TEMPERATURE AND STRAIN RATE EFFECTS ON TRIP SHEET STEEL. MEAUSREMENT OF TEMPERATURE BY INFRARED THERMOGRAPH

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Summary *More frequently, new sheet steels are applied to assure a high energy level absorption, for example DP steel or TRIP steel. The high energy level absorption of this materials is due to high stress level combined with large ductility. However some problems appear to define precisely analytical behavior of TRIP steel since the behavior is strongly dependent on the phase transformation which occurs during plastic deformation. To obtain a complete knowledge of the behavior affected by phase transformation, a series of experiments has been performed in the form of tensile test and shear test at different strain rates and temperatures. During those tests, a thermographic set-up has been used to measure the temperature increase with plastic deformation. This complementary information may be useful to explain and understand the phase transformation in TRIP steel during plastic deformation. Preliminary analysis of the temperature gradients in specimen has been performed via relaxation tests.*

EXPERIMENTAL SET-UP

To analyse the thermoviscoplastic behavior of TRIP 800 a special arrangement has been used with an infrared thermographic camera. The range of strain rate applied during experimental tests was from $10^{-3}\,s^{-1} \le \dot{\varepsilon} \le 100\,s^{-1}$. Several temperatures have applied for TRIP 800 steel to study the effect of temperature on the phase transformation during plastic deformation. The test temperature varied in the following limits $213\,K \le T \le 373\,K$. The temperature affects strongly the plastic behavior as it is shown, Fig. 1-a-b.

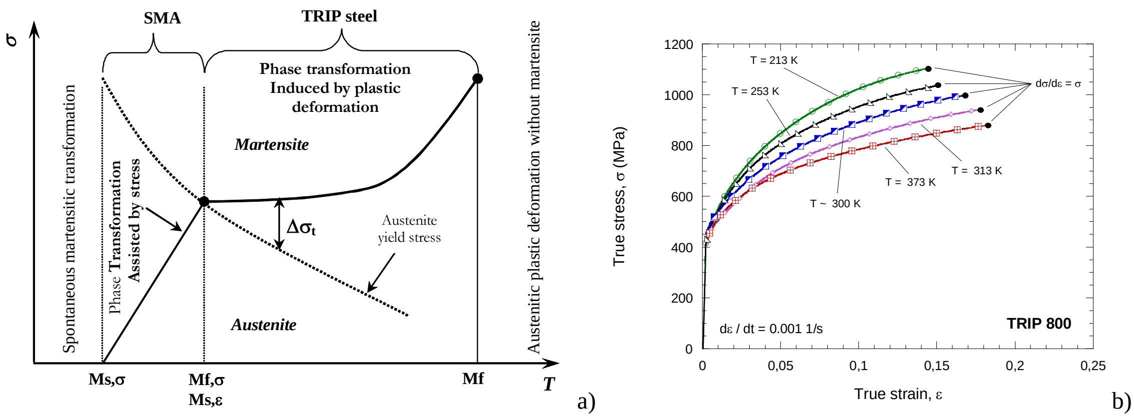

Fig.1. a - Schematic representation of the kinetic phase transformation with the initial temperature, b – Effect of the initial temperature on the plastic behavior in quasi-static tension

In Fig. 1-a substantial increase of strain hardening is observed when the initial temperature decreases. In fact, at low temperature ($T = 213\,K$), Fig. 1-a, the phase transformation austenite-martensite appears without plastic deformation in comparison to other temperatures inducing an instantaneous increase of stress level, Fig. 1-b. To approximate of the correctly the behavior of TRIP steel the temperature must be introduced in the kinetic description of transformation. In fact, the TRIP steels are strongly affected by the temperature sensitivity in comparison to mild steel, Fig. 2-a. Concerning the strain rate sensitivity it is essential to take into account this variable to take into account correctly the viscoplastic effect and the coupling strain rate-temperature, Fig. 2-b. The temperature increase has been measured to complete analysis of the mechanical behavior of TRIP 800 sheet steel. We observe on the following curves maximum temperature in the necking zone, Fig. 3-a, equal to $\Delta T = 86\,K$. The substantial temperature increase in TRIP steel is due to high failure stress level and high ductility with $\varepsilon_{max} \ge 0.2$ induces a high temperature increase. This phenomenon is a negative factor on the phase transformation as is shown on Fig. 3-b since the phase transformation is reduced by temperature increase. In fact, an approach which takes into account a constant temperature in the volume (specimen) will induce an overestimation of the martensite volume faction. In fact the phase transformation is not uniform (path (a)), Fig. 3-b, and it is closed to path (b) defined by (◊), Fig. 3-b. A complete analysis on the temperature increase is given in [3] in quais-static and dynamic loading.

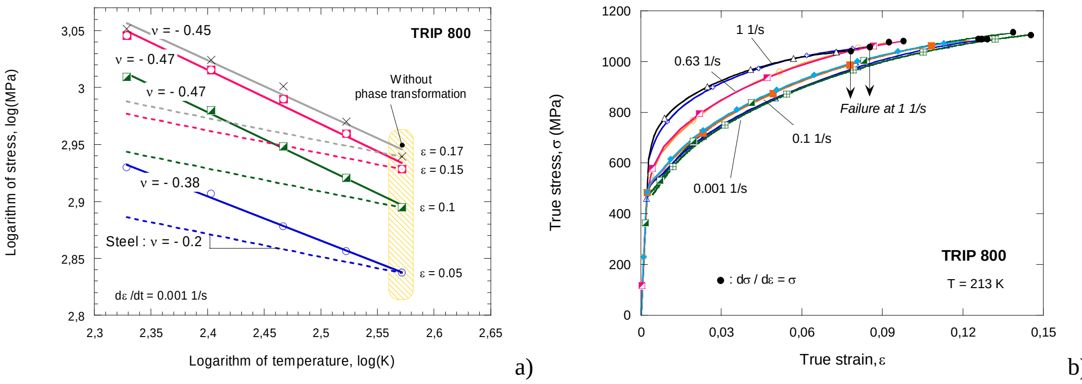

Fig.2. a – Temperature sensitivity in quasi-static loading, b – Strain rate sensitivity at low temperature, $T = 213\,K$

Moreover, with the complete experimental analyse a correlation has been found between the temperature sensitivity $\nu(\varepsilon) = \partial \log\sigma / \partial \log T|_{\dot{\varepsilon},T}$ and the velocity of the volume fraction of transformed martensite $\dot{f}(\varepsilon)$, [1]. The experimental analysis has also permitted to verify that at high strain rate, or in adiabatic conditions, the latent heat generation due to phase transformation is very reduced.

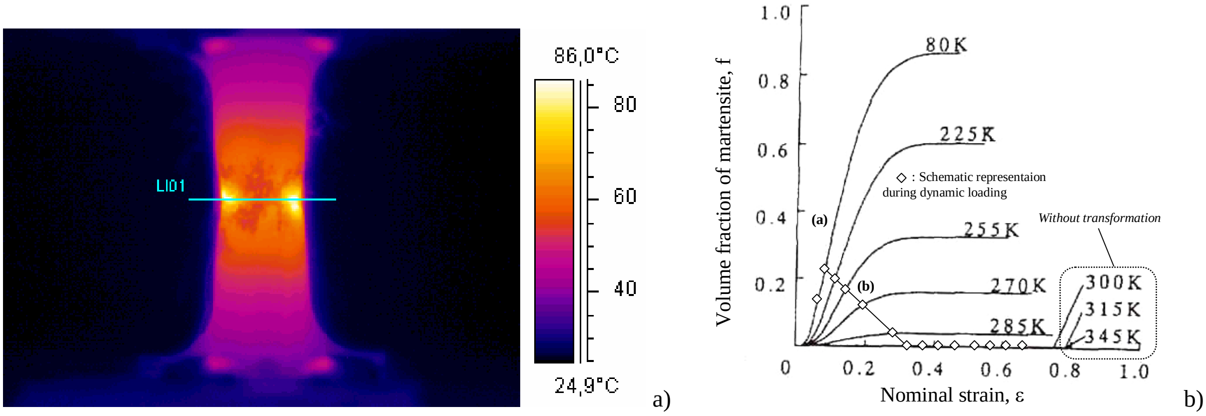

Fig.3. a – Temperature measurement during quasi-static tensile loading, $\dot{\varepsilon} = 10^{-2}\,s^{-1}$ and $t = 27.4\,s$, b - Kinetics of phase transformation versus strain for different initial temperatures [2]

The observation of the previous curves, Fig. 1-a and Fig. 3 a-b, allows to show that the temperature and the strain rate increase have a negative effect on the rate of phase transformation, $\dot{f} \to 0$. Analysis has been performed on temperature increase in TRIP 800 steel at different strain rates. At $\dot{\varepsilon} = 10\,s^{-1}$ the ΔT is equal to 150 K for maximum strain equal to $\varepsilon_{max} = 0.2$ in the necking zone. A more general comparison has been made between several kinds of sheet steels in [3].

CONCLUSIONS

Application of standard experimental techniques coupled with infrared thermograph a complementary information on the local temperature during transformation is obtained. The temperature is essential to define correctly the phase transformation during plastic deformation. The effect of temperature must be added to the viscous effect notably at low temperatures since temperature effect on the phase transformation is very reduce at high temperature. Thus, a description of thermoviscoplastic behavior for TRIP steel without these effects does not allow a correct description transformation kinetics. A constitutive description with a semi-physical approach as in [4] coupled with strain rate and temperature to define the phase transformation seem to be a good way in comparison to micro-macro approach where the strain rate and temperature sensitivity are rarely considered.

References

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