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DEFORMATION PROPERTIES OF TWIP SHEETS

Abstract:

*This paper deals with the extraordinary properties of new type of high-strength material – so called **TWIP** (**TW**inning **I**nduced **P**lasticity) sheets. Such material exhibits very specific properties mainly from the mechanical and forming point of view – very high yield and ultimate strength but on the other hand elongation up to 60%. In the experimental part this material was measured by means of contactless optical system **ARAMIS**. Results can help for better understanding of deformation behavior such kind of material.*

Keywords:

Twinning, Deformation, Hardening, Optical System

INTRODUCTION

Sheets producers are still under quite large pressure from automotive industry. Because there is requirement for safety of passengers on the one hand and on the other hand quite large requirement for light weight material. Everything is basically oriented on economical and ecological requirements. There are considerable reductions in weight, in fuel consumption and in the emission of exhaust gases. And that is why during last years were developed wide spectrum of materials suitable for automotive industry (Dee-drawing, IF, BH, DP, CP, TRIP steels etc). This paper gives a very short overview about one of the newest materials called TWIP steels (Twinning Induced Plasticity). Such type of steels is suitable for the development and design of the types of high strength lightweight steels. TWIP are high manganese steels where the phase transformation is suppressed and heavy twinning formation is sustained (TWIP effect) – due to high stacking fault energy. So basic of these steels is mechanical twinning formation instead of phase transformation. Mechanical properties of these steels and mentioned trends in automotive industry have led to great interest in these high strength and tough steels. On the other this kind of material is still in the development stage and it is really necessary to describe their behaviour at first. Comparison of different types of material from the static tensile test view is given in fig. 1.

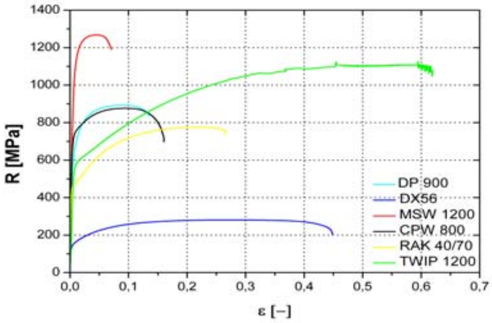

Fig. 1 Static tensile test – comparison of different materials.

TWIP SHEETS

TWIP steels (twinning induced plasticity) are group of materials where the increasing elongation with decreasing temperature is attributed to strain-induced twinning: the TWIP effect. These sheets belong to so-called high-strength steels and are still mainly in the development process. Such kind of materials contains austenite stabilising elements, e.g. Mn or Ni. The developed light weight high manganese steels exhibit an extremely large elongation in combination with quite large yield strength. It is due to reality that with increasing manganese content up to about 20 wt-% Mn the stacking fault energy will be decreased and extensive mechanical twinning occurs and these steels exhibit extraordinary high plasticity.

EXPERIMENTAL PART

First part of experiment was carried out on the static tensile test device and were measured basic mechanical properties ($R_{p0.2}$, R_m, A_{50mm}, C, n). First of all specimens from material marked like TWIP 1200 were cut by water jet. It is both due to their high strength and because of non-heat influenced area by water jet. The results are shown in the table 1 and table 2.

Tab. 1 Static tensile test – results of $R_{p0.2}$, R_m and A_{50mm}

Statistical evaluation	$R_{p0.2}$ [MPa]	R_m [MPa]	A_{50mm} [%]
1	567,21	1118,65	55,02
2	557,19	1125,77	56,42
3	556,45	1125,26	60,69
4	558,63	1131,77	57,25
5	554,47	1126,37	61,34
x	558,79	1125,56	58,14
s	4,94	4,67	2,75
min	554,47	1118,65	55,02
max	567,21	1131,77	61,34

Tab. 2 Static tensile test – results of C and n

Statistical evaluation	C [MPa]	n [-]
1	2331,272	0,425
2	2348,079	0,428
3	2388,208	0,431
4	2376,321	0,426
5	2388,048	0,432
x	2366,386	0,429
s	25,555	0,003
min	2331,272	0,425
max	2388,208	0,432

In September of 2008 was bought on the Department of Engineering Technology one of the optical measurement systems from German company GOM. In this case it was system ARAMIS – v6.1.1-2 which is device enables contactless measuring of deformation. It is much more different approach to material behavior description during deformation than is typical of static tensile test was material TWIP 1200 measured by means of this system.

System ARAMIS using for measuring material deformation scanning of given sample by means of two cameras. Before measuring the system has to be calibrate which enables to get relevant measuring of deformation in given calibration volume. Size of this calibration volume depends on used calibration plate. This plate contains calibration points of predefined coordinates which cameras scanned from different angles. During real measuring is so necessary to be still inside such calibration volume. In fig. 2 is shown workplace lay-out for measuring static tensile test by means of system ARAMIS.

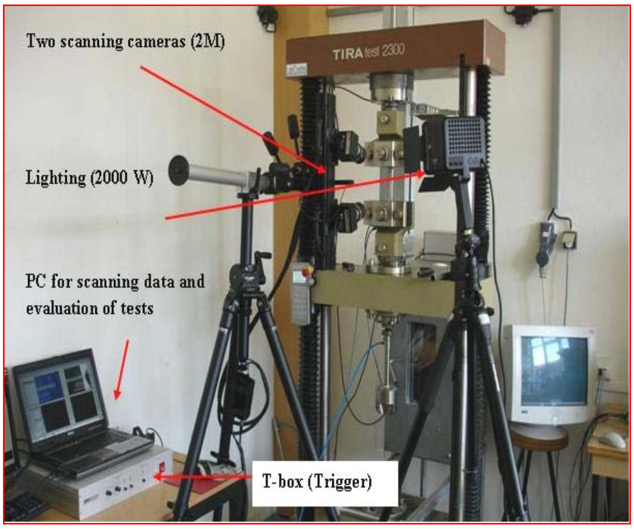

Fig. 2 Workplace lay-out.

In fig. 2 are shown two cameras for scanning measured sample, lighting device with load of 2000 W, T-box (Trigger) for controlling scanning rate and PC for evaluation of tests. On the measured sample is then necessary to apply stochastic pattern. System ARAMIS by the help of this pattern allocates to each point characteristic number (grey shade) and apply own mesh. Deformation measuring is carried out by scanning of these points displacements and deformation of mesh. Tested material TWIP 1200 with applied stochastic pattern is shown in fig. 3.

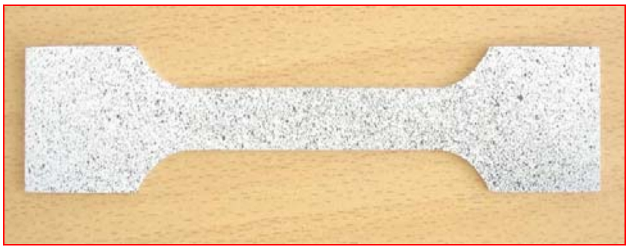

Fig. 3 Material TWIP 1200 with stochastic pattern.

After calibration and creation of stochastic pattern is activated system ARAMIS and measurement can start. The sample is fixture between jaws and parameters for whole experiment are set. It is namely about sensitivity of cameras (set of stop) and choosing the right frame rate. There is tendency to have maximal frame rate (in our case it is 6 frame/rate) at the end of rupture of measured sample.

In the fig. 4 is shown first stage (from left camera) and in fig. 5 calculated strain distribution for this stage. Both of them are without any deformation.

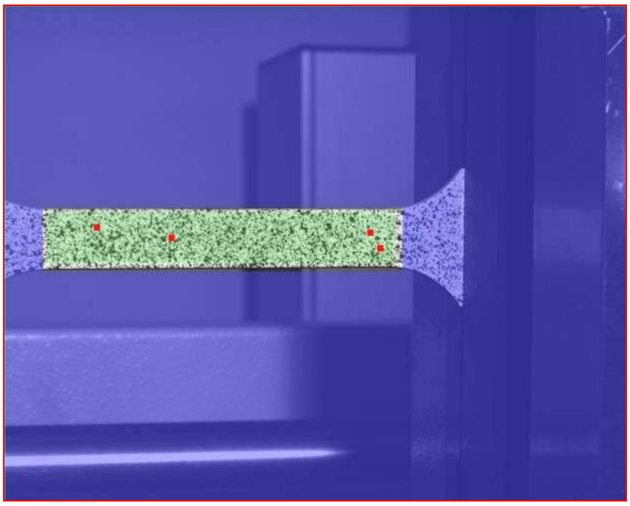

Fig. 4 First stage (left camera) .

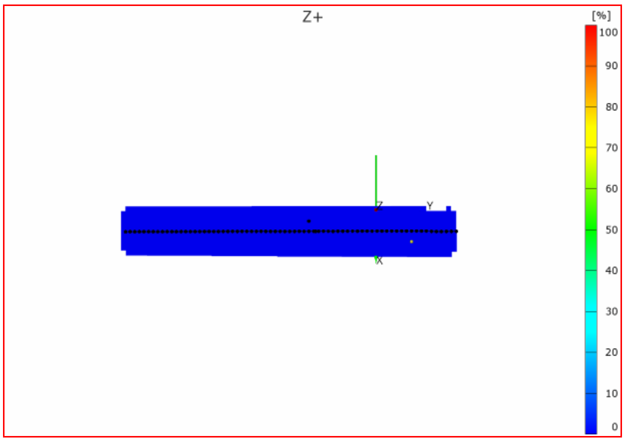

Fig. 5 First stage (left camera) – strain distribution.

Following figures shown development of strain during deformation. It is clear that about ε = 30% there is change of deformation behavior. Till this limit it was already homogenous then there is something like "wave" – whole volume is formed one wave after another until sample ruptures without creation neck. Almost every part of sample is formed so there is a lot of plasticity.

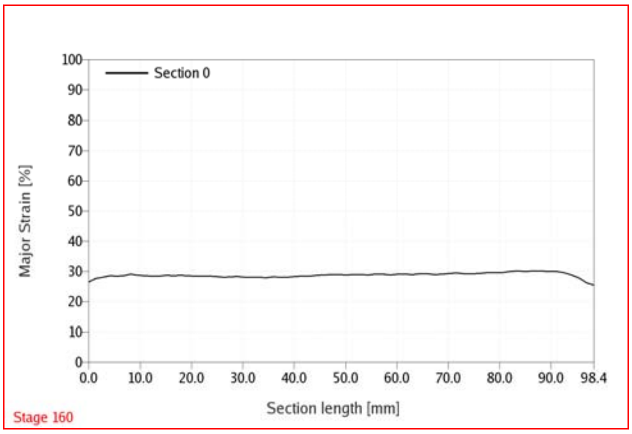

Fig. 6 Strain distribution for ε ≈ 30%.

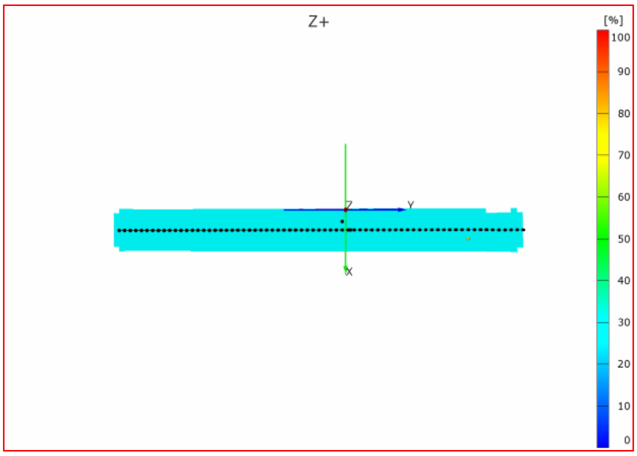

Fig. 7 Strain distribution (graphic) for ε ≈ 30%.

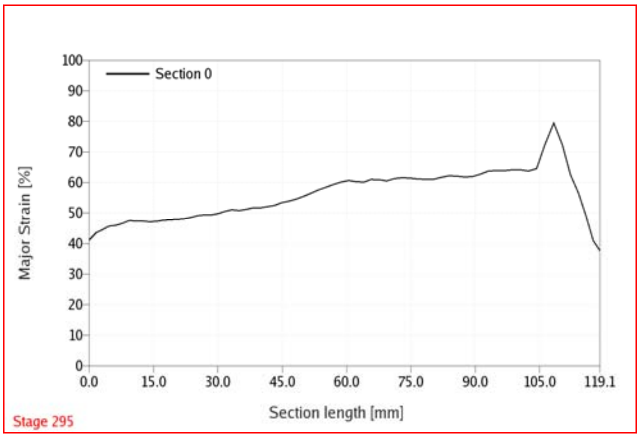

Fig. 8 Strain distribution just before rupture.

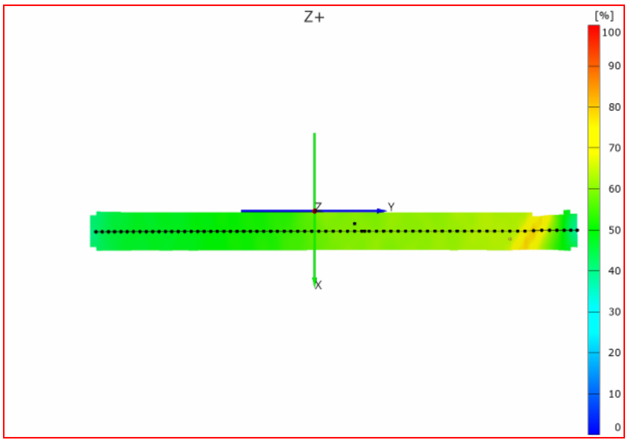

Fig. 9 Strain distribution (graphic) just before rupture.

Situation between fig. 6 and 8 is clear from fig. 10. Here are shown "waves" which increase deformation of whole volume of sample – almost no necking.

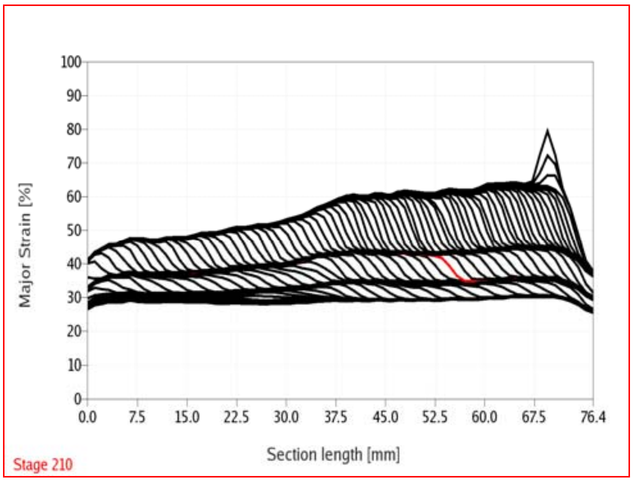

Fig. 10 Strain distribution between ε ≈ 30% and rupture

CONCLUSIONS

At first sight it is evident that TWIP steels represent a material group with extraordinary values which have led to a great interest in these steels. The excellent mechanical properties are due to massive twinning in the austenitic matrix during deformation. According to results of C and n coefficients is evident that these values are extraordinary high. There is still increase in coordinates R-ε which means that there is not almost at all necking part for testing samples. The main advantages of TWIP steels are evident from graphic results of tensile tests. There is a huge measure of the energy absorbed before and during the fracture process. The area under the tensile stress-strain curve provides an excellent value of toughness. There is deep-drawing material (e.g. DX56) with excellent elongation and on the other hand quite lower mechanical values (yield and ultimate strength). High-strength materials (e.g. MSW1200) have very good mechanical properties but are not too suitable for forming processes. The high ductility together with the high strength of these newly developed lightweight TWIP steels could improve the crash resistance of structural body parts. The excellent formability enables deep and stretch forming of parts with complex shape at room temperature. The reduced specific weight leads to an overall weight reduction of the car body. The potential applications of these steels are to be considered as deep drawing sheets, reinforcing bars and beams in automotive vehicles. On the other hand there are of course also disadvantages for processors of these materials. The main of them is probably tendency to fracture after deformation and welding.

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