MS&IA
Modern Steels & Iron Alloys
INTERNATIONAL CONFERENCE · WARSAW 2023

28–30 June 2023
Warsaw, POLAND

CONTROL OF THERMAL STABILITY OF BAINITIC STRUCTURES USING TWO DIFFERENT CHEMICAL COMPOSITION DESIGN APPROACHES

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Key words: nanocrystalline bainite, retained austenite, microstructure characterization, tempering, thermal stability

1. Abstract

Considering the significance of thermal stability regarding the in-use properties of nanocrystalline bainitic steels, two novel steels have been developed using various strategies to improve the stability of bainitic ferrite and retained austenite. It was particularly designed that the targeted bainitic structure would be classified as nanocrystalline or ultrafine along with the both morphologies of retained austenite (film-like and blocky). Steel named BainTS was the first designed material, which is consistent with the standard concept to designing nanocrystalline bainitic steels with a negligible content of carbide precipitates [1], also named as carbide-free bainite. The designed carbon content (0.5 wt.%) enables to obtain high-strength mechanical properties. The high silicon content (2.0 wt.%) was applied to retained austenite stabilization by retarding the precipitate of carbon from the austenite. Moreover, higher contents of silicon in bainitic steels delays the decomposition mechanisms of retained austenite during prolonged isothermal holding, preserves the dislocation density after tempering processes, and refines the cementite and carbide precipitation inside bainitic ferrite during tempering processes[2]. Although manganese is an effective stabilizer of austenite, it was determined to reduce its content (0.5 wt.%) and increase the chromium content (1.5 wt.%) to ensure high hardenability and accelerate bainite transformation. Furthermore, vanadium (0.2 wt.%) has a favorable effect on the resistance to tempering processes, delaying the decomposition mechanisms. BainTS steel also contains molybdenum (0.5 wt.%) due to the beneficial effect on the thermal stability of retained austenite, and simultaneously in addition to increasing the refinement of the bainitic ferrite laths. On the other hand, a different strategy was applied for the second material, named as BainNiAlCu. In this steel, the retained austenite is stabilized without silicon - by nickel (8.0 wt.%) and manganese (0.5 wt.%). Additionally, the relatively high content of aluminum (2.8 wt.%) is fundamental in terms of possibilities to formation intermetallic phase ($\beta_{B2(Fe,\ Ni,\ Al)}$) during tempering processes, and thus enhancing the thermal stability[3].

The purpose of this work was a comparison of various strategies for improving thermal stability along with an explanation of the decomposition mechanisms considering bainitic ferrite and retained austenite. The results of these investigations may be of fundamental importance towards the development of optimized grades of bainitic steels also subjected to working at elevated temperatures, e.g. highly loaded diesel injections systems, hot and worm

working forging tools, load-bearing elements, welded parts, pressure containers, gears turbines and more [4].

2. Conclusions

- BainTS was developed to achieve thermally stable retained austenite. Moreover, secondary hardening was considered. BainNiAlCu was proposed to improve thermal stability of structure using intermetallics strengthening with nickel aluminide preciputations. Both tested steels, after isothermal heat treatment (at 280 °C), were characterized by a structure consisting of bainitic ferrite laths and retained austenite with blocky and filmy morphology BainTS steel was classified as nanocrystalline bainitic steel, while BainNiAlCu steel was in the sub-micrometer scale.
- Both steels were characterized by the highest hardness value after tempering at 550 °C. For BainTS the hardness was comparable to the isothermal heat treatment, while hardness of BainNiAlCu steel was higher by 30% (140 HV) in comparison to the isothermal heat treatment.
- Severe decomposition mechanisms of the retained austenite after the tempering process were observed, which was confirmed by the quantitative XRD analysis, the EBSD technique, and microstructure observations. Considering thermal stability of retained austenite, the BainTS steel provided higher thermal stability.
- Despite the general lower thermal stability of bainitic ferrite and retained austenite of BainNiAlCu steel, its significantly highest level of hardening after tempering processes was clearly noticed. This proves that intermetallics strengthening is a promising perspective towards enhancing the tempering resistance of nanocrystalline and ultra-fine bainitic steels.

Acknowledgments

This work was supported by the National Science Centre (Preludium Project, No. 2020/37/N/ST8/03324, title: „*The concept of high-strength, thermal stable nanostructured bainitic steel with increased weldability*"). Part of the investigations was carried out with the support of The Polish National Agency for Academic Exchange, The Bekker Programme, title: "*Modeling of the multi-phase structure of nanostructured bainitic steels focused on improving their technological properties*".

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