Structure and properties of high manganese MnSiAlNbTi25-1-3 steels with increased store of cold plastic deformation energy

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Abstract

Purpose: *The purpose of this study are the investigations of austenitic X8MnSiAlNbTi25-1-3 and X73MnSiAlNbTi25-1-3 steels containing approx. 25% of Mn, approx. 1% of Si, approx. of 3% Al and Nb and Ti microadditions, with a diverse concentration of, respectively, 0.08 and 0.73% C, in order to determine and describe structural mechanisms decisive for increasing the store of cold plastic deformation energy of such steels, which makes them suitable for use in the automotive industry for sheets and structural components of cars for, respectively, reinforcement and controlled deformation zones, behaving in a controlled and pre-programmed manner, during dynamic cold plastic deformation occurring, in particular, during cars accidents.*

Project/methodology/approach: *Experimental vacuum melts of two newly developed high manganese X8MnSiAlNbTi25-1-3 and X73MnSiAlNbTi25-1-3 steels were carried out, their thermomechanical treatment on a semi-industrial rolling line was designed and performed with three variants of cooling and simulations of thermomechanical treatment consisting of eight and four stages using a Gleeble metallurgical simulator. The influence of the given treatment variants on the structure of the investigated steels and on structural mechanisms decisive for their properties was analysed. Specialist research instrumentation was employed for this purpose such as scanning electron microscopy (SEM) (including EBSD examinations), conventional (TEM) and high-resolution transmission electron microscopy (HRTEM) together with diffraction tests, X-ray phase analysis, stereological and metallographic tests. The influence of the established variants of thermomechanical treatment with a semi-industrial hot rolling on the mechanical properties of the newly developed steels at room temperature and at elevated and lowered temperature in static and dynamic conditions was also examined.*

Achievements: *A thesis claimed in the work was proved by demonstrating that the synergic interaction of manganese and carbon with appropriately selected mutual proportions, which are directly conditioning the phase transitions taking place in plastic deformation, of aluminium and silicone additions influencing solution hardening, of niobium and titanium microadditions and hot plastic deformation conditions, together with a possibility of applying thermomechanical treatment, ensures the appropriate, high strength properties and significant elongation of MnSiAlNbTi25-1-3 steel with a diverse concentration of 0.08 and 0.73% of carbon by refining the austenite structure and by intensifying mechanical twinning in austenite*

representing the TWIP (Twinning Induced Plasticity) effect, and hence is increasing the store of cold plastic deformation energy of steel. It was found out that the primary cause of the higher store of cold plastic deformation energy of the tested steels in dynamic conditions is the activation of mechanical twinning in the intersecting systems which, in the case of the both tested steels, even with small deformation of 0.05 or 0.10, is causing the activation of twinning and presence of the intersecting slip bands and of deformation twins in the grains of austenite and annealing twins, which are densifying as deformation is increasing to 0.2-0.3 and until rupture, which confirms the basic mechanism of TWIP. The store of plasticity of, respectively, over 500 and to 300 MJ/m^3, can be ensured by employing thermomechanical treatment of the investigated steels consisting of hot plastic deformation and adjustable cooling as a result of dynamic and static cold plastic deformation, higher by 0,1-0,2 due to applying such treatment than in the case of this commonly used for this type of steel, completely separated from plastic treatment applied.

Research limitations/implications: *The monograph presents the results of structural investigations and the properties of newly developed experimental high manganese steels. It is expected that industrial melts and ready structural parts will be made in the next stages of the assignment.*

Practical implications: *By achieving the aim of this work, a basis is set for applying the newly developed high manganese steels in the automotive industry for sheets and structural components of cars for, respectively, reinforcement and controlled plastic deformation zones of cars, behaving in a controlled and pre-programmed manner, during dynamic cold plastic deformation occurring, in particular, in a car accident. The work also presents technological hints for the use of thermomechanical treatment of such steels in order to achieve the appropriately optimised set of properties for the given applications.*

Originality/value: *Assumptions have been verified positively of a concept of preventing fractures in structural parts and bodywork of a car during an accident or road collision by absorbing a large store of the then produced energy, used for inducing structural changes and phase transformations, occurring in the conditions of dynamic plastic deformation of critical parts of the car made of such steels as a relatively large store of plasticity gives a possibility to absorb energy and counteract the premature fracture of the car parts being damaged, due to intensive mechanical twinning in the intersecting systems, ensuring an increased store of energy, especially in the conditions of dynamic cold plastic steel deformation.*

Key words: *High manganese steels, Mechanical twinning; Store of plasticity, Thermomechanical treatment, Impact tension, Metallurgical simulator*

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