Mechanical behaviour of TRIP steels subjected to low impact velocity at wide range of temperatures

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1. Introduction

The response of materials under impact loading has a considerable interest. It allows for clarification of several problems in different application fields such as civil, military, aeronautical and automotive engineering, [1-2]. The use of TRIP steels is widespread in the industry as a structural element responsible for the absorption of energy during an eventual impact or accident as for example in crashworthiness application. Thus, in the present work mechanical behaviour of **TRIP 600** and **TRIP 1000** sheets subjected to low impact velocity at different initial temperatures is analyzed.

2. Experimental setup

For this task a drop weight tower has been used. Thus, it was possible to perforate the TRIP steel sheets for initial velocities $V_0 \leq 5\mathrm{m/s}$ in a wide range of initial temperatures $173\mathrm{K} \leq T_0 \leq 373\mathrm{K}$. The dimensions of the square sheets impacted are $100x100$ mm. The steel sheets of thickness t = 1.0 mm and t = 0.5 mm in the case of **TRIP 600** and **TRIP 1000** respectively. The impactor used had a shape of conical nose with diameter of $\phi_p = 20\mathrm{mm}$ and mass of $M_p = 18.7\mathrm{kg}$. The experimental set-up allows to obtain measurements of the force-time history and both, the initial and residual velocities. Finally, the process has been filmed using a high speed camera.

3. Mechanical characterization of TRIP 600 and TRIP 1000

The mechanical behaviour of both, **TRIP 600** and **TRIP 1000**, has been defined using different strain rates and initial temperatures, Figs 1-2. In Fig. 1 experimental results are reported for **TRIP 600** and **TRIP 1000** at room temperature for different strain rates. For **TRIP 1000** a Lüders' band propagation is also observed corresponding to a plateau of stress at the beginning of loading, Fig. 1-b.

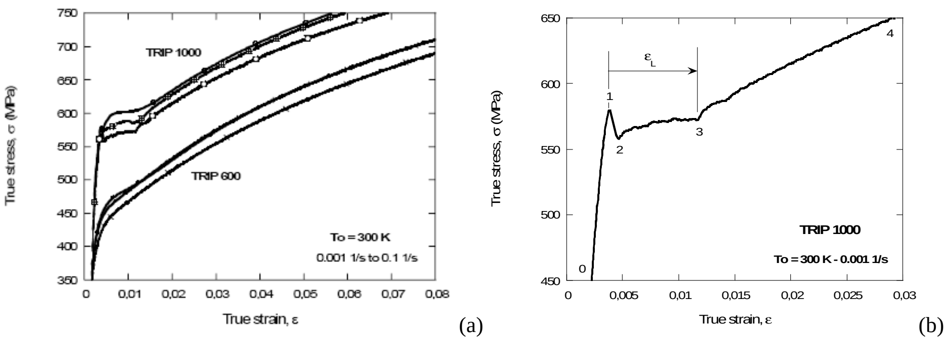

Fig. 1. Experimental results for **TRIP 600** and **TRIP 1000** steels at room temperature and different strain rates

The influence of the temperature on the behaviour of the materials studied is shown in Fig. 2. It is observed a strong dependency of the strain hardening with temperature

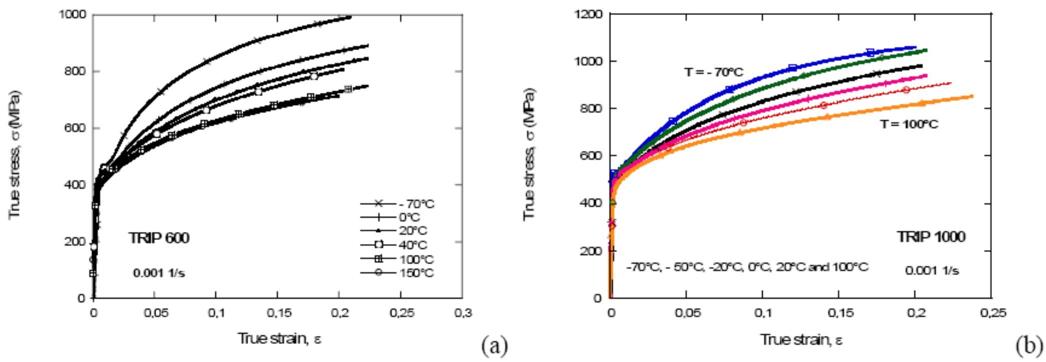

Fig.2 Experimental results in quasi-static loading at different temperatures for (a) **TRIP 600** and (b) **TRIP 1000**

It is also observed during experiments, due to high stress levels and large ductility, a substantial increase of temperature, Fig. 3-a. This observation is also true for the quasi-static loading, $\dot{\varepsilon} > 10^{-3}\,\mathrm{s}^{-1}$, where the temperature increase near the necking zone is close to $\Delta T \approx 100\mathrm{K}$. Thus, the process of phase transformation is reduced for quasi-static loading and does not exist in the case of dynamic loading. On the contrary for low temperature, phase transformation is observed reducing strain hardening Fig 2-a-b. An analytical approach is proposed to describe the temperature increase along the specimen. Analytical predictions are compared with experimental results, Fig. 3-a.

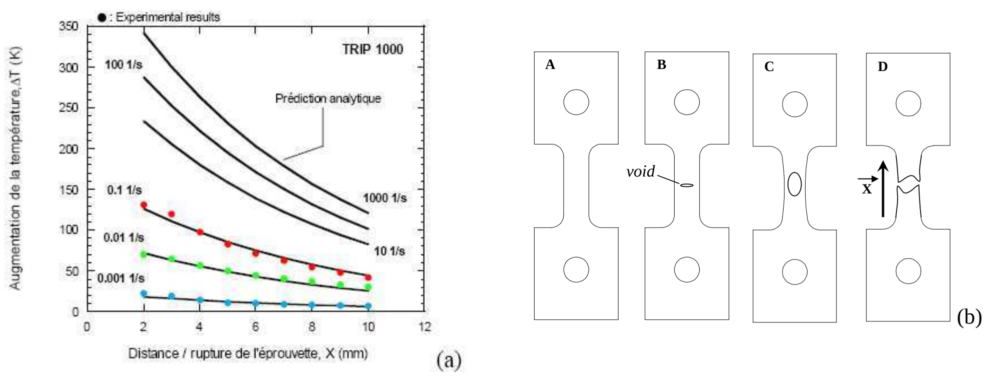

Fig.3 (a) Analytical predictions of RK model and comparison with experimental results in the case of **TRIP 1000** steel (b) Definition of failure during tension test due to necking appearance

4. Analysis of the perforation process for high strength steels

The perforation tests have revealed that the failure mode of the steel sheets is due to ductile hole enlargement with presence of petalling, Fig. 4, more accentuated in the case of **TRIP 1000** due to the reduced thickness of the plates in comparison with **TRIP 600,** Fig. 5. The experimental observations in terms on number of petals have been compared with the analytical predictions reported in [4] and a good agreement has been found between them.

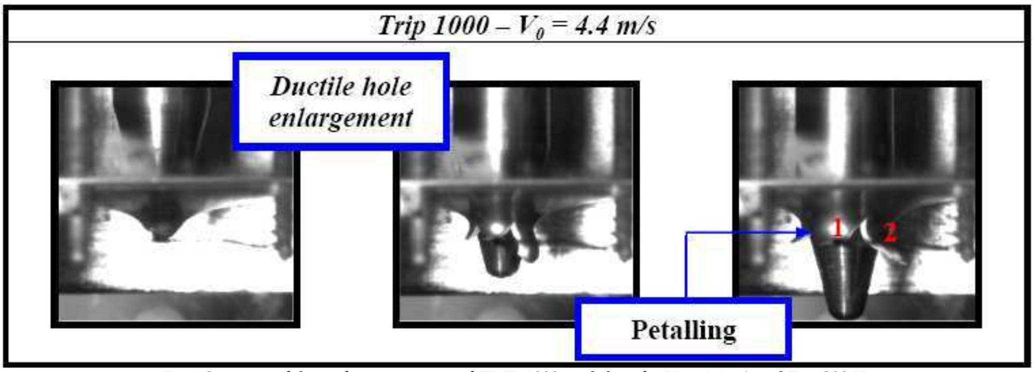

Fig.4 Sequence of the perforation process of **TRIP 1000** steel sheet for V_0 = 4.4 m/s and T_0 = 300 K.

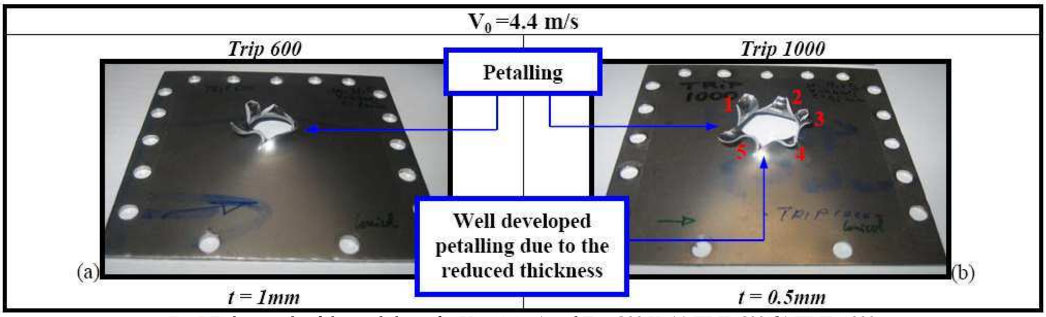

Fig.5 Failure mode of the steel sheets for V_0 = 4.4 m/s and T_0 = 300 K. (a) **TRIP 600** (b) **TRIP 1000**

The ballistic limit in the case of room temperature for both steels has been found close to $V_{bl} \approx 3.5 m/s$. This value is reduced in the case of higher temperatures, for example $T_0 = 373K$, due to the thermal softening of the material and considerably augmented for low temperature, $T_0 = 173K$, due to the transformation of the austenitic phase into martensite.

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