中锰 TRIP 钢的疲劳行为研究

张健，周静，谢季佳*，武晓雷
（中国科学院力学研究所，非线性力学国家重点实验室，北京 100190）

摘要：相变诱导塑性 (TRIP) 钢由于应变诱导奥氏体向马氏体转变，强化了材料并抑制了颈缩，从而使材料具有高的强度和均匀延伸率。这一性能特点，使 TRIP 钢成为汽车用钢的重要选项。对这类材料的疲劳行为进行研究，具有重要的工程与理论意义。

选择热轧的 0.1C5Mn 的 TRIP 钢板为实验材料，通过奥氏体逆相变处理获得了不同奥氏体含量的两相组织。通过光学显微镜、扫描电镜与电子背散射衍射 (EBSD) 分析技术、X 射线衍射 (XRD)、准静态拉伸试验与显微硬度试验对两种样品进行了显微组织与力学性能的表征。然后开展了疲劳试验，测试得到了疲劳应力-寿命 (S-N) 曲线。进一步的选择疲劳极限附近的最大应力，进行了疲劳中途停机实验，从表面形貌、显微组织、相组成与硬度变化等方面，对疲劳损伤机理进行了研究。

通过实验与结果分析，获得如下主要结论：

1. 0.1C5Mn TRIP 钢的微观结构具有团簇特征，团簇内部为片层状，团簇尺寸为 10 到 20 μm。团簇以片层状铁素体相为基体，奥氏体片层在铁素体片层中析出，铁素体基体与逆转变奥氏体之间存在确定的相位关系。

2. 0.1C5Mn TRIP 钢的疲劳损伤累积首先将在奥氏体颗粒中产生，随着疲劳周次增加奥氏体逐渐转变成马氏体。且由于奥氏体片分布在铁素体片层中间，因此导致样品表面出现成束的变形条带。最终损伤沿这些变形条带发展而形成疲劳裂纹。

关键词：中锰钢；相变诱导塑性；裂纹起源；疲劳机理；微结构表征

The high cycle fatigue of a medium-Mn TRIP steel

Zhang Jiang, Zhou Jing, Xie Jijia, Wu Xiaolei
(State *Key Laboratory of Nonlinear Mechanics, Institute of Mechanics*
Chinese Academy of Sciences, Beijing 100190, *China*)

Abstract: For the transformation induced plasticity (TRIP) steel, the austenite transforms to martensite with the increase of the strain, which will strengthen the material and restrain the necking in tensile testing. For the high strength and plasticity, TRIP steel become one of the most used steel in the application of automotive. The investigation on the fatigue mechanism of the TRIP steel is important not only in engineering but also with theoretical value.

At first, the hot rolling steel plate of 0.1C5Mn TRIP steel was chosen to be the material. Specimens with different austenite volume fraction were produced by austenite revert transformation (ART) annealing treatment. Then, the micro structures and the mechanical properties were characterized by using optical microscopy, scanning electron microscopy and back scatter electron diffraction (EBSD) analysis, X ray diffraction (XRD), tensile testing and hardness testing. The fatigue testing was carried on to measure the S-N curves. In order to discover the micro mechanism of the fatigue damage in TRIP steel, some specimens were taken down from the test machine after different loading cycles. Then, the evolution of the surface roughness, micro hardness, austenite volume fraction was inspected by using XRD, EBSD and Nano-indenter.

The experimental results indicate:

1. After ART annealing treatment, the micro structure of specimens is clusters with lamellar structure. The size of the cluster is about 10 to 20 μm. The phase maps of the EBSD analysis indicate that the matrix of the cluster is the lamellar ferrite, and the lamellar austenite slice is inside the ferrite lamellar.

2. The fatigue damage appear from austenite grains. With the increase of the loading cycles, the austenite transforms to martensite and induced deformation bands on the sample surface. Finally, damage developed alone these bands to be cracks.

Key words: Medium-manganese steel; Transformation induced plasticity; crack initiation; fatigue mechanism; micro-structure characterization