学 位 論 文 要 旨
(Summary of the Doctoral Dissertation)

学位論文題目 (Dissertation Title)	Dynamic effect of a high-speed train on superstructure of railway system; reliability and fracture characteristics of continuous welded rails (鉄道システムの上部構造に対する高速列車の動的効果; 連続溶接レールの信頼性と破壊特性)
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Dense population and needs for mobility of the people require optimization in transport mechanisms for an efficient transport. Therefore, railway systems become an important alternative according to this demand. Criteria such as capacity, speed and environment, where railway systems have advantages than any other transport mechanisms make the railway construction as a priority area. Increase in capacity resulted with increase in repetition of cyclic loads and phenomena of fatigue damage and failure that occur faster and frequent. Fatigue in railway systems occurs not only in railway vehicles but also in other components of the system such as railway rails, and thus, fatigue damage and failure are treated as the most serious problem in the superstructure and rails.

This thesis covers the actual loading mechanisms in high speed train lines and its effect on continuous welded rails. Rail materials are one of the most important components of railway systems as it works under harsh environmental conditions. Railroad track is a very complex system that many interactions and potential locations where a crack may occur should be considered to prevent any system failure and accident. Under operational conditions, repeated wheel loads may cause fatigue failures to the railway rails. Especially, due to repeated loading between wheel and rail, rails and rail joints are prone to fatigue failures. Fatigue failure of metallic materials occurs in three phases including crack initiation, crack propagation and final fracture stages. Crack initiation and fracture mechanisms under different boundary conditions should be evaluated in detail to design safe and reliable railway systems. Also crack propagation and detection of discontinuities in the structure should be evaluated by using non-destructive techniques (i.e. magnetic particle inspection, ultrasonic inspection etc.) where visual inspection is not accurate enough to evaluate propagation of defects under operational conditions. For surface and near-surface defects magnetic particle inspection and eddy current inspection are the applicable methods. For detection

of internal defects ultrasonic inspection can be applied by using contact and non-contact techniques.

It is known that the deflection of a bolted joint in track system leads high dynamic impact which is a source of rapid track deterioration and high noise levels. Thus, on high speed train lines CWRs are constructed which eliminates the impact force via discontinuity. CWR systems, eliminates large number of rail joints, decreases noise and vibration that leads longer service life with lower maintenance costs for both track and rolling stock, provides steady train operations with less environmental impact. However, along the whole railway system, these welded regions are still the weakest points which have big possibility to fail under operational conditions. Some researchers also emphasized that the rail welds used both for continuous weld and repair weld may act as weak points in the track system from a mechanical point of view. In CWR system failure may initiate at various positions such as at the upper head to web, or lower web to foot or at foot regions. Thus, mechanical properties, crack initiation, fatigue, and strength reliability analysis of continuous welded rails (CWRs) on high speed train lines are quite important research tasks that should be solved immediately. Against such background, experimental and theoretical investigations were conducted as explained in the following chapters.

It is important to understand failure and fracture mechanisms on welded joints of rails for reliable and sustainable operations especially for high speed train lines. For better understanding the dynamic loads on welded joints it is necessary to determine actual loading when trains are under operation. Thus, in Chapter 2 actual loading parameters evaluated in detail when the rolling stock operates for speeds over 200 km/h. Field data collected on a ballasted track of a high speed line to evaluate the dynamic loading conditions of a rolling stock. Both rosette gauge and load cell applications used for evaluation of wheel/rail interaction. According to the results the static and dynamic loading conditions compared in detail for actual operations for speeds over 200 km/h. In Chapter 3, experimental study is conducted on the fatigue characteristics, tensile properties, and micrographs of CWRs to evaluate the system reliability in detail. The welded joints are subjected to static and dynamic loads under various boundary conditions. S-N (Stress-life) diagram established, and fracture surfaces of the failed specimens investigated to specify the crack initiation points. According to microstructural examination many spherical cementite are observed especially in the web section of the joint which affects the fatigue life. In Chapter 4, fracture surfaces of the failed specimens after tensile and fatigue tests are evaluated by using field emission scanning electron microscope for rail sections centring the

weld collar. In rail foot, majority of the fatigue failure stems from stress concentration due to shear slip deformation. In rail head, both slip deformation and C-rich inclusions were observed in the specimen surface. In the web section, lower fatigue lives were observed at the specified loading conditions. The premature fatigue crack occurs in rail web according to the stress concentration caused by C-rich inclusions near the specimen surface around the welding line. It is concluded that the difference between the fatigue lives is attributed to the difference between crack occurrence mechanisms.

The obtained results in this study are important guide for maintenance management, reliable and sustainable operation of railway systems especially for higher speeds and higher axle loads.