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A Study on Optimal Preventive Maintenance Overhaul of Running Gear for High Speed Rolling Stock

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Abstract. Although running gear, which consists of 4 devices (i.e. TM, MRU, ARU and wheel), is a mechanically integrated structure, its preventive maintenance overhaul (PMO) requires different intervals according to conventional maintenance directives. To avoid an unnecessary amount of PMO, this study used a genetic algorithm (GA) to find an optimal PMO from the viewpoint of reliability-center maintenance (RCM) with a view towards a cost-effective solution. The optimal PMO derived from the genetic algorithm is 2.85 million km, which is a reduction of about 22% compared to the conventional method.

Keywords: general inspection, limited inspection, overhaul, reliability, running gear, systematic works on trainset

1. Introduction

It is important to modify the preventive maintenance (PM) schedules of imported components for rolling stock due to our different environment (climate, daylight time, altitude) and operating conditions (distance between stations, track). It is important to evaluate an optimal PM schedule by considering economic feasibility and RMAS (reliability, availability, Maintenance and safety) of each component.

Running gear, which is a major subsystem of Korean high speed rolling stock (KHRS), is a mechanically integrated assembly consisting of traction motor (TM), motor reduction unit (MRU), axle reduction unit (ARU) and wheel. These 4 devices are detached and attached for maintenance simultaneously every time according to the PMO schedule. The differences in PMO intervals of the TM (2.5 million km), the MRU (1.8 million km), the ARU (1.8 million km) and the wheel (0.9 ~ 1.2million km) give rise to unnecessary maintenance work and reduced availability. Therefore, to reduce the unnecessary number of PMOs, it is important to evaluate the optimal PMO from the viewpoint of RCM with a view towards a cost-effective solution. Although previous studies have proposed a PM methodology for railway vehicles from the viewpoint of RCM, the studies have remained at the conceptual stage of introducing RCM into railway vehicle maintenance. Thus, in order both to satisfy operational safety and to reduce the amount of running gear maintenance, it is

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necessary to evaluate the optimal PMO schedule of the 4 devices of the subsystem. This study aims to evaluate their optimal PMO with the least maintenance cost by examining criticality and reliability based on the maintenance schedule of each device for running gear and removing an unnecessary PMO.

2. Results and Discussion

2.1 Maintenance Cost Considering Reliability Improvement and Criticality

In order to obtain an optimal PMO of the 4 devices of the running gear, this study sets out to evaluate total maintenance cost, as shown in Fig. 1. The cost takes into account a risk priority number (*RPN*) and a reliability improvement factor (y_i) [1] following general PM, as well as its own reliability and a failure rate for each component. The following three conditions were hypothesized. Firstly, it is supposed that a minimal repair of each component cannot affect the reliability of the device; there is no change of reliability in the aging process of components before and after minimal repair [1]. Secondly, the PMO (Level II) is presumed to improve reliability to '1', which is the original status of the product as shown in Fig 1. Lastly, 'Level I or general PM (SWT, LI, GI, and FGI)', improves reliability during the aging process. Meanwhile, the Risk Priority Number (*RPN*) was introduced to take into account the contribution of the failure rate of each component to the results on failure mode effects and criticality analysis. As shown in the right-hand diagram, the cost optimization of the PM is derived from the 'genetic algorithm' [2] considering simultaneously target reliability (RM_t) and improvement factor. In this algorithm, an individual which is a single part is comprised of the same number of chromosomes, and a genotype that performs each stage is expressed as a whole number, '0, 1, 2'. The cost optimization is derived from the fitness function of the individual in generation.

2.2 Optimal PMO Evaluation using Genetic Algorithm

Fig. 2(a) and (b) shows changes of reliability for 4 devices under to the PM schedule that was simulated through genetic algorithm. The running distance where the four PMOs meet for the first time is 2.85 million km, and this is the optimal PMO interval found in this study. According to this result, the accumulated total maintenance cost depending on running distance is as shown in Fig. 2(c). As seen in this diagram, the genetic algorithm yields a cost reduction of 22% compared to the conventional method.

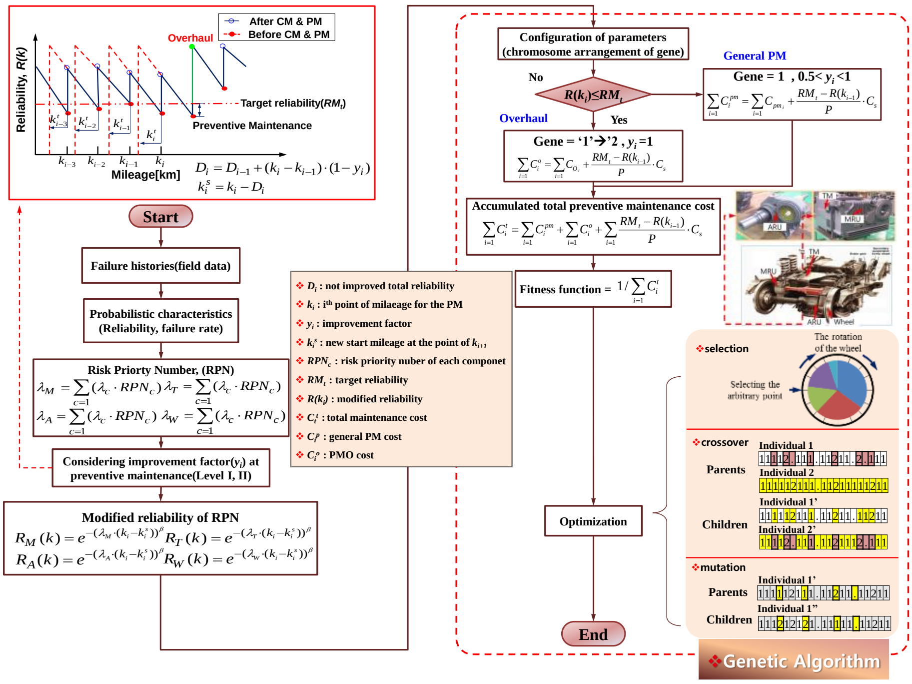
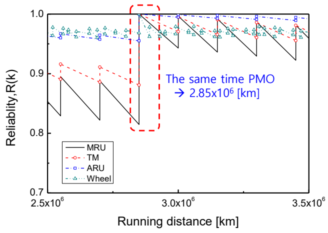


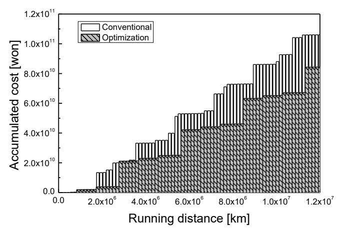
Fig. 1 Flow diagram of evaluation of PM cost



(a) optimal PMO

	Conventional method (10⁴km)				Optimization method (10⁴km)			
	MRU	TM	Wheel	ARU	MRU	TM	Wheel	ARU
1st			120				90	
2nd	180			180			180	
3rd		250			285	285	285	285
4th	360		360	360			375	
5th			480				465	
6th		500			570	570	570	570
7th	540			540			660	
8th			600				750	
9th	720		720	720	855	855	855	855
10th		750					945	
11th			840				1035	
12th	900			900	1140	1140	1140	1140
13th			960					
14th		1000						
15th	1080		1080	1080				
16th			1200					
17th		1250						
18th	1260			1260				
Sub total	7	5	9	7	4	4	12	4
Total	18th				12th			

(b) comparison of two methods



(c) accumulated cost

Fig. 2. The simulated results of reliability and accumulated cost with an increase of running distance

3. Conclusion

This study evaluated the optimal level of PMO required in order to minimize the maintenance cost on the PM schedule of 4 component devices of running gear for KHRS. The optimal PMO interval found by using a genetic algorithm was 2.85 million km. The total PM costs (about 84.5 billion won) with optimal PMO up to the railway vehicle half-life are reduced by about 22% compared to when using the conventional method (about 108 billion won). Therefore, a minimal cost is calculated by using the optimal PMO derived from the genetic algorithm in consideration of reliability and criticality.

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