Deterioration Analysis of a Diesel Shunting Locomotive for Safety Assessment

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Abstract

The deterioration of a shunting locomotive was characterized for the safety evaluation. The locomotive has been used for shunting works in steel industry, and in this paper, several engineering characterization techniques for the deterioration evaluation of a shunting locomotive were introduced, and the analysis results have been presented. Unlike other rolling stocks in railway applications, the diesel shunting locomotive is composed of major components such as diesel engine, transmission, gear box, brake system, etc., which cover more than 70 percent of the total price of the locomotive. Therefore, in this investigation, each part of major components in the diesel locomotive was analyzed in terms of the degree of deterioration. The performance evaluation tests were performed on the diesel engine and gear box, and precision inspection was conducted on each part of transmission to provide the current wear information. Also, corrosion test and nondestructive evaluation techniques were employed to demonstrate the wear status of coachwork and bogie parts in locomotive. Through the current investigation, the following results have been obtained: the need of change in the exterior of car body due to corrosion, deterioration of the diesel engine performance, tooth surface damage of the gear, corrosion phenomenon and leak problems on the cylinders of the braking system, low insulation resistance voltage values in some signal wires, etc. Furthermore, from the precision assessment results of each component, the remaining lifetime evaluation of the locomotive was required for the decision on the repair for extended use or the replacement with new locomotive since the serious safety concerns might be considered when continuous operation is conducted without any treatments for above mentioned deteriorated parts.

Introduction and the Locomotive

The shunting locomotive is working at a relatively low speed under 20 km per hour mainly for traction power, and operating for shunting work around manufacturing or service area. The shunting locomotive is composed of mainly car body and bogies, and other essential components such as a diesel engine, power transmission devices including transmission, reduction gears, etc., braking systems, electrical components, etc. [1].

In this research, the shunting locomotive has been used for shunting works in steel making industry for 13 years, but due to continuous work by 24 hours a day and 7 days a week, the deterioration of car body and major components occurred although pertinent maintenance has been conducted. In this investigation, various types of technical evaluation methods for the locomotive parts were employed to assess the current deterioration status and to provide important clue for lifetime prediction. Unlike other rolling stocks in railway applications, the diesel shunting locomotive is composed of major components such as diesel engine, transmission, gear box, brake system, etc., which cover more than 70 percent of the total price of the locomotive. Therefore, each part of major components in the diesel locomotive needs to be analyzed in terms of the degree of deterioration in order to provide the current wear information [1-4].

The dimension of current shunting locomotive was 14 × 2.8 × 4.2 m, the running speed was less than 20 km per hour, the main usage of the locomotive was for shunting work at inside line of the factory, the traction power of 1,200 to 1,320 ton, the operation condition was 24 hours a day, and the fuel type was diesel. The major components of the shunting locomotive include a diesel engine, transmission, gear box, electrical and braking system, etc.

Therefore, the main objectives of current research are to introduce various types of engineering analysis tools and/or techniques for deterioration characterization of shunting locomotive, to investigate the
techniques on precise diagnosis of shunting locomotive, to provide safety performance information of major parts in the locomotive, and to provide the critical technical information on current deterioration status for replacement or purchasing decision.

**Experimental Procedures and Results**

The deterioration of a shunting locomotive was characterized for the safety evaluation. In this investigation, several engineering characterization techniques for the deterioration evaluation of a shunting locomotive were introduced, and the analysis results have been presented.

In order to investigate the degree of deterioration in the shunting locomotive, each part of major components in the diesel locomotive was needed to analyze in terms of deterioration. The performance evaluation tests were performed on the diesel engine and gear box, and precision inspection was conducted on each part of transmission to provide the current wear information. Also, corrosion test and nondestructive evaluation techniques were employed to demonstrate the wear status of coachwork and bogie parts in locomotive.

**Fig. 1.** Classification on deterioration evaluation of the shunting locomotive.
Figure 1 presents classification on deterioration evaluation of the shunting locomotive. The evaluation was performed on each separate part of the locomotive, and finally, the running performance evaluation was carried out to assess the current performance of locomotive as compared with a brand new locomotive.

The each area of evaluation includes carbody, bogies, diesel engine, transmission and gear box, electrical system, and brake system. In each evaluation, detailed evaluation was achieved to verify the current wear status or performance of the part.

In addition to main parts evaluation, corrosion test and nondestructive evaluation (NDE) techniques were employed to demonstrate the wear status of the carbody and bogie parts in the locomotive. Since the locomotive has been working under corrosive environment, the corrosion tests with x-ray analysis for exterior part of the locomotive were conducted to examine the evolution of corrosion reaction, and NDE techniques such as ultrasonic testing, magnetic particle testing, and γ-ray radiography, were conducted on the carbody and bogies to inspect any possible inherent and/or in-service flaws. However, no eminent surface and subsurface defects have been observed at carbody and bogies [5-6].

Besides carbody and bogies investigation, several performance tests were performed on diesel engine, transmission, braking system and electrical system. In order to examine the current performance of diesel engine, exterior visual inspection, dimension measurements of each component, and finally, performance testing were conducted and the results were compared with new diesel engine. For transmission exterior visual inspection and break down inspection were carried out, and the exterior visual inspection and loading testing were performed for gear box. To check out the electrical system, insulation resistance measurement was introduced. For braking system, degradation tests leak testing, and braking performance testing were carried out for the current performance evaluation.

After the partial inspection and analysis for each component, overall performance results were summarized to assess the lifetime concerns based on the partial performance and inspection results of each component in the locomotive. Furthermore, vehicle performance tests were performed under the locomotive manufacture guidelines to explain the current driving condition. The life-cycle-cost (LCC) analysis was performed based on the maintenance and repair history as compared with economical cost to provide the cost-effective prediction, i.e., to assess either repair for reuse or putting the locomotive out of service based on cost-effective calculation.

**Summary**

In order to assess the deterioration of the locomotive, after the precision assessment for carbody and bogies, the current operation status and deterioration evaluation was performed on the major components of the locomotive, i.e., the diesel engine, transmission parts, electronic devices, and brake system, and the following results have been obtained; the need of change in the exterior of carbody due to corrosion, deterioration of the diesel engine performance, tooth surface damage of the reduction gear, corrosion phenomenon and leak problems on the cylinders of the braking system, low insulation resistance voltage values in some signal wires, etc.

From the precision assessment results of each component, the remaining lifetime evaluation of the locomotive was required for the decision on the repair for extended use or the replacement with new locomotive since the serious safety concerns might be considered when continuous operation is conducted without any treatments for above mentioned deteriorated parts. For the prediction of remained lifetime on the deteriorated locomotive, in the safety viewpoint, the safety concerns of the structural parts such as carbody and bogies should be considered, and in the economical viewpoint, maintenance cost for the locomotive needs to be considered.

Through the review of examples from foreign countries, it was summarized that, the cost-effective way was to invest one thirds of the total cost of the locomotive for the one thirds extension of the total lifetime. Currently in Japan, the single lifetime rolling stock (SLRS) concept was introduced, which is based on the life and cycle of the rolling stock, and the SLRS will be used for 13 years without any major maintenance
schedules [4]. After 13 years, the SLRS will be assessed for the further use depends on the performance conditions. In this case, the life-cost-cycle (LCC) evaluation is required from the introduction point since no maintenance information will be available. In the cases from the U.K. and the U.S.A., the consideration of the current status of the locomotive such as cost and performance conditions, is an important factor for the determination on disuse, replacement, or refurbishment.

In this investigation, through the LCC evaluation, it was suggested that the purchase of new locomotive should be more cost-effective way for the further use of 15 more years as compared with the reuse of the locomotive with pertinent repair treatments.

Based on the reviews on the replacement of deteriorated major parts for the locomotive, it was suggested that the reuse of the locomotive with replacement of deteriorated components was not a cost-effective way since the more than 70 % maintenance cost of the total locomotive price will be required after 15 years use.

In conclusion, in order to determine the endurance lifetime of the locomotive, several parameters should be considered, i.e., the LCC evaluation needs to be considered from the introduction of the locomotive; the locomotive maker should provide all information on major components with reliable technical and cost information for user; the user should establish the pertinent maintenance system and conduct proper maintenance work. The fatal safety accidents could be prevented during operation when the user establishes a good maintenance system, and the operation and management efficiency could also be improved through better maintenance and reliability conditions.

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References