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RISK ASSESSMENT OF COUPLING SYSTEM FAILURE ON TRAIN IN CURRENT MAINTENANCE SYSTEM

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Abstract *– Development of new management approaches on the railway, based on risk management, with the adoption of standards EN 50126-1 and EN 50126-2 provide safety management processes for railway applications. Risk factors can be determined using different risk assessment methods like FMEA, FMECA, FTA etc. or their combination. The permissible risk values based on accepted values and defined preventive measures are designed on the current maintenance plan for freight wagons. Preventive measures are established for revision maintenance which is carried out every 4-6 years. Risk analysis of coupling system failure can be different depending on the time of analysis (regulations, exploitation conditions) and the applied maintenance practice. FMEC analysis applied to train coupling systems based on regulation shows different permissible risk values that don't match exploitation data.*

Keywords – railway, train coupling failure, FMECA, risk analysis, maintenance.

1. INTRODUCTION

The introduction of new management approaches, based on risk management (RAMS - Reliability, Availability, Maintainability and Safety) was initiated on the railway with the adoption of standard EN 50126 in 1999. Development based on standards EN 50126-1 [1] and EN 50126-2 [2] provide safety management processes for railway applications with instructions and methods for their implementation. Though the application of these standards is intended primarily for new systems, it is also desirable for significant modifications and reconstructions of existing systems.

The application of the EN 50126 series standard in defining reliability and safety and the instructions for application of management based on RAMS was made as an example on wheelsets and bogies in UIC B169, RP 29 and RP 43 [3]. Risk analysis identifies risks, assesses their acceptability and, concerning the criticality level, recommcends measures to reduce risks, i.e. to achieve acceptable risk. Failures are ranked according to the criticality level, known as the Risk Priority Number (RPN).

The risk of trains breaking apart, caused by coupling failure, in railway traffic is a quantitative measure of the severity, detectability and frequency. Taking measures to reduce coupling failure is to manage improvement by preventive maintenance, quality, design and operation [3].

Risk assessment using Failure Mode and Effects and Criticality Analysis (FMECA) for mechanical components in railways and the application of the same methodology in risk assessment is based on Failure Mode and Effects Analysis (FMEA). The difference is the additional critical analysis performed after the implemented FMEA.

2. APPLICATION OF FMECA METHOD

The ranking of the severity, detectability and frequency of coupling failure for freight wagons was made according to ranks in UIC B169, RP 43 [3], where the rank have values from 1 to 10. For severity, values range from „no impact“ for 1 rank to „unsafe without warning“ for rank 10. The ranking of detectability of failures goes from „nearly certain“ for rank 1 to „nearly uncertain“ for value 10. The frequency range has values from rank 1 „little - failure is implausible“ for a value less than 10^{-9} to „very high: Failures in very short cycle which are not avoidable“ for a value more than $8 \cdot 10^{-3}$ per year for rank 10 [3].

Some failure of mechanical components could, due to deterioration over time, become causes of severe

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failure. "Failure mode" is defined according to EN 50126 as: "The predicted or observed results of a failure cause on a stated item in relation to the operating conditions at the time of the failure" [3]. That means that the observed object can no longer perform the function and afforded the operating conditions. Therefore, the quality deteriorating of the component does not mean failure at the same time. During the analysis, some failures become failure root causes [3] forming failure cascades (Fig.1), so a separate assessment is performed for each cause to determine its risk.

Risk evaluation is the assessment of the obtained RPN with the limited RPN value, defined in the risk analysis process, to identify the criticality level with increased risk. If the calculated RPN is above the set limit value, it is considered unacceptable and improvement measures must be implemented. If the RPN is below the set limit value, but it is not negligible, it is considered conditionally acceptable and only economically justified measures, so-called ALARP measures (As Low As Reasonably Practical) are applied [4].

For the coupling system of freight wagons in railway operator "Srbija Cargo", consisting of screw coupling and draw gear, quantitative values of failure can be obtained, based on Reports on accidents and incidents in „Serbia Cargo" [5].

For one or more components of the coupling system, due to the deterioration of their condition over time (wear, corrosion, etc.) or overload, severity could progressively increase. For example, under the action of load, the external damage of an component of the coupling system expands, and a small crack is created. Due the corrosion, damage to an component, if not properly maintained, inevitably leads to fracture and coupling failure (Fig.1). Fishbone diagram of train break apart identify the root cause of coupling failure (Fig.2) [6].

The rank of severity (S), detectability (D) and frequency (F) have values between 1 and 10, so the risk evolution in RPN range from 1 to 1000. An overview of risk evolution according to the FMECA is given in table 1 [6].

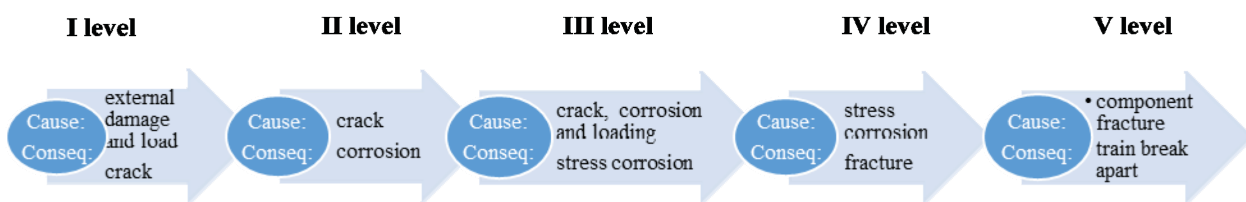

Fig.1. Progressive change of consequences and causes of coupling system components failures

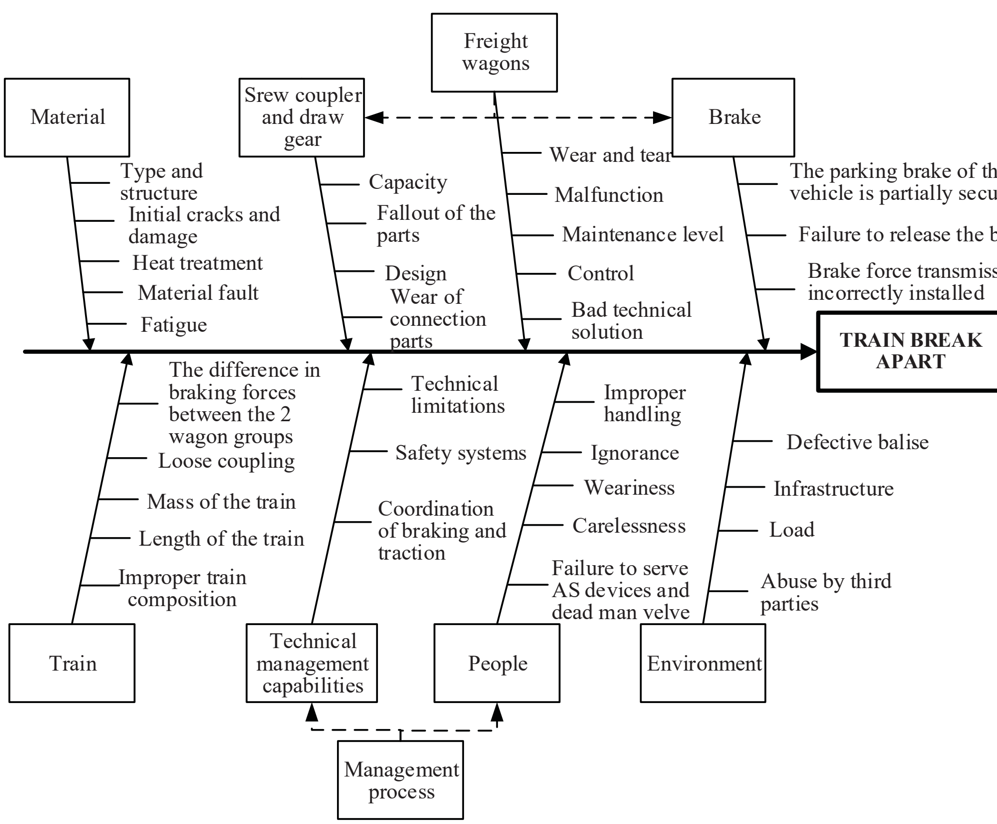

Fig.2. Fishbone diagram of train break apart

FMECA application on systems in operation that have operational data, never applied due to numerous conditions and parameters, that needs assessment, and may never occur in operation. Risk analysis by FMECA for coupling systems in operation would be very long and extensive. Using experience and data from an operation, taking into account the worst outcome in the failure chain for all components, the result is always coupling failure leading to trains breaking apart. Thus, the risk analysis was significantly cut by assessment of component failures (fractures) only. Results of risk analysis of coupling system of "Srbija Cargo" freight wagons were based on the number, equipment and technical condition of the vehicles in use in 2018-2020.

Tab.1. Risk analysis of coupling system

Component	Failure root cause	Failure	Severity (S)	Detectability (D)	Frequency (F)	Risk Priority Number (RPN)
Shackle	overload, corrosion, initial crack, material fatigue	fracture	4	6	8	192
Coupling links			4	8	9	288
Pin			4	8	1	32
Trunnion nut (shackle fitting)			4	8	1	32
Trunnion nut (link fitting)			4	9	1	36
Screw			4	9	8	288
Split pin	loosening, initial crack, fallout	fallout	4	8	1	32
Draw hook	overload, corrosion, initial crack, material fatigue	fracture	4	8	10	320
Joint pin			4	8	9	288
Drawbar			4	10	10	400
Bolt and nut (joint pin)			4	10	1	40
Nut (drawbar)			4	10	1	40
Elastic device	overload, initial crack, material fatigue	fracture	4	10	7	280
Coupling head and hose	external damage, tire aging	damage	4	8	8	256
Angle cock	external damage	fracture	4	8	6	192
Brake pipe	external damage, loosening of the joint	damage	4	8	8	256

The analysis of the risk of coupling failure showed that the RPN is the highest for component failure with the consequence of the train breaking apart. As the severity for all component failures is equal, the RPN depends on detectability and frequency. The application of the EN 50126 series standard set limited RPN value at 250 [3] and that was used in this analysis as well. The most critical component failures were [6]:

- drawbar, RPN = 400, due to the high frequency and low detectability in operation (inaccessible in preventive maintenance in operation),
- draw hook, RPN = 320, also due to the high frequency and low detectability in operation (inaccessible),
- coupling links, screw and joint pin, RPN = 288, lower risk of fracture due to lower frequency and better detectability in operation (accessible for inspection),
- elastic device, RPN = 280, lower frequency failure and low detectability in operation (inaccessible),
- coupling head and hose and brake pipe, RPN = 256, lower frequency failure and better detectability in operation.

3. APPLICATION OF DATA FROM OPERATION

The relative indicator of train breaks apart in railway freight traffic is the ratio of the number of train breaks and the traffic volume shown in millions of tonne-kilometre. This relative indicator represents the frequency of train breaks apart reduced to ton-km per year. Based on the determined frequency of train breaks apart and their effects on railway traffic in recent years, it was possible to predict the risk of train breaks accordingly. The prediction was based on data obtained for equal or similar:

- types of vehicles (wagons and engines) and their condition (quality and maintenance),
- traffic condition,
- train driving and
- external and other conditions in operation.

Limitation of train breaks apart predictions are assig data for particular railway vehicles, traffic, etc., that can not be applied on other railways. If any of the listed parameters change, the projection will not correspond to the achieved data. An example of the proposed prediction was made for train breaks apart of the operator "Srbija Cargo" in the year 2020, based on the frequency of train breaks apart from 2016 to 2019.

The frequency of train breaks apart reduced to ton-km per year for the period 2016-2019. in the freight traffic of the operator "Srbija Cargo" amounts to 0,0079 breaks/mil. ton-km per year (Fig.3). For the projected or, in our case, realized volume of 4,178 million ton-km freight traffic of "Srbija Cargo" in 2020, we can expect 33 cases of train breaks apart. However, in 2020, were only 24 cases of train breaks apart. The reduction of train breaks number as much as 36,8% compared to the previous years is not unforeseen, when it's known that decreasing trend is almost 27,5% for all accidents and incidents from 2010 [6]. This decrease in the number of trains breaking apart and the total number of accidents and incidents is significant, as it is clear that it is not an effect of the decrease in traffic volume, which amounts to only 8,5% in 2020 compared to 2019 (Fig.3). Based on presented data, it is the evident influence of new impact factor.

Within the safety management system of the railway operator "Srbija Cargo" the Accident and incident analysis team was formed at the end of 2019. The team was aim to re-analyzing all accidents and incidents after submitting the final investigation reports. The team for the analysis of accidents and incidents in which the vehicles of "Serbia Cargo" participated, as a result of their work, propose improvement measures for increasing traffic safety. The establishment of an Accident and incident analysis team resulted in greater responsibility for all involved in the railway traffic operation. A decrease in the total number of accidents and incidents, and therefore train breaks apart, have an effect due to the implementation of measures and security recommendations of the Accident and incident analysis team and the entire security management system.

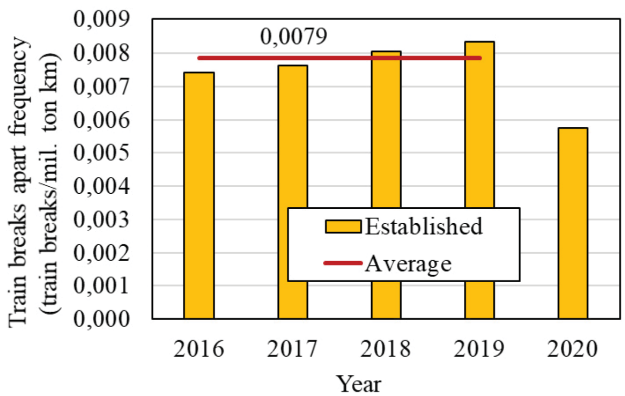

Fig.3. Frequency of train break apart from 2016 to 2020

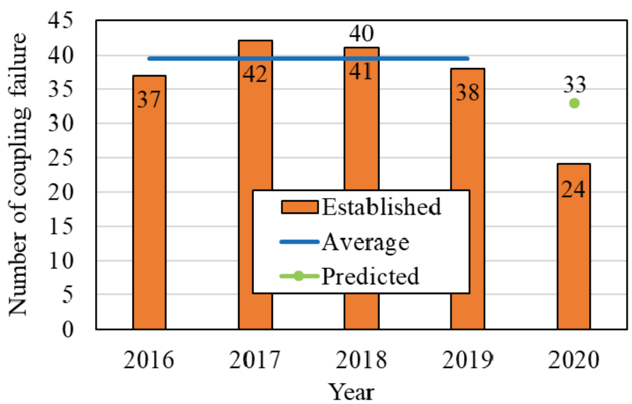

Fig.4. Prediction of train break apart number

4. CONCLUSION

To increase the safety of railway traffic according to the Regulations [7], monitoring and analysis of common safety indicators (CSI) are performed. Based on the analysis, a report is made which, in addition to the data on the CSI, contains the results of safety analysis and recommendations for improving the safety of railway traffic based on safety measures adopted as a result of previous accidents. Risk assessment should be performed by the railway infrastructure management or railway undertakers and through the review of changes in the railway network and analysis of railway safety in the previous period and the need to implement measures to reduce risk.

The cause of the train breaking apart is coupling failure, usually as a result of superposing several negative aspects. Although separated parts of the train are automatically breaked, it could lead to an increase in stopping distance, passing through a signal or crossing, and to a serious accident. Therefore, the relatively low severity of the consequences of coupling failure in everyday practice shouldn't be a reason not to take all measures to reduce them. Taking measures to reduce or eliminate the causes of coupling failure is to manage the risk of the train breaking apart usually by preventive maintenance, quality, design and operation.

ACKNOWLEDGEMENT

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