PROPOSAL OF NEW MAINTENANCE SYSTEM OF AIR BRAKE SYSTEM ON SEMI-TRAILER COMBINATION AIMED AT INCREASE OF OPERATIONAL SAFETY

Abstract

The paper deals with the proposal of new maintenance system of air brake system on a semi-trailer combination. The structure of semi-trailer and the current maintenance system of trailers are described with focus on the basic air brake system design. Analysis of wear and damage of air brake system components used on the semi-trailer combination based on real experience from practice and creation of the FMECA analysis of the system using software support are presented. Based on the analysis performed, a new system of maintenance was designed which was aimed at reduction of the risk related to failure consequences. The proposed system uses RPN (risk priority number) values resulting from the proposed preventive maintenance system and is compared with the current maintenance system. Main objective was to reduce the impact of any failure in any component on the air brake system. On the basis of the analysis subsequently new methods of failures detection of air brake system components, preventive measures, and suggested new intervals of preventive maintenance for the air brake system are also proposed. Proposed intervals of preventive maintenance execution are based on the calculation of the total costs associated with the consequences of failures that may arise from them and compared with costs associated with service inspections carried out on the analysed semi-trailer fleet. The proposed maintenance system has decreased RPN values in comparison with the current system and in practical operation is expected to increase safety of semi-trailer combinations, thus minimize probability of a failure in any component of the air brake system.

INTRODUCTION

The most commonly used means of transport in road freight transport is a semi–trailer combination. This consists of tandem truck or truck with semi-trailer. This type is the most commonly used means of transport in Slovakia and became a subject of interest in the solution of the research in which maintenance of selected parts of semi–trailer combination was solved.

Function of air brake system on semi-trailer is to ensure deceleration, stopping and parking a semi–trailer. Two systems are used in practice, which are anti-block system ABS and electronic braking system EBS. The research was focused only to electronic braking system EBS.

The structure of semi-trailer and the current system maintenance of trailers are described with focus on the basic air brake system design. Following is an analysis of wear and damage of air brake system components used on the semi-trailer combination based on real experience.
from practice and creation of the FMECA (Failure Modes, Effects and Criticality Analysis) analysis of the system using a software support. Based on the analysis performed, a new system of maintenance was designed which was aimed at reduction of the risk. The proposed system uses RPN (risk priority number) values resulting from proposed preventive maintenance and is compared with the current maintenance system. Main objective was to reduce the impact of any failure in any component on the air brake system.

Fig. 1 3-axle sliding tarpaulin platform semi-trailer PANAV

1. SEMI–TRAILERS

The semi–trailers serve for transport of large volume goods. According to EEC standards, the most important parameters of semi-trailer combinations are:
– Total weight,
– Maximum load on each axle,
– Total length and width,
– Total cargo volume for goods transported

1.1. Main components of semi-trailers

The main components, described for a 3-axle sliding tarpaulin platform semi–trailer, are:
– frame, king pin, support fixtures, axles, air brake system, side impact protection, rear bumper, superstructure, floor,
– accessories: spare wheel bracket for spare wheel, water tank, plastic toolbox, retractable step unit.

Fig. 2 Schematic description of basic semi-trailer components
1.2. Air brake system

Air brake system has direct influence on driving safety in road traffic. The main function of the entire brake system is controlled by EBS. The air brake system consists of two branches - air and electrical (EBS).

Fig. 3 Air brake system

2. MAINTENANCE SYSTEM OF SEMI–TRAILERS

2.1. Current maintenance system of semi-trailers

Every semi-trailer has to be reliable, safe and efficient in service and therefore it should be given an adequate attention. They have to adhere to the principles specified in the maintenance plan for a particular semi-trailer. For the 3-axle sliding tarpaulin platform semi-trailer, the first maintenance inspection, i.e. running in inspection after 5000 km or within two months after delivery of the semi-trailer is prescribed. For the first maintenance inspection the tolerance for kilometers is maximum + / - 2000 km. The second maintenance inspection and every other will always be after running 75 000 km or will be no later than six months from the date of sale or will be no later than six months since the previous inspection. On the air brake system, the prescribed activities for the particular inspection level have to be done. These activities are: visual inspection and tightness test of individual components using a manometer and check of individual components of electrical branch with diagnostics.

2.2. Analysis of wear and damage of air brake system

An analysis of wear and damage of air brake system components was done on a fleet composed of 1 470 semi-trailers. Out of examined 1 470 semi-trailers, 800 semi – trailers came with a failure into the inspection service and in case of 670 semi – trailers failure was found within the maintenance inspection. The following graph (fig. 4) shows the exact number of failed components of air brake system which were replaced in the company during the calendar year 2011 for mileage in the interval of 75 000 km (that is after 75 000 km, 150 000 km and 225 000 km). When wear or damage is detected on a component, the particular air brake system component it has to be replaced.
2.3. The FMECA analysis

The FMECA Analysis of EBS system was done with the criticality analysis of nodes, including functional and fault networks.

The first step is to create the structure of the air brake system. It is also necessary to establish the elements of the structure and their functions and failures. Then we can create function networks and failure networks. The next step in the FMECA analysis is a risk assessment. Values of probability, severity and detection are entered into FMECA forms.

2.4. RPN values for the current maintenance system

For the risk assessment of the failure consequences of air brake system level of risk RPN (Risk Priority Number) are very important factors. The level of risk RPN values are normally between 500 to 80, see Fig. 6 for air brake system using current methods for the detection of failures. These values are unacceptable for the road traffic. It is necessary to reduce the value of all the risks to an acceptable value and to reduce value of the consequences of failures to prevent possible losses of human lives (the worst case) and a semi-trailer should permanently be in operational state.

3. PROPOSAL OF A NEW MAINTENANCE SYSTEM FOR AIR BRAKE SYSTEM

RPN values of the current system of maintenance are very high and also the consequences of failures occurring at the individual components of air brake system are of high values, so the current maintenance system should be changed. Proposed change will consist of a new interval of planned preventive inspections, using the new methods for the detection of failures of individual components, as well as the use of preventive measures, that is exchanging air brake system components after a certain number of kilometers run by a semi-trailer.

Fig. 4 The number of failures of the components of the air brake system of a selected number of 1470 semi–trailers
3.1. Proposal of maintenance intervals for air brake system

With the growing number of kilometers traveled there are more worn components and subsequently their failures. The failures may have the highest values the consequences, that is loss of human lives or semi-trailer will not be in operational state. The proposed intervals for the service inspections consist of three levels of maintenance interventions, which meet the definition of the preventive maintenance and are intended to reduce the probability of failure or the degradation of the functioning of an item.

The first level of the preventative maintenance is proposed for every 45 000 km with a tolerance of + / - 2000 km or will be no later than 4 months from the date of sale or will be no later than 4 months since the previous inspection. Visual inspection is performed only, which is used to detect failures of individual components that could occur in the manufacturing process and will show up within operation after a certain number of kilometers traveled.

The second level of the preventative maintenance is proposed for every 75 000 km with a tolerance of + / - 5000 km or will be no later than 8 months from the date of sale or will be no later than 8 months since the second inspection. More complex check will be performed with using the proposed methods to detect failures.

This interval is designed by calculating the total cost of the consequences of failures that may arise from the examined 1470 semi–trailers and costs associated with service inspections that are performed on the 1470 semi–trailers.

The costs associated with the consequences of failures on the air brake system are approx. 40,000 euros (all prices with VAT). These costs include the average cost of the Slovak Statistical Office and individual insurance [4] in case of loss of human life and the average price of a new semi - trailer combination and the average price of the cargo carried and the average cost of towing semi-trailer combination from the location of breakdown on a road to the repair shop. The total cost of the 1470 semi – trailers related to failures consequences of air brake system after running from 0 km to 75 000 km are 999 600 Euro, after running from 75 000 km to 150 000 km are 2 469 600 and after running from 150 000 km to 225 000 km are 17 434 200 Euro.

The average price of a service inspection for one semi - trailer is 193.52 Euro. If the service inspections will be performed on 1470 semi - trailers every 15000 km, the costs associated with service inspections are after running 15000 km 1 422 372 Euro, after running 30 000 km are 711 186 Euro, after running 45 000 km are 474 124 Euro and after running 60 000 km are 355 593 Euro. Dependences of inspection costs and failure consequences on mileage run are shown in the graph (Fig. 5). Intersection of the two curves is at about 90 000 km and this value is designed for the second level of the preventive maintenance determined at every 90 000 km.

The third level of the preventive maintenance is proposed for every 180 000 km with a tolerance of + / - 5000 km or will be no later than 16 months from the date of sale or will be no later than 16 months since the third inspection. Exchange of all components of air brake system except air pipes and cables in a professional workplace will be performed.
3.2. Proposal of detection measures

In the proposed preventive maintenance, two methods to detect failures - visual inspection and checking of tightness and functionality of using diagnostics are proposed. The role of the visual inspection is based on more frequent intervals by visual inspection to avoid unexpected failures that could have consequences in the loss of human life or in removal of the air brake system from operation.

3.3. Proposal of preventive measures

In FMECA analysis, it was found that it is appropriate to change all air brake system components except pipe and cables after running 180 000 km, thus the current maintenance system will be more expensive but minimizes the risk of failures and the consequences associated with them.

3.4. RPN values of proposed maintenance system

In Fig. 6 we can see that there was a significant reduction in RPN values on proposed detection methods, as well as preventive measures. RPN values for the first stage of the preventive maintenance are in the range from 400 to 60. RPN values range from 80 to 32 when we use preventive measures. The green columns in the picture represent RPN values for individual components and well-defined cause failures when we use the first level of the preventive maintenance.
3.5. Economic evaluation

The current system maintenance has running-in check after running 5000 km, which is the average price of 66.8 Euro. Then after running every 75 000 km inspections are carried out for the average price of 232.2 Euro.

The total costs of the current system of maintenance for one semi-trailer after running 225 000 km are 799.9 Euro. The proposed maintenance system after running every 45 000 km has visual inspection which price is 27.1 Euro. After running every 90 000 km all components are checked with using diagnostics. The price is 72 Euro. Then after running 180 000 km there is an exchange of all components of air brake system except pipes and cables. The total exchange price is 1640.7 Euro. The total costs of the proposed maintenance system for one semi-trailer after running 225 000 km are 1793.9 Euro.

In the total costs, prices of parts that are exchanged on the basis of proposed preventive measures in the FMECA analysis are included. The total cost of the proposed maintenance system includes the use of instruments that are used to detect failures on individual components, workers’ salaries and prices of all components being replaced.

CONCLUSIONS

The costs of the proposed maintenance system are 2.2 times higher than the costs of the current maintenance system after running 225 000 km. The analysis showed that the current maintenance system has 32.9% probability that after running 225 000 km there will be a failure in one component of air brake system.

Consequence of failure was estimated in an average of 40 000 Euro. The increased costs of the proposed maintenance system are justified because there is a minimization of failures and their consequences, and thus there is a potential to save a human health and lives.

REFERENCES

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