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A new Taylor tensile impact test for the identification of dynamic material behavior law

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Abstract

Strain rate has a significant influence on the material behavior subjected to dynamic loading, that is why a lot of work has been concentrated on accurate high strain rate experiments to identify the parameters of such dynamic constitutive laws. Taylor impact test, based on the use of gas gun, is well known because some ultra-high strain rates (around 10^5 s^{-1}) can be attained in this kind of test. An original tensile test, based on Taylor impact technique, has already been proposed in our laboratory (Laboratoire Génie de Production) for characterizing the behavior of materials subjected to high strain rate tensile loading, where a projectile is launched to impact a specially designed target and tensile deformation is mainly generated in the center zone of the target. In the present paper, a new design of this target is proposed in order to optimize the results.

Keywords: Taylor impact technique, Dynamic tensile test, Optimization of specimens

1 Introduction

A widely used method for characterizing the behavior of materials subjected to dynamic traction is the Split Hopkinson Tension Bar (SHTB) [1]. This test is realized from the modification of the Split Hopkinson Pressure Bar (SHPB) introduced by Kolsky [2] where strain rates ranging from 10^2 to 10^3 s^{-1} can be attained, where a typical specimen for the SHTB test has a dog bone geometry with a middle section of small cross-sectional area and ends with a larger cross-sectional area.

In order to characterize the behavior of materials subjected to dynamic traction, the Taylor impact technique [3] has been originally extended in LGP in the last past years [4], which is referred to as the Taylor tensile test in this work. In this test, the Taylor gas gun device is used to launch a projectile into a specially designed target with different impact velocities, and tensile deformation mainly occurs in the center zone of the target. The strain rates of the Taylor tensile test range from 10^3 to 10^4 s^{-1} . In the current work, the geometry of the tensile target has been modified with regards to the previous version and optimized in order to obtain higher strains and more elongation without reaching the critical state of the rupture of the target. Both numerical simulations and experimental tests are performed in order to validate the proposed optimization.

Section 2 presents the proposed new version of the target for the Taylor tensile test. Section 3 shows some results of the experimental tests and comparisons with numerical simulations made in our laboratory.

2 Optimized Taylor tensile target

A massive target support, with a mass of $m = 2.85 \text{ kg}$, which is not fixed during impact, is used to sustain the target during impact and ensure a good alignment between the target and the projectile in the impact chamber of

the gas gun. The projectile used in the Taylor tensile test, consists of a 42CrMo4 steel head and a polycarbonate sabot used to guide the projectile during its movement along the barrel. The total weight of the projectile is $m = 49.1 \text{ gr}$. The initial geometry of the target for the previously designed Taylor tensile test has already been published some years ago by Abichou *et al.* [4]. In the present work, the geometry of the target has been modified with regards to the previous approach and optimized in order to obtain higher strains and higher strain rates without reaching the critical state of the rupture of the specimen. Figure 1 shows the final optimized geometry of the target.

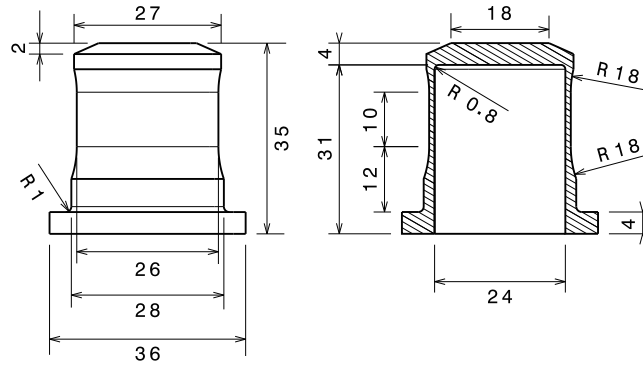


Figure 1: The geometry of the optimized target for the Taylor tensile test

3 Results of experiments and numerical simulations

The numerical models of the Taylor tensile test are built thanks to Abaqus/Explicit [5]. Because of the symmetric structure, axis-symmetric 2D models are established including 4 parts: a sabot made of polycarbonate, a projectile made of 42CrMo4 steel, a target made of 2017-T3 aluminum and a target support made of steel. The widely used Johnson-Cook hardening flow law [6] has been selected to simulate the behavior of all materials. Details concerning the finite element models, constitutive law parameters and boundary conditions can be found in the thesis of L. Ming [7].

Figure 2 shows the results of an experimental test with an impact velocity $V_i = 63.5 \text{ m/s}$ and its comparison with the numerical simulation. Table 1 reports some comparison of selected measurements on the deformed target for two selected impact velocities. A good agreement has been found between the experimental and numerical results.

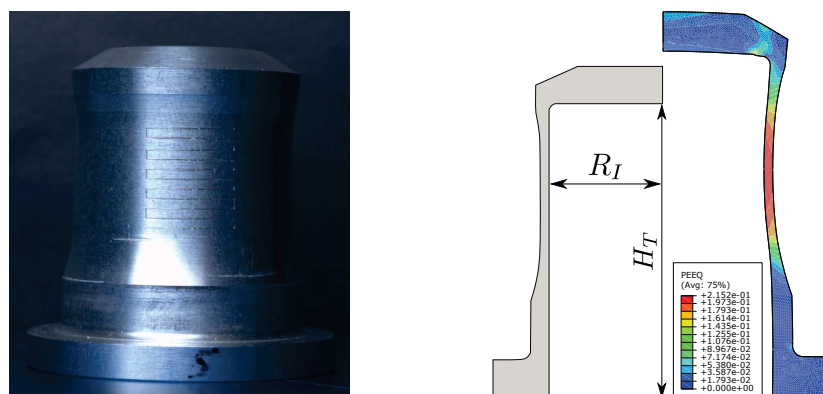


Figure 2: Comparison of experimental results and numerical simulations for $V_i = 63.5 \text{ m/s}$

4 Conclusions

The target of the Taylor tensile test proposed for characterizing the behavior of materials subjected to dynamic traction has been optimized. The optimization was validated by the numerical simulations and experimental tests presented in this paper. Compared with the previous version, the optimized target can achieve less strain

Table 1: Comparison of the Taylor tensile test results

	$V_i = 50.6 \text{ m/s}$		$V_i = 63.5 \text{ m/s}$	
	H_T (mm)	R_I (mm)	H_T (mm)	R_I (mm)
undeformed	35.00	12.00	35.00	12.00
experimental	37.10	11.63	38.20	11.46
numerical	36.99	11.52	37.93	11.29
$\Delta = \frac{r_n - r_e}{r_e}$	-0.30%	-0.94%	-0.71%	-1.48%

concentration in the useful zone which can avoid necking and rupture, and larger deformation in a shorter distance.

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