Texture developed during deformation of Transformation Induced Plasticity (TRIP) steels

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Abstract. Automotive industry is currently focusing on using advanced high strength steels (AHSS) due to its high strength and formability for closure applications. Transformation Induced Plasticity (TRIP) steel is promising material for this application among other AHSS. The present work is focused on the microstructure development during deformation of TRIP steel sheets. To mimic complex strain path condition during forming of automotive body, Limit Dome Height (LDH) tests were conducted and samples were deformed in servo hydraulic press to find the different strain path. FEM Simulations were done to predict different strain path diagrams and compared with experimental results. There is a significant difference between experimental and simulation results as the existing material models are not applicable for TRIP steels. Micro texture studies were performed on the samples using EBSD and X-RD techniques. It was observed that austenite is transformed to martensite and texture developed during deformation had strong impact on limit strain and strain path.

1. Introduction

Advance high strength steels (AHSS) are often the material of choice for light weight structures as they combine various attractive properties such as formability, strength and weldability. It is predicted that the usage of AHSS will increase to 35% by 2015 whereas mild steel would decrease to 29% [1]. TRIP steels are first generation steels with low content in Mn. It has a microstructure consisting of ferrite and austenite. During plastic deformation the metastable retained austenite phase is transformed into martensite. This transformation helps in enhancing the strength and ductility of the steel. Mechanical and microstructure characterization were done for TRIP steel to study the forming behaviour [2-6]. However limited work is done on complete Strain path diagram (SPD). Due to texture development and phase transformation during deformation there is huge difference in experimental and simulation results. This is the motivation for the present work. The present work is focused on to study the complete SPD by experimental and simulated method. It is observed that there is a difference between experimental and simulated SPD as the existing material models are not applicable for TRIP steels and there is a strong impact on limit strain and strain path as during deformation austenite is transformed to martensite. A microstructure analysis was done to understand these behaviours.

2. Experimental procedure

The samples were cleaned with acetone and painted with black on one side. The samples were dried for few hours and white paint was sprinkled on it to produce a random speckle pattern. Lubrication system was applied on the other side of the sample to reduce friction. The samples were deformed in a hydraulic press with a hemispherical punch. The deformation process was captured with two high resolution high-speed cameras and post processing was done to calculate the surface strains using Digital Image Correlation. The simulation was done on PAMSTAMP 2G with the help of mechanical properties obtained from tensile tests. EBSD and X-RD techniques were used for micro structural characterization. Samples were cut near failure zone and followed by mechanical polishing, diamond polishing and finally with colloidal silica polishing. EBSD measurements were done on an area of 45 x45 micron with step size of 0.05 and confidence.
index of 0.1 is maintained for all the scans. Results obtained from EBSD measurements were used to calculate phase fraction and grain average misorientation (GAM) values. The orientation distribution function (ODF), maximum ODF, texture index and \( r \) value is computed with the help of MTM-FHM.

3. Results and discussion
Experimental and simulated SPD of TRIP steel was calculated and shown in Fig. 1. The experimental SPD was plotted by creating a point near the localized region. The simulated strain path was plotted by selecting points where the mesh elongation starts. Solid lines and dotted lines represent the experimental and simulation results respectively. Black solid curve and black dotted curve represents failure and green solid curve and green dotted curve represents localisation curves respectively. Simulation results are matching with the experimental data in drawing and plane strain region but not in stretching region. It is observed that strains are decreasing in stretching region. Microstructural studies are done for this peculiar behaviour. The difference in simulation results was due to the material models used in this study does not include microstructure evolutions.

![Fig.1: Experimental and simulated strain path diagram of TRIP steel](image)

The variation of maximum ODF and texture index at failure zone for TRIP steel are shown in Fig. 2. It is observed that ODF and texture index decreases from uniaxial drawing to plane strain followed by stretching region. This gives some indication about the effect of strain path on the development of texture in TRIP material. Figure 3 shows the variation of normal anisotropy ‘\( r \)’ value for deformed specimens of TRIP steel and compared with the undeformed sample. It is observed that \( r \) value decreases in deformed samples as compared to undeformed but the rate of decrease of \( r \) value is more in uniaxial drawing than that of biaxial stretching.
Micro-texture and phases of undeformed and deformed specimens of TRIP steel for extreme strain paths, such as uniaxial drawing, plane strain and biaxial stretching at high strains were studied. It is observed that austenite was decreasing in deformed samples and transforming to martensite. This transformation helps in improving the strength and ductility of steel. Effect of strain paths on development of GAM and phase transformation are shown in Fig. 4. In biaxial
stretching the development of GAM and rate of phase transformation is more compared to plane strain and uniaxial drawing.

Fig. 4: Phase transformation and development of GAM in deformed specimens of TRIP steels for different strain paths.

The phase transformation is mostly taking place in stretching region. So after finite element (FE) simulation it was observed that there is a large difference between experimental and simulated strain paths in stretching region. To reveal this observation a material model for TRIP steel based on the evolution of microstructure has to be developed.

4. Conclusion

The phase transformation and development of texture during deformation had strong impact on limit strain and strain path. The strain decreases in stretching region. In stretching region the development of GAM and rate of phase transformation is more compared to plane strain and uniaxial drawing. Maximum ODF value, texture index decreases in stretching region. Deviation of experimental and simulated strain paths were observed in stretching region as the existing material models are not applicable for TRIP steels.

References

[1] Emmanuel M et al 2010 J. Iron and Steel Technol. 7 1-13
[2] Zhao J et al 2012 J. Iron and Steel Research, Int. 19 57-62
[3] Tian Y and Zhuang L 2012 J. Iron and Steel Research, Int. 19 47-52
[4] Ding H et al 2011 J. Iron and Steel Research, Int. 18 36-40
[5] Koh-Ichi S et al 2006 J. Mat. Proc. Technol. 177 390–395
[6] Zhang M et al 2011 J. Iron and Steel Research, Int. 18 73-78