied load.

- The maximum principal stress and S11 show similar variations.
- As the pitch (spacing) increases, the stress intensity decreases.
- In the case of a longitudinal distribution, the stress increases significantly in the direction of the applied load.
- The contact zones between the base metal, the heat-affected zone (HAZ), and the molten metal always show a noticeable effect on the stress variation, with a peak occurring when passing from one zone to another.
- The histogram results indicate that the heat-affected zone represents the weakest link in the MB–HAZ–WM chain, as it is the first area affected during loading.
- The numerical simulation shows that damage in the base metal starts at around 160 MPa, whereas the heat-affected zone begins to fail at around 100 MPa. Meanwhile, the weld nugget shows no sign of damage for the four models with different spacings (X1, X2, X3, X4).
- The weld metal (WM) exhibits no sign of damage in any of the four welding models.
- The HAZ shows signs of damage starting from 100 MPa, which is due to the low stiffness of this region.
- The weakest area in resistance spot welding remains the heat-affected zone, regardless of the influence of the weld pitch.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

Conflict of Interest

* The authors declare that they have no conflicts of interest

Funding

* This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Acknowledgements or Notes

* This article was presented as a poster presentation at the International Conference on Technology, Engineering and Science (www.icontes.net) held in Antalya/Türkiye on November 12-15, 2025.

* We acknowledge the Ministry of Higher Education and Scientific Research, Algeria, for technical and financial support.

* We acknowledge the support received from faculty of technology of SIDI BEL ABBES and laboratory of mechanics and physics of materials for their financial assistance, which made this research possible.

References

Angeli, E., Wagner, J., Lawrick, E., Moore, K., Anderson, M., Soderland, L., & Brizee, A. (2010, May 5). *General format*. Purdue Online Writing Lab. Retrieved from http://owl.english.purdue.edu/owl/resource/560/01/

Calfee, R. C., & Valencia, R. R. (1991). *APA guide to preparing manuscripts for journal publication*. American Psychological Association.

Cherfi, M., Kaci Djafar, A., Abdelmajid, M., Abderahmane, S., & Ghermaoui, I. M. A. (2024). Numerical study of tensile-shear fracture behaviour of resistance spot welded sheet steel with DP 450 and DP 980. *Acta Mechanica Slovaca, 28*(4), 14-24.

Dancette, S. (2009). *Comportement mécanique des soudures par points: Mécanismes et stratégies de prédiction dans le cas des tôles en acier pour automobile* (Doctoral dissertation). École Doctorale Matériaux de Lyon.

Guzel, M., Goktas, M., Acarer, M., & Demir, B. (2023). Finite element modelling of the fatigue damage in an explosive welded Al-dual-phase steel. *Materials Testing, 65*(5), 787–801.

Lebbal, H. (2016). *Analyse expérimentale et modélisation du comportement thermodynamique des aciers inoxydables et dual phase: Application au procédé du soudage par résistance par point* (Doctoral dissertation). Université Mouloud Mammeri de Tizi Ouzou.

Rajalingam, P., Rajakumar, S., Balasubramanian, V., Sonar, T., & Kavitha, S. (2023). Tensile shear fracture load bearing capability, softening of HAZ and microstructural characteristics of resistance spot welded DP-1000 steel joints. *Materials Testing, 65*(1), 94–110.

Wang, J., Wang, H. P., Lu, F., Carlson, B. E., & Sigler, D. R. (2015). Analysis of Al-steel resistance spot welding process by developing a fully coupled multi-physics simulation model. *International Journal of Heat and Mass Transfer, 89*, 1061–1072.

Author(s) Information

Cherfi Mohamed
University of SidiBel Abbes, BP 89, cite Ben M'hidi, SidiBel Abbes, 22000, Algeria
Contact e-mail: *Mouh_cherfi@hotmail.fr*

Reffas Sid Ahmad
University of Sidi Bel Abbes, BP 89, cite Ben M'hidi, SidiBel Abbes, 22000, Algeria

Sahli Abderahmane
University of Sidi Bel Abbes, BP 89, cite Ben M'hidi, SidiBel Abbes, 22000, Algeria

Moulgada Abdelmajid
University of Sidi Bel Abbes, BP 89, cite Ben M'hidi, SidiBel Abbes, 22000, Algeria

Ghermaoui Mohammed Ilyes
University of Sidi Bel Abbes, BP 89, cite Ben M'hidi, SidiBel Abbes, 22000, Algeria

To cite this article:

Mohamed, C., Sid Ahmad, R., Abderahmane, S., Abdelmajid, M., & Ilyes, G.M. (2025). Numerical analysis of weld spot spacing effects on shear tensile behavior of TRIP 800 steel. *The Eurasia Proceedings of Science, Technology, Engineering and Mathematics (EPSTEM), 38,* 115-120.