

Enhancing Contact Pressure Uniformity in Strip Drawing Tests: A Geometric Approach to Mitigate Edge Stress Risers

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Abstract. The strip drawing test is widely used to assess the friction coefficient in sheet metal forming processes. A significant challenge in these tests is the presence of stress risers at the edges of flat punch configurations with rounded edges, which result in uneven contact pressure distributions and complicate friction characterization. To address this, a stress reliever concept involving geometric modifications is proposed. The study employed finite element simulations to explore an optimized geometry. Experimentally, two sets of die blocks—with and without stress relievers—were manufactured and tested under controlled loading conditions using a compression machine.

Keywords: Sheet Metal Forming; Contact Mechanics; Friction Tests; Strip Drawing Test

1 Introduction

Friction and contact mechanics play a critical role in sheet metal forming processes. Strip drawing tests are commonly used to evaluate friction under controlled conditions [1,2]. However, a key issue in these tests is the presence of stress risers at the edges of the contact interface. These localized stress concentrations can lead to inaccuracies in friction characterization if the geometry of the faces is not modified by polishing the edges [2]. This study explores a novel stress reliever concept designed to improve contact pressure uniformity by introducing geometric modifications.

1.1 Contact mechanics

This section introduces normal pressure analytical solutions for three different 2D contact types (Fig. 1): (i) Cylindrical pad to flat contact configuration (CTF), (ii) Square-ended flat punch to flat contact configuration (FTFS), and (iii) Flat punch with rounded edges to flat surface contact configuration (FTFR) [3].

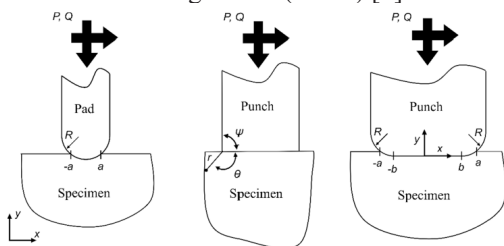


Fig. 1. From left to right: Sketch of a cylinder pad pressed onto a flat surface, a square-ended punch pressed onto a flat surface and a flat punch with rounded edges to flat surface contact configuration [3].

For strip drawing tests, the FTFR model exhibits a non-uniform stress distribution (Fig. 2), deviating from the theoretical constant pressure approximation derived from the ratio between contact force and contact area.

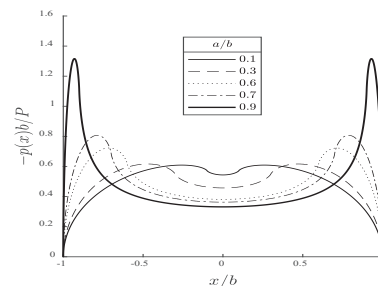


Fig. 2. FTFR contact pressure distribution for a/b ratios.

1.2 Stress Reliever Concept

Sheet metal forming typically employs the 3D version of the FTFR contact configuration, which is prone to stress risers at the edges. The proposed stress reliever concept aims to flatten the contact pressure distribution by introducing geometric voids that lower local stiffness (Fig. 3).

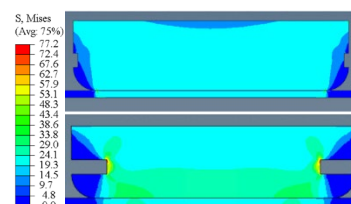


Fig. 3. Simulation stress results of two configuration stress reliever blocks.

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Linear elastic finite element simulations evaluated different configurations, showing that classical solutions exhibit two stress risers at the contact edges, while incorporating stress relievers eliminates them (Fig 4.).

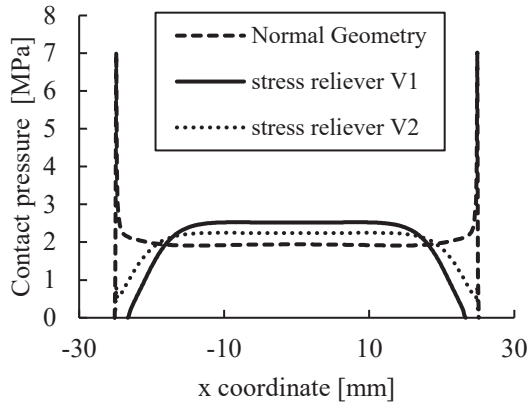


Fig. 4. Contact pressure distribution for different a/b ratios of normal geometry (without stress reliever) and two stress reliever designs.

1.3 Experimental study

To validate the concept experimentally, two sets of blocks were manufactured: one with the base geometry [2] and another incorporating an optimized stress-relieving groove derived from 3D finite element modelling. The base geometry, based on previous strip drawing tests, featured a 100 mm x 50 mm contact surface with a 10 mm leading radius. The optimized groove dimensions were 5 mm x 8 mm.

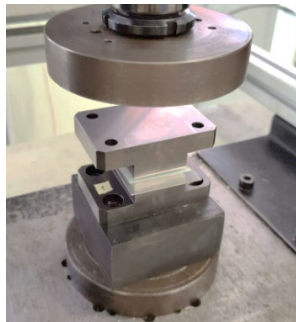


Fig. 5. Experimental configuration.

The tests were conducted using a ZWICK machine with a 100 kN force sensor. Uniaxial pressure was applied at 3 mm/min and held for 20 seconds to ensure proper pressure-sensitive film behaviour. The tooling system (Fig. 6) included a pressure-sensitive film, a 6 mm ground steel plate representing a sheet, the die blocks, a 20 mm thick shore A90 rubber, and an alignment system. Target pressures were 50, 60, 70, 80, and 90 MPa. Fujifilm Prescale films were used to measure pressure distributions.

2 Results

The experimental results confirmed the findings obtained through finite element simulations, demonstrating that the stress risers observed in the

standard block configuration were effectively mitigated by the stress-reliever geometry.

A representative example of the contact pressure distribution is shown in Fig. 6, where the classical configuration exhibits localized peaks at the edges in x axis sections, indicating stress risers. Conversely, the modified geometry with the stress reliever eliminates these peaks, resulting in a more uniform pressure distribution across the contact area (Fig. 7).

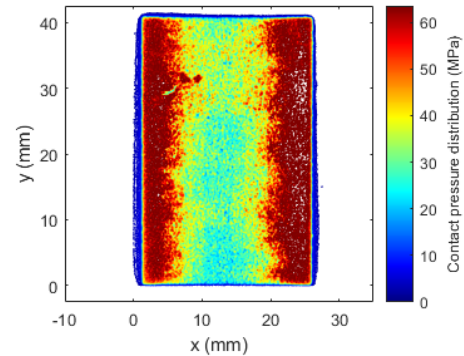


Fig. 6. Pressure distribution of a test performed at 72 kN without stress reliever geometry, with edge risers in x axis sections.

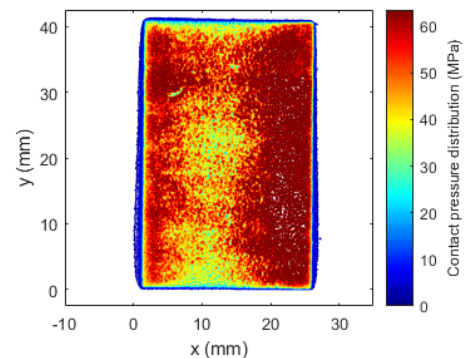


Fig. 7. Pressure distribution of a test performed at 72 kN with stress reliever geometry.

3 Conclusions

A novel stress-reliever concept was proposed and optimized using finite element simulations. Experimental results using pressure-sensitive films confirmed the potential of the optimized geometry, showing a more uniform contact pressure distribution. The proposed approach can help improve friction characterization accuracy in strip drawing tests.

References

1. M. Merklein, F. Zöller, V. Sturm, *Adv. Mater. Res.* **966**, 270 (2014)
2. A. Zabala, I. Llavori, E. Sáenz de Argandoña, J. Mendiguren, *J. Manuf. Process.* **58**, 1285 (2020)
3. D. Infante-Garcia, A. Zabala, E. Giner, I. Llavori, *Theor. Appl. Fract. Mech.* **121**, 103476 (2022)