Research on the Reliability of the Collection System of Heavy Haul Railway Based on the Dynamic Fault Tree

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Abstract Reliability theory is applied to the reliability study of the collection System. Systematic analysis method, DFT and professional knowledge of railway transportation and mining engineering are used to do integrate analysis and system research about the characteristics, main research contents and methods of reliability of the system. Based on these methods, combined with example in the transportation work in Daqin line, final analysis result comes out, which provided reference for correlated problem.
Key words Heavy haul railway; Collection system;Reliability; Dynamic fault tree

1 Introduction

China's heavy haul railway has made great contribution on alleviating the tension situation of China's railway transportation capacity and promoting the national economic. The collection system of heavy haul railway is the origin of supply chain. Its security and reliability is not only the assurance of high efficiency and quantity of coal mining, but also influences organization of train flow and line smoothie. However, the study on the reliability of the Heavy-load Railway Cargo system is relatively inadequate. So finding out effective methods for collection system study is significant.

As one of the basic methods, Fault Tree analysis was initiated by Dr. H. A. Waston from the Bell Lab of the United States while he was studying the automatic control system's reliability of the Telephone dial-up machine. After researchers'40 years arduous work, it has been the indispensable method to study the system reliability in the field of nuclear [1], mining metallurgy [2], transportation [3] and computer software [4] etc...

This thesis will firstly analyze the specificity of the Heavy Haul Rail collection system. Dynamic fault tree model would be used in the reliability analysis. A new model for the reliability analysis of the system would be proposed and used to obtain the results of the reliability analysis.

2 Heavy Haul Rail Collection Systems

The Heavy Haul Rail collection system setting in the structure of heavy transport systems may be expressed as Figure 1

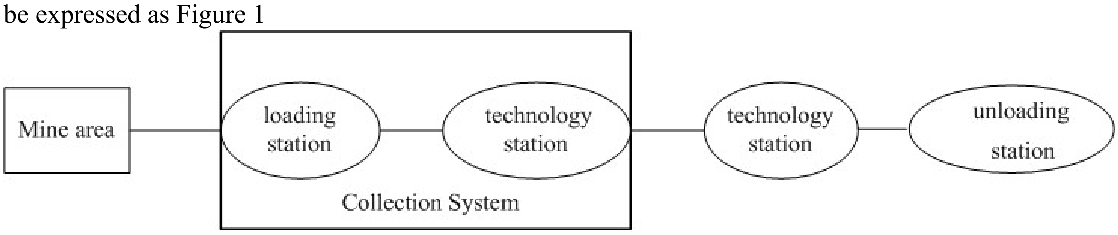

Figure 1 Relationship Diagram of Collection System and System of Heavy Haul Railway

Generally progresses are as follows: sending empty container by heavy haul train from the station of departure to loading station, loading through the loop or series loading line, returning to the departure technology station for the technical inspection of the train and the inspection operations of the locomotive, composing those trains from loading station that can not composed as an entire loading train as a heavy haul train. Finishing all these progresses, heavy haul train would depart from the technical station to the unloading station.

2 Dynamic Fault Tree Reliability Analyses

2.1 Applicability of the reliability appraisal method

Reliability block diagram method, truth table method, Bayesian method, the minimum cut-set method, fault tree analysis, etc, are general methods for system reliability analysis. Although the traditional fault tree analysis method can not indicate the dynamic process of some system, and there are some combinatorial explosion problems, however, after years of development, the improved classification based on the dynamic fault tree module is right for this collection system. The heavy haul collection system is in large size. It includes a certain amount of dynamic factors, so it belongs to those that can not be solved by non-static methods, which makes structured system more complicated. Therefore, this article uses the dynamic fault tree for heavy haul railway collection system.

2.2 System analysis

Analyzing the reliability of complex systems, the Dynamic Fault Tree uses DFLM algorithm for fault tree module partition. Fault tree are divided into static and dynamic sub-trees. The static sub-trees are supposed to be analyzed by using BDD, which the dynamic sub-trees will be transformed into Markov chain analysis.

3 System Analyses

Use DFLM searching to get the first steps and the end steps of the visit of all events, and get the minimum subtrees of the DFT. Then use BDD to static subtrees and Markov chain to dynamic subtrees to the analysis. In the system, every event is given a number as Table 1.

Table 1 Numbers of DFT

<table>
<tr><td rowspan="20">T:The heavy load train plan could not be carried out at technological station.</td><td rowspan="16">G1：Abnormal train departure due to technological station problem</td><td rowspan="3">G3：influence of locomotive</td><td colspan="4">E3： mismatched locomotive types</td></tr>
<tr><td colspan="2">G7：assignment of crews(Dynamic Subtree)</td><td colspan="2">E11:mismatched locomotive and driver</td></tr>
<tr><td colspan="2"></td><td colspan="2">E12: influence of prepared locomotive driver</td></tr>
<tr><td rowspan="9">G4：influence of traffic flow</td><td colspan="4">E4：late train acceptance at junction station</td></tr>
<tr><td rowspan="8">G8：late train acceptation from loading station</td><td rowspan="5">G9：abnormal loading process</td><td colspan="2">E13：coal warehouse shortage</td></tr>
<tr><td rowspan="3">G11：loading equipment fault</td><td>E14：conveyor belt fault</td></tr>
<tr><td>E15：loading tower fault</td></tr>
<tr><td>E16：coal warehouse fault</td></tr>
<tr><td colspan="2">E17： human fault</td></tr>
<tr><td rowspan="3">G10：late returning at technological station after train loading</td><td colspan="2">E18：abnormal section from loading site to technological station</td></tr>
<tr><td colspan="2">E19：unavailable receiving and departure tracks at technological station</td></tr>
<tr><td colspan="2">E20：human fault</td></tr>
<tr><td rowspan="3">G5：influence of technological process at station</td><td colspan="4">E5：train delay spread</td></tr>
<tr><td colspan="4">E6：train operation equipment fault</td></tr>
<tr><td colspan="4">E7：human fault</td></tr>
<tr><td colspan="5">E1:overload vehicle detaching</td></tr>
<tr><td rowspan="4">G2：unavailable section ahead</td><td rowspan="3">G6：late unloading at unloading station</td><td colspan="4">E8：unloading equipment fault</td></tr>
<tr><td colspan="4">E9：abnormal unloading process</td></tr>
<tr><td colspan="4">E10： mismatched coal category</td></tr>
<tr><td colspan="5">E2：influence of construction</td></tr>
</table>

Through calculation, failure probability of every event is got as Table 2.

Table 2 Failure Probability of Every Event

Top Events	Bottom Events	Time （h）	Failure probability
G11	E14	1	0.00007459
	E15	10	0.00074564
	E16	100	0.00743148
G9	E13	1	0.00147335
	G11	10	0.02122572
	E17	100	0.58648272
G10	E18	1	0.00109928
	E19	10	0.01093859
	E20	100	0.10415565
G7	E11	1	0.00000064
	E12	10	0.00000000
		100	0.00590992
G3	E3	1	0.00020060
	G7	10	0.00199779
		100	0.45715342
G8	G9	1	0.00256906
	G10	10	0.27501893
		100	1.00000000
G4	E4	1	0.00306404
	G8	10	0.93638485
		100	1.00000000
G5	E5	1	0.00149273
	E6	10	0.01482743
	E7	100	0.13876210
G6	E8	1	0.00109928
	E9	10	0.01093859
	E10	100	0.10415565
G1	G3	1	0.00554138
	G4	10	0.99992802
	G5	100	1.00000000
	E1		
G2	G6	1	0.00209686
	E2	10	0.11252378
		100	0.99997286
T	G1	1	0.00760836
	G2	10	0.99995455
		100	1.00000000

And then we can also get the important probability relative to their top events as table 3

Table 3 Important Probability of Every Event(Relative to their top events)

Top Events	Bottom Events	Important Probability		
		T=1h	T=10h	T=100h
G11	E14	0.99993601	0.99936034	0.99362785
	E15	0.99993641	0.99936434	0.99366781
	E16	0.99997840	0.99978416	0.99785396
G9	E13	0.99952605	0.98872342	0.50867048
	G11	0.99860123	0.98620223	0.93786609
	E17	0.99892653	0.98276588	0.45272385
G10	E18	0.99950048	0.99504282	0.95407396
	E19	0.99900070	0.99006080	0.90579349
	E20	0.99930060	0.99305300	0.93505093
G7(Dynamic Subtree)	E11	0.00000128	8.19E-13	0.01181984
	E12	0.00000128	8.19E-13	0.01181984
G3	E3	0.99999936	1.00000000	0.56264588
	G7	0.99980004	0.99800221	0.98903492
G8	G9	0.99890305	0.91620657	1.00000000
	G10	0.99852950	0.82858649	0.99997001
G4	E4	0.99743579	0.06860215	0.04876564
	G8	0.99950146	0.99968116	1.00000000
G5	E5	0.99950667	0.99512171	0.95639110
	E6	0.99860126	0.98611204	0.87059289
	E7	0.99890715	0.98916417	0.90044447
G6	E8	0.99950048	0.99504282	0.99950048
	E9	0.99900070	0.99006080	0.99900070
	E10	0.99930060	0.99305300	0.99930060
G1	G3	0.99465918	0.01984966	1.00000000
	G4	0.99751765	0.99998613	1.00000000
	G5	0.99595008	0.13786411	0.99999906
	E1	0.99525822	0.05412418	1.00000000
G2	G6	0.999001701	0.991081645	0.999997146
	E2	0.998902534	0.908248085	0.696940185
T	G1	0.99791712	0.99999997	1.00000000
	G2	0.99448609	0.67543231	1.00000000

4 Conclusion

Through these data, we can easily get the failure probabilities of different events. The more possibility one events may happen, the more attention we should pay to. Besides this, we also get the important probability of every event to judge how much contribution this event make to top events' happening. Thus, this research help workers to manage the system better, and even optimize it.

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