Hole Expansion Tests of Metal Sheets: Numerical Study

Armando Marques[1], Pedro Prates[1], André Pereira[1], Marta Oliveira[1], José Fernandes[1]

[1] CEMMPRE – Departamento de Engenharia Mecânica, Faculdade de Ciências e Tecnologia, Universidade de Coimbra, Portugal (armando.marques@uc.pt; {pedro.prates, andre.pereira, marta.oliveira, valdemar.fernandes}@dem.uc.pt)

Abstract

A numerical analysis of the hole expansion test is presented. It focuses on the impact that different values of initial blank hole diameter have on the maximum values achieved for the principal strains, during the test. This analysis considers a case in full conformity with the ISO 16630 standard. The remaining cases studied differ from this, changing only the initial value of the blank hole. The results show that a smaller blank hole allows the test to reach higher values of major strain.

Author Keywords. Sheet metal forming, hole expansion test, plastic strain, numerical analysis.

1. Introduction

Advanced high-strength steels (AHSS) have been increasingly used in the automotive industry due to their good strength-to-weight ratio. However, forming of AHSS steel sheets can lead to cracks at the edge of a flange, submitted to tensile stress states. The hole expansion test is commonly used to evaluate the occurrence of edge cracking during flanging. This test consists of expanding a circular hole by the action of a conical punch. The minimum displacement of the punch required to cause a crack is measured. The hole expansion test is generally performed according to ISO 16630 standard (2017), however, there are studies in the literature that propose deviations in some geometrical features, namely the initial blank hole diameter (Uthaisangsuk et al. 2008). In this work, a numerical study is carried out to evaluate the impact of the initial blank hole diameter on the maximum values achieved for the principal strains.

2. Numerical Model and Procedure

The numerical model consists of a circular blank with a diameter of 120 mm and a thickness of 2 mm, a conical punch with a tip-angle of 60º, and a die with an inner diameter of 70 mm. Due to material and geometry symmetries, only one fourth of the blank is simulated, resulting in a finite element mesh with 13860, 8-node hexahedral solid elements. The numerical simulations were carried out with the in-house finite element code DD3IMP (Menezes et al. 2000). The material considered consists of a S460MC high-strength low-alloy steel. For each case studied, the evolution of the major in-plane principal strain (ε_1) with the punch displacement (Δl) is evaluated.

3. Results and Discussion

Four cases were defined for this analysis, considering the initial blank hole diameters equal to 10 mm, 20 mm, 30 mm and 40 mm. The results are presented in (Figure 1). It is clear from these results that lower values of the initial blank hole diameter lead to higher values of ε_1.

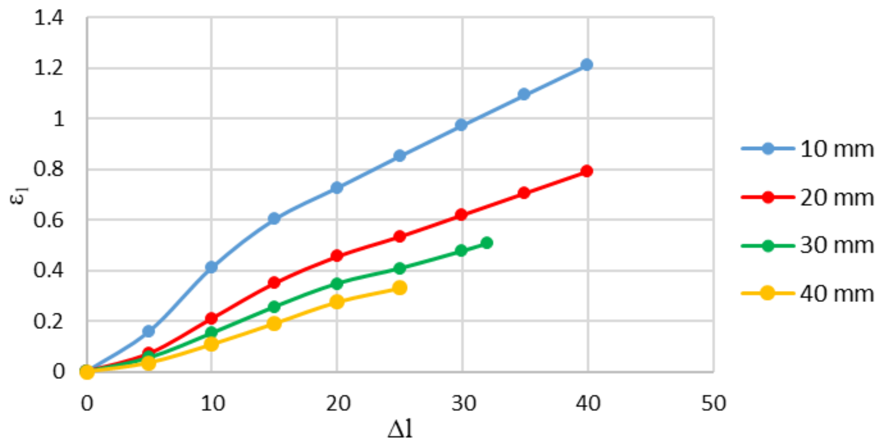

Figure 1: Influence of the initial blank hole diameter on the major principal strain values achieved during the hole expansion test.

The 30 mm and 40 mm cases studied had their tests ended before the punch displacement value was equal to the other two cases (40 mm). This is due to the fact that the punch displacement measurement starts at the instant that it contacts with the blank. For higher values of blank hole diameter, this instant occurs for a lower position of the punch, and the tests are considered finished when the cylindrical portion of the punch contacts with the blank, which happens for these two cases before Δl reaches 40 mm.

4. Conclusions

A numerical study was performed on the influence of the initial blank hole diameter on the major strain values achieved during a hole expansion test. This test shows that lower values of the initial hole diameter allow the test to achieve higher values of major strain. Future studies will focus on the effect of the die diameter and sheet thickness, as well as material hardening behaviour.

References

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