# REVISITING THE DISC TEST METHOD FOR THE STUDY OF HYDROGEN EMBRITTLEMENT IN STEEL

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**Abstract**
The ISO 11114 standard describes the disc test (method A) for selecting materials resistant to hydrogen embrittlement. However, the disc-shaped specimen geometry specified by this standard usually fails in the clamping area, making the test analysis more difficult. This work suggests two new sample geometries to obtain the disc rupture outside the clamping area.

## 1. Introduction

The transport of hydrogen by the existing natural gas pipeline is a possible way to introduce hydrogen as an energy vector, contributing to the decarbonization of the energy matrix. However, the steel from which these pipelines are built could be embrittled due to the effect of hydrogen. The need to perform this conversion, conciliating both economy and safety, instigates the exploration of different test methods. These are performed to evaluate and select materials, as well as to investigate the hydrogen embrittlement phenomena. The disc test specified by ISO 11114 (method A) within the current test procedures stands out as a consolidated methodology to select materials resistant to hydrogen embrittlement. The test uses a disc-shaped specimen subjected to an increasing gas pressure at a constant rate until it bursts or cracks. The Hydrogen Embrittlement Index (HEI) is then calculated as the ratio between the rupture pressure under helium and the rupture pressure under hydrogen for different pressurization rates. The standard specifies performing the test on a disc with a thickness of 0.75 mm. When using this geometry, failure frequently occurs in the clamping area, which can be problematic for test analysis. The objective of this study is to evaluate two new specimen geometries to obtain the disc rupture out of the clamping area.

## 2. Results

**Methodology:** Two different steel grades were studied: a vintage X52 steel for pipeline applications and a modern E355 steel (E355Mod). Previous tensile mechanical tests performed with these materials showed that the modern E355 steel has higher elongation than the vintage X52 steel. Two specimen geometries for the disc test were conceived using Finite Elements (FE) analysis. The first geometry consists in a 3 mm thick disc in which a truncated spherical cup is machined in the center, obtaining a minimum thickness of 0.75 mm (Cup Disc). The second geometry is a 2 mm thick disc with an axisymmetric notch machined with a radius of 1.25 mm, obtaining the same minimum thickness of 0.75 mm (Notched Disc). Tests using the geometry proposed by the standard were also performed for comparison. The specimens are depicted in Figure 1(a).
After machining, metrology assured that all specimens had the specified roughness in the region of interest (i.e., the center of the cup and the bottom of the notch). Before each test, the specimens were cleaned with alcohol and acetone in an ultrasonic bath to avoid contamination with oil and grease. The test system was subjected 10 times to a vacuum-nitrogen cycle after mounting the specimen to obtain surfaces free from humidity contamination. During the test, the pressure applied to the disk was recorded simultaneously with the displacement of the point located at the center of the outer surface of the disk.

**Experimental results:** An example of a result obtained from a notched specimen fabricated with E355Mod steel can be seen in Figure 1-(c). It can be seen the lower value for rupture pressure with hydrogen, if compared with rupture pressure with helium. Furthermore, it is possible to observe the good repeatability of the test. Results showed that both geometries allowed to successfully locate the disc rupture out from the clamping area, as can be seen in Figure 1-(b). In all tests (under helium and hydrogen), the cup disc burst

in the central region, and the notched disc burst or cracked at the bottom of the notch. The standard specimen burst in the clamping area, as usual.
However, the HEI were different for each particular geometry. The cup disc obtained an average HEI of 1.07, and the notched disc obtained 1.69. In contrast, the standard disc burst preferentially in the clamping zone, resulting in an average HEI of 2.02. These results support the assumption that HEI is sensitive to specimen geometry. The SEM observation of the fracture surfaces revealed a predominance of shearing mechanisms in both inert and hydrogen environments. Quasi-cleavage fracture was observed in small regions in the specimens tested under hydrogen.

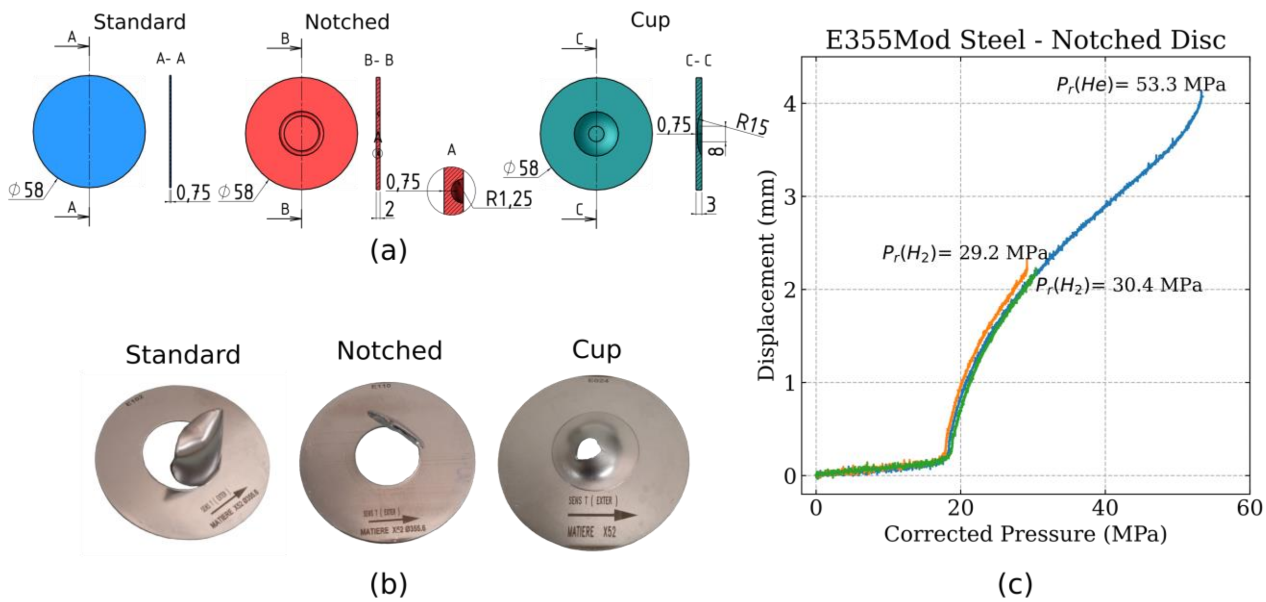


Fig.1 – (a) Specimen dimensions; (b) Different specimen geometries and rupture localization; (c) Example of a result obtained from a notched specimen fabricated with E355Mod steel

## 3. Conclusions

This study proposed two new sample geometries for ISO 11114-4 standard disc test method, being succesfull to localize the disc rupture out from the clamping area. The investigation has also shown that HEI may be sensitive to the specimen geometry, which should be considered for future investigations on this subject.

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