HETEROGENNÍ KONTAKTNÍ VRSTVY PRO ZVÝŠENÍ DYNAMICKÉ ODOLNOSTI ŽELEZNIČNÍCH VÝHYBEK

HETEROGENEOUS CONTACT LAYERS FOR INCREASED DYNAMIC RESISTANCE OF THE RAILWAY CROSSING

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Summary:Presented work is dealing with the high loaded part of railway svitches or croosings, the prospective ways to increase the operational resistance are discussed. Typical degradation processes of currently widely applied austenitic cast steel are demonstrated by performed failure analyses. The strengthening effect based on the local heterogeneous layer in rail-wheel contact is introduced.

Key words: railway crossings, rolling-contact fatigue, gradient steels, wear resistance

INTRODUCTION

Contact area of rail surface undergoes to very specific loading conditions, rolling-contact fatigue combined with adhesive and abrasive wearing is predominant and it presents complex loading system, as a source of typical damage of contact surface. Operational behavior is driven by local deformation capability of steel, while local stres-strain conditions in different depth under surface has to be considered. The influence of stress gradient on surface rolling contact fatigue (RCF) has been investigated mainly in connection with influence of the particular traction coefficient on magnitude of interfacial shear stresses (1, 2). A residual plastic strain is an unavoidable effect of RCF and its magnitude is decisive for the energy consumption during loading, also for surface initiated crack propagation.

There are a number of different ideas considered (and also used technologies available) today for a heterogeneous material creation in surface layers. Applications of laser cladding, either to repair existing damage or during manufacturing, have been attempted to extend service lives and maintenance intervals, while conserving the properties of the parent rails. Previous studies (3, 4, 5) addressing the localized damage on railhead surfaces by the utilization of the laser surface treatments, particularly laser cladding technique, have

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demonstrated encouraging results and promising potential for alleviating the rate of component degradation. All of the mention approaches are based on bulk steel, or fusion process in case of surface cladding. Thermomechanical processes and corresponding strengthening processes are under evaluation in laboratory conditions for prospective usage for hypo and hyper eutectoid rail steels (6). Direct laser deposition methods and following isothermal treatment were investigated to improove the wear resistance of rail steels (7).

In this work, the specific degradation effects in rail-wheel contact for currently used high strength steels are interpreted using operational failure analyses. Concept of funcionally graded material, using the combination of standard pearlitic steel and novel bainitic steel is intepreted. The heterogeneous welding interphase after flash but welding was employed for preliminary evaluation of conceptual capability.

1. HIGH STRENGTR STEELS IN RAIL-WHEEL CONTACT

Upper part of the particular cross-section profile can be created by variety of steels. Hadfield’s steel has been widely used for railway switch and frogs because of its desirable mechanical behavior under high load applications. Austenitic Hadfield´s steel containing about 1.2 mass % of C and 12 mass % of Mn is known for a high resistance to impact wear caused by rapid cold work hardening. There are a few natural restrictions in this application, which create the typical operational problems. The first one is a difficult weldability with standard pearlitic steel. The wrought rails made from the pearlitic steel contain approximately 0.6 % of the carbon, so the physical properties of these two materials create the problem during the welding process. The carbide precipitation on austenitic grain in the heat-affected zone (HAZ) of the Hadfield´s steel decrease the mechanical parameters and simultaneously reduce the fracture behaviour, especially fracture toughness, strength or plasticity. It is well known fact that, the very fast cooling after welding process could decrease the carbide creating but on the other hand could have an effect for sufficient welding quality. Even some phosphide eutectic surrounded by thin shaped carbides can be created with the tendency to hot tearing in HAZ (Fig.1). Anyway, rapid cooling process of pearlitic steel creates the martensitic transformation near to the welding line. The high carbon level at martensite phase brings the deficiency of the plasticity, which is necessary for residual stress relaxation after cooling process. These two consequences could cause the cold cracking problem in the HAZ. If we used the preheating process with controlled cooling speed for pearlitic part of the weld joint, we can improve the steel weldability. Generally, the preheating process has unfavourable influence on cooling speed, which is important for austenited parts of welded joint. Nowadays, heterogeneous joints welding technology using low carbon austenitic steel as an interposed connector between wear resistant high manganese casting steel and carbon rail steel is patented in a several countries.

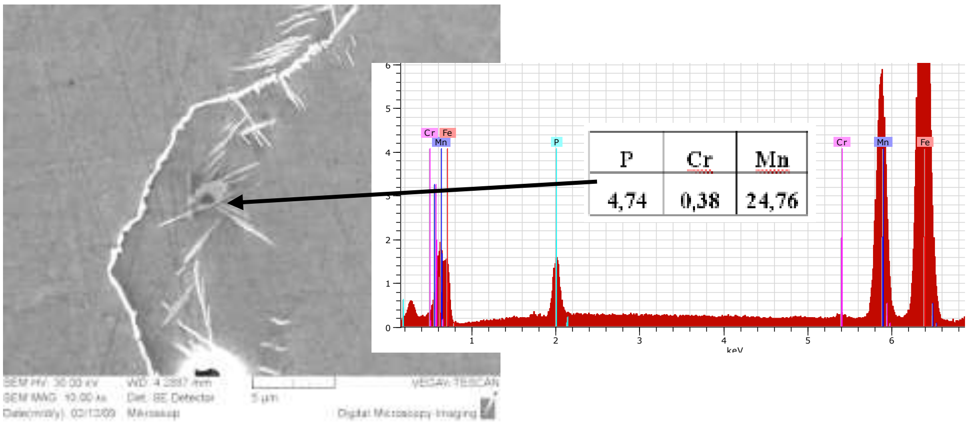

Fig.2- Fosfide eutectics and carbide formation along the grain boundaries

The second problem of Hadfield steel is diificult process to reach required casting quality. Because of high complexity of casted frogs and high thermal expansion coefficient it is very difficult to prepare the castings without any internal defect. Restriction of dislocation hardening and cracks initiation are the typical consequences during operational dynamic loading (Fig.2).

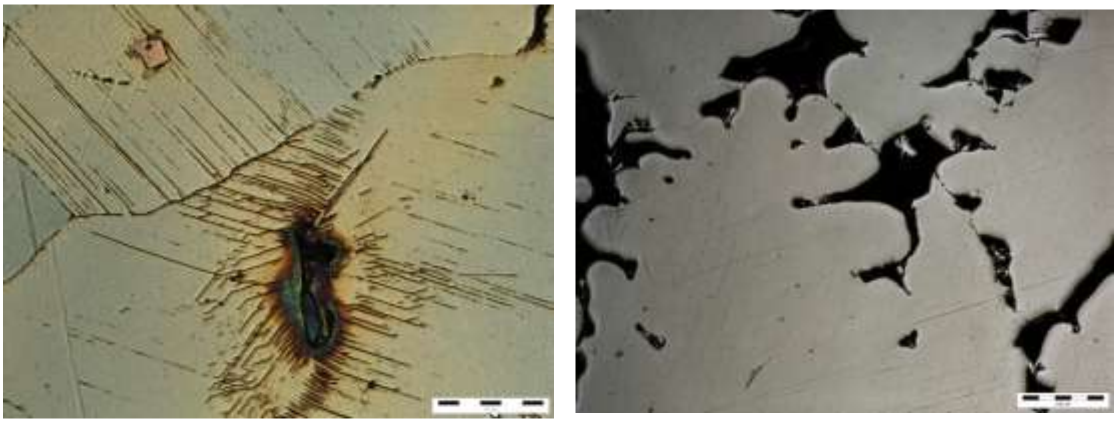

Fig.2 - Blocking of dislocation along the micro-shrinkages, leading to cracks initiation

The current research reveals the distinctive advantages of bainitic steels in sense of good strength / plasticity ratio, required in many applications. Diffusionless bainite transformation have been applied to develop steel with microstructure consisting of a mixture of bainitic ferrite, retained austenite, and/or some martensite (Fig.3a). Bainitic carbide free steels presents the prospective way to fulfil contradicting requirements for mechanical behaviour of materials in rail-wheel contact, especially for highly dynamic loaded parts of switches and crossings (S&C). The chemical composition of the carbide free bainitice steel, mainly the limited carbon content guarantees the enhanced thermal stability. Good weldability is based on the same principle. It means mainly the resistance to unacceptable phase transformation due to slip in rail-wheel contact, followed by intensive heating and fast cooling. The tendency to immediate brittle phase on contact surface, followed by spalling is suppressed as opposed to the standard pearlitic steels.

2. EFFECT OF HETEROGENEOUS SURFACE LAYERS

The superior contact-fatigue resistance of the carbide free bainitice steel is based on the high dislocation density together with the film of retained austenite between the bainitic lathes, that acts against the crack propagation. This steel with improved rolling contact resistance and increased wear resistance compared to standard pearlitic steel can be considered for the contact layer of the high loaded parts of S&C. Proposed concept presents the way how to meet the contradictory requirements for contact layers of S&C (high wear resistance, fatigue resistance together with high impact toughness) and to reverse the primary welding problems to the benefits. “Layered” material can be formed during the joining, while the surface will have refined microstructure. Interlayers at bainite/pearlite welding interface can present the softened zone (based on decarburization process) and thanks to that they can restrict the perpendicular propagation of the surface initiated cracks.

To find out the sensitivity to mentioned processes, the specific material for surface layer needs to be prepared in different stages of primary deformation state.

2.1 Principle of crack sensitivity restriction

The surface microcracks creation, caused by depletion of plasticity, is natural response to contact fatigue loading. In this sense, to increase the operational safety in rolling contact means to modify the natural micro-cracks propagation. To avoid the cross-sectional damage, the driving of the cracks propagation will be based on local deformation at a crack tip. Improvement of crack resistance can be achieved by the hardness scattering, i.e. by distribution of hard and soft phases in the microstructure. Thus, the concept is based on intentional structural heterogeneities creation creating the obstacles for critical crack propagation. The thinner residual layer, and the more intense plane strain stage suppression results in the higher energy consumption during destruction.

Besides the well-known advantages of this specific bainitic microstructure, two subsequent structural transformation of steel is estimated:

- processes due to additional heat and pressure while connecting the surface layer to the rest of crossing profiles,
- diffusionless transformation in surface layer during the dynamic loading.

Consequently, the final wear is decreased while fatigue resistance will be substantially enhanced against operational loading. Contrary to some additive technology, the primary deformation state of cladded surface can be preserved. Required ratio of the hardness and the other mechanical parameters between S&C and wheels should be controlled. Difusive interface is presented in Fig.3b.

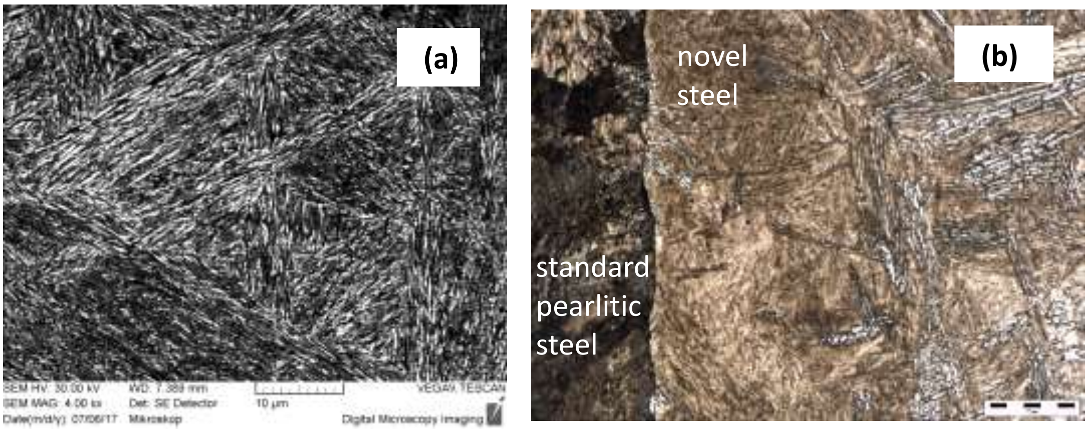

Fig.3 - Microstructure of bainitic steel (a), used for the surface layers of S&C (b).

Based on this concept the comprehensive analyses of the used steel will enable to find the prospective technology solution. To evaluate the response to different heat/pressure ratio, the adjusted flash butt welding technique will be employed to prepare experimental heterogeneous joints.

The first analyses of mechanical parameters has pointed the high sensitivity to deformation rate. Preliminary creation of the longitudinal micro-cracks was observed after more than 6 degree of forming - Fig.4. Structural analyses has shown a reliable suppression of carbide re-precipitation, using the forming in inter-critical (dual phase) zone. Colour etching was used to distinguish the tendency to martenzite phase during the mechanical loading.

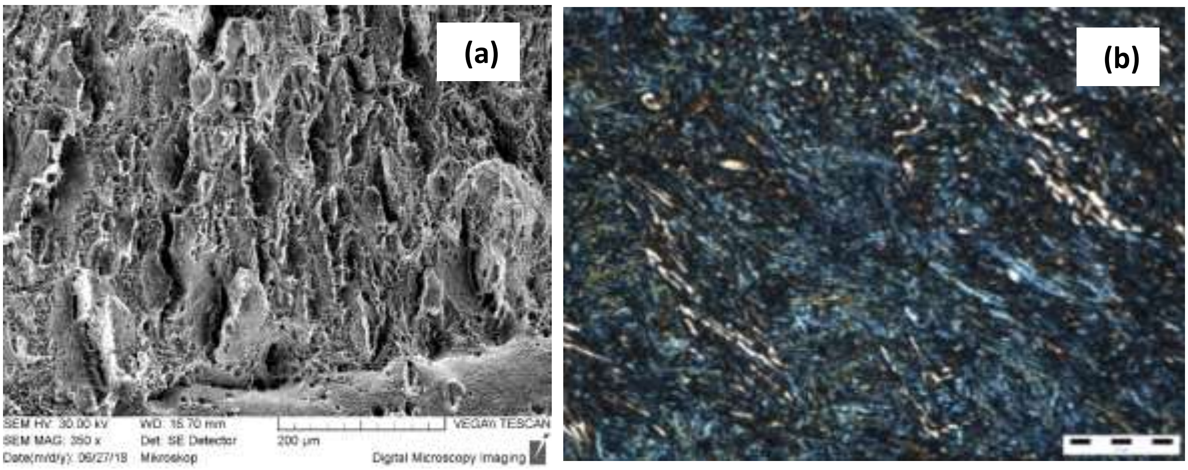

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Fig. 4 - Fracture mechanisms (a) and microstructure (b) after increased deformation rate

3. CONCLUSION

Concept of heterogeneous surface layers was considered as a way to improove the operational durability of the critical parts of S&C. Preliminary experiments were performed to evaluate the thermal sensitivity of novel bainitic steel using the standard flash-butt welding technology.

The structural stability of the used novel steel at defined stress-strain conditions were prooved. High sensitivity to increased strain-rate deformation is based on involved phase transformation processes of the residual austenite. Optimizing of the content and morphology of residual austenite are therefore an inevitable preconditions for this processes to lead to increased service life.

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