Surface modification TRIP \ TWIP steels

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Abstract. TRIP/TWIP steels have high tensile strength, plasticity, and much higher yield stress than other structural steels. Currently class of TRIP/TWIP steels with austenite-martensite structure is used in highly loaded parts, such as helicopter propeller torsion bars. TRIP steels are most in demand in the automotive industry. However, this steel has a problem with fatigue strength, because martensite of deformation (product of austenite-martensite transformation induced by plastic deformation) is stress concentrator. Surface modification will increase fatigue strength and ductility, as well as high corrosion resistance in aggressive environments. It is supposed to evaluate the effect of a particular chemical element or chemical compound in the interaction with steels with a high austenite content and make first steps towards to technology of Surface modification TRIP \ TWIP steels.

Introduction

Metal matrix composites and steels with modified surface replace traditional metal materials because every new day industries require higher performance properties for production details with high relative strength properties. Materials that contain in composite cannot perform on the same level separately as composition of these materials, because interface (border region between phases) plays a huge role in properties of product.

In comparison with metal alloys, metal matrix composites and steels with modified surface can offer [1]:

- Increased static, dynamic and cyclic strength properties;
- Form stability;
- Heat resistance and high temperature strength;
- Corrosion resistance.

For creation of new advanced composite material, we supposed to use TWIP (Transformation Induced Plasticity) or TWIP (Twinning-Induced Plasticity) steels as matrix. In comparison to maraging or alloyed high-strength steels, TRIP/TWIP steels have higher strength, plasticity, and much higher yield stress (figure 1). In addition, these steels have high deformability and ability to absorb energy during impacts and crushing.

Currently class of TRIP/TWIP steels with austenite-martensite structure are used in highly loaded parts, such as helicopter propeller torsion bars. TRIP steels are most in demand in the automotive industry: their usage allows to optimize (reduce) the weight of products, calculate loaded car parts taking into account changes in material properties during collisions (important for ensuring passenger safety). Steel with transformation induced plasticity (TRIP) possess high strength and high plasticity: when material is plastically deformed austenite transforms into deformation martensite, and strain hardening, that leads to increase of strenght of the products, occurs [3-6]. Targeted kinetic transformation...
regulation in process of deformation will make it possible to obtain the required set of physic-mechanical characteristics.

Figure 1. Comparative diagram of tensile strengths to elongation at break TRIP/TWIP and other steels [2].

In deformation process of TWIP steel dominant process is dislocation slip, but in the dynamic Hall-Petch effect, mechanical twins, the formation of stacking faults, also continuously form during deformation [7]. Since the formation of mechanical twins involves the creation of new orientations of crystals, twins gradually reduce the effective “mean free path” or effective slip distance of dislocations and increase the stress caused by dislocations leading to hardening [8]. The key to understanding the cause of formation of twins is to understand the effect of stacking fault energy (SFE): if SFE <20 mJ m$^{-2}$, deformation caused by the appearance of twins is more likely; if SFE 50> mJ m$^{-2}$, twinning is suppressed [8]. The manifestation of this or that effect is more dependent on the content of manganese Mn in the composition of the alloy and other alloying elements. Alloys with manganese content less than 15 wt. % are more prone to the TRIP effect, while with an increase manganese content in composition, appear the TWIP effect.

Such high properties provide steels with the TRIP / TWIP effect superiority over other metal materials common in automotive industry. Over the past decade, the percentage of these steels in the global automotive and aircraft industries has grown by 80%. However, high mechanical properties and impact characteristics of TRIP steels containing residual austenite depend on its diffusion-free transformation caused by deformation into high-carbon martensite. Formed deformation martensite will negatively affect fatigue properties of the material. The increased density of dislocations and a pronounced acicular structure have a strong effect on the rate of nucleation of microcracks. Also, due to the methods used for the production of these steels (large reduction ratios up to 80%), phase composition and, accordingly, physical and mechanical properties on the surface and in volume can vary. Surface micro- and macro-defects act as serious stress concentrators and especially negatively affect fatigue and corrosion properties, including wear resistance.

Traditional methods of heat and pressure treatment can significantly improve the set of mechanical characteristics. However, they leave a significantly defective surface with both micro- and macro-defects. By now, it has been theoretically established and experimentally confirmed that state of surface layers largely determines not only corrosion resistance of metallic materials, but also their mechanical (fatigue) properties. Due to the creation of thin (1-100 μm) modified layers on the surface of TRIP / TWIP steels, including usage of ion-vacuum technologies, it is possible to achieve an improvement in state (change in properties) of the surface and, as a result, simultaneously increase the fatigue strength.
characteristics. In this regard, the development of a composite based on these steels and metal coatings is especially relevant. This approach will ensure production of a material that, in comparison with the indicated steels, will have simultaneously increased strength and ductility, as well as high corrosion resistance in aggressive environments.

**Approaches to solving the problem**

One of main reasons for improving the characteristics of fatigue strength and ductility when modifying the surface of metallic materials is considered to be an increase in uniformity and a decrease in the localization of the processes of deformation and accumulation of defects in surface layers, as well as a slowdown process of nucleation surface microcracks (figure 2).

![Figure 2. Crack nucleation and growth caused by martensite deformation.](image)

An analysis of literature data cited in Russian sources on the effect of coating on the properties of TRIP / TWIP steels yielded not many results, since such steels themselves have not yet been sufficiently studied. So, in VIAM V.Ya. Belous dealt with the problem of preparing the surface of the VNS-9-Sh (Russian nomenclature) steel to create a composite material based on it [9], but this work had no further development. As part of a literature study, common works by Russian and German researchers was found (Joint Institute for Nuclear Research, Dubna; Institute for Metal Forming, Technical University of Freiberg Mining Academy, Freiberg, Germany) to study the mechanical properties of a composite material based on TRIP steel and ceramic from zirconium dioxide (Study of plastically deformed TRIP composites by neutron diffraction and small angle neutron scattering) [10, 11]. Other works related to such a composite material were also found in foreign sources [12-15], however, this composite is a material of a fundamentally different class, since in such a composite the content of ceramics can reach 50-70% of the total volume, which may complicate manufacturing technology and accordingly increase production costs.

It is supposed to evaluate the effect of a particular chemical element or chemical compound in the interaction with steels with a high austenite content. In particular, it is necessary to take into account not only the mechanical properties of the applied surfaces that meet the design requirements of composite materials, but also the thermodynamic interaction and phase equilibrium on interface.

First, using the finite element method, we should calculate the rate of crack nucleation and growth and analyze the effect of the applied coating using programs that simulate thermodynamic parameters.

We proposed to make on the surface of steel a layer with a thickness not more than 500 μm, the material selected at the stage of analysis that will increase the set of operational properties (fatigue life, ductility, corrosion resistance, etc.) at low additional cost in future mass production. The most promising materials for coating can be steels and alloys with higher plastic and anticorrosion properties compared to TRIP / TWIP steels, for example, austenitic stainless steels, aluminum alloys and alloys based on Ni, Cr and Co. Elimination of negative influence of surface defects of the base (matrix) material due to the applied protective and functional layer, leading to improved fatigue properties, can extend the service life of composite products. That will give a high economic effect due to the high cost of production of
TRIP \ TWIP steels, however, the influence of one or another element on the set of composite properties remains to be determined in future works.

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