Chapter 7
Properties and Applications of Bainitic Railway Steel Prepared by Mechanical Alloying

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ABSTRACT

Researchers face a significant challenge in designing low-carbon bainite rail steel, which offers better mechanical properties and corrosion resistance than high-carbon pearlitic steel tracks. High-carbon bainitic steel takes a long time to manufacture, so low-carbon bainite steel is preferred for heavy-haul railway tracks due to its shorter production time and cost-effectiveness. The steel is prepared through a specific heat treatment process, and although carbide formation is limited at lower temperatures, precipitation hardening is used to improve its properties. Mechanical alloying with the elements like Si, Ni, and Co is also considered to enhance further the mechanical and chemical properties of the bainitic rail steel. This chapter aims to find an economical solution to reduce accidents caused by the failure of pearlitic steel and improve safety in rail transportation.

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1. INTRODUCTION

In modern times, the demand for lightweight and high-strength to low-weight ratio materials has increased significantly. Researchers are keen to develop mechanically alloyed bainitic rail steel for heavy haul railway tracks. Railway transportation is considered one of the most important modes worldwide (Zhang et al., 2019). At present, pearlitic steels with high carbon percentages are used widely as rail material (Caballero et al., 2009). In this modern era, high-carbon pearlitic rail steel has become a key component that significantly affects efficiency and, most importantly, railway transportation safety (Beynon & Perez-Unzueta, 1993; Gui et al., 2016; Satoh & Iwafuchi, 2005). In this scenario, the development of heavy-haul railways worldwide effectively increases traffic density and train speed (Hasan et al., 2021). Conventional pearlitic rail steel has faced more severe damage problems, such as rolling contact fatigue (RCF), wear, and catastrophic fracture (Gao et al., 2022). Pearlitic steel becomes brittle due to the presence of cementite (Fe_3C), which acts as a notch and tends to initiate cracks at low fracture toughness portions of the matrix. Meanwhile, bainitic steel, due to its non-lamellar structure of ferrite and carbide, reveals higher ductility and fracture toughness. Advanced bainitic steels consisting of a multiphase structure of bainitic ferrite can effectively retain both martensite and austenite, which shows a characteristic fatigue crack initiation behavior during high cycle fatigue/very high cycle fatigue (HCF/VHCF) regimes (Gao et al., 2022). For the fatigue crack initiation, inclusion and microstructure play vital roles. However, the non-inclusion-induced fatigue crack initiation is a chief failure mode for the advanced carbide-free bainitic (C.F.B.) steels. This article deals with an insight into the properties and applications of bainitic railway steel prepared by mechanical alloying.

2. RATIONALE

The failure of currently used pearlitic rail steels can significantly threaten the safety measures of train operations and is followed by an increase in railway maintenance costs. Researchers have found that bainitic steels have the exciting potential to become at the forefront of the development of the steel industry (Garcia-Mateo & Caballero, 2007; Takahashi & Bhadeshia, 1991). Moreover, compared to traditional pearlitic rail steels with high carbon percentages, low-alloyed bainitic rail steels effectively showed a much better combination of toughness, wear resistance, and strength (Adamczyk-Cieślak et al., 2021; Pereloma & Edmonds, 2012; Tasak et al., 2014). Therefore, a significant need has occurred to fill the gap or mitigate the above-discussed problem. Thus, developing a new generation of rail materials, such as low alloyed bainitic steel with high performance, is very much required.

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