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INCREASING THE EFFICIENCY OF RAILWAY TRANSPORT BY IMPROVEMENT OF SUSPENSION OF FREIGHT WAGONS

ABSTRACT

Railway transport has a very important role in economy of every country. The efficiency of railway transport depends both on the quality of transport organization and on the technical reliability of the railway rolling stock. During operation of the railway freight wagons in the last years, a large number of breaks of suspension system elements have been noticed. This feature is especially reported at four-axle double wagon for coal transport (designated Fbd) and three-axle wagon for transport of cars (designated DDam). Frequent breaks of suspension system elements reduce the efficiency of transport and in some cases cause derailment of wagons and lead to large economic losses. In this paper, the causes of breakage of suspension on both wagons (Fbd and DDam) have been analyzed, but also the possibilities of how to resolve these problems, i.e. how to reduce them to a minimum or avoid them completely.

KEY WORDS

railway transport, freight wagons, suspension system, increasing efficiency

1. INTRODUCTION

Rail transport is of great importance for the functioning of the economic system of each country. The efficiency of rail transport indirectly affects the efficiency and functioning of the entire economic system of a country. This is especially true when it comes to systems whose functioning is based directly on rail transport. The termination of operation of rail transport stops functioning of the entire system, and then creates huge problems and great economic losses. One such system, for example, is the system of electricity generation by thermal power plants. In most thermal power plants, the coal transportation from the place of excavation to the power plant is based on rail transport. The occurrence of accident and disruption of rail transport can affect the supply of thermal power plant by coal which may lead to termination of its work, thereby compromising the normal operation of electrical power system. So, in this particular example one can see the importance of rail transport, and the importance of its reliability and efficiency.

Railway vehicles are very complex technical systems that consist of a large number of assemblies and subassemblies. Cancellation of the elements of railway vehicles may occur due to various influential parameters. It is worth noting that it is sometimes enough to cancel only one part of a railway vehicle subassembly and it may then lead to a possible breakdown of the entire train, with unforeseeable consequences. Therefore, after every disaster extensive measures are taken and reconstruction and detailed expertise are carried out in order to determine the causes that had led to failure [1–5]. Based on the results of such research the appropriate studies and regulations which define the directions of further development of railways, as well as binding measures aimed to prevent the occurrence of failure and accidents are formed [6–9].

Among the dominant causes of delays and accidents on railway vehicles, especially in freight transport, there are failures of the suspension system that can be of different nature. The modern approach is based on scientific research in order to complete the theoretical and experimental identification of the causes that lead to the failure of the suspension system of railway vehicles [10–20]. Accordingly, the Railway Vehicles Center of the Faculty of Mechanical Engineering Kraljevo has conducted a research about the rationalization of freight railway transport that is presented in this paper. The aim of research in this paper has been to reach the level of more efficient and safer freight railway transport while reducing the costs. The particular problem in this research were frequent breaks of suspension system elements which result in derailment of wagons. Special attention was paid to Fbd wagon for coal transport and DDam wagon for car transport. The suspension of both wagons is based on the leaf springs. For resolving the problem of frequent fractures of leaf springs the starting point was the experimental and exploitation identification of all parameters that cause the possible break of the spring. The quality of the leaf spring, the quality of the track, the conditions of exploitation, uniformity of loading, are random sizes, whose influence on the break of the spring is enormous and must be taken into consideration in order to prevent the breaks of suspension system elements.

Figure 1 - Four-axle double wagon Fbd for coal transport

Figure 2 - Three-axle DDam car transport wagon

2. PROBLEM DESCRIPTION

For coal transport in thermal power plant "Nikola Tesla" in Obrenovac, Serbia, the four-axle double wagon Fbd is used. This wagon is made of two-axle cells, and it is shown in *Figure 1*. This wagon is specialized for the technology of loading and unloading in the environment (coal pit – power plant). These were the reasons that resulted in the solution of constructions with specifications in the body, supporting framework and mechanism for unloading. A door with hydro pneumatic propulsion has been embedded in the wagon floor. This mechanism provides automatic unloading and closedown after that. Because of these features, the construction of suspension that is based on leaf spring, differed from the standard construction. The remission of the spring length in regard to standard resolution caused stress amplification. Additionally, the operation loads are more frequent in comparison to exploitation in public railway transport.

The drawbacks in the mentioned system can be noticed at breaking of suspension member and appearance of fracture on supporting framework. Frequent breakages of the main leaf of the leaf springs reduced significantly the efficiency of regular coal transport. The thermal power plant "Nikola Tesla" in Obrenovac reported an average breakage of suspension of 2.8 on one Fbd wagon yearly (about 400 wagons are in exploitation).

Another problem in this paper refers to DDam wagon for car transport. In order to improve the safety of transport of cars by railway, the existent open wagon (Laaekks) in covered three-axle DDam wagon has been reconstructed. This wagon is shown in *Figure 2*.

The reconstruction consists of adding funicular railing and also a roof to the existent wagon. Moreover, the existent leaf springs have been reconstructed so that their distance between eyes has been reduced by 25mm. Because of the occurrence of breakages, according to fatigue, the main leaves of all springs were exchanged by new ones. In order to improve the efficiency of loading and unloading, the reconstruction of the floor on the upper platform as well as on the bottom platform, has been made. It is important to note that the specific characteristic of DDam wagon lies in the elastic connection of two rigid bodies, above the spring of the second wheelset in the middle of the car. As in the abovementioned wagon Fbd for coal transport, the spring breakages in exploitation were noticed, especially on the secondary axle.

3. ANALYSIS OF CAUSES OF SPRING BREAKAGES

Researching the reasons for excluding the Fbd wagon from traffic, the following data about breakages of the suspension system have been noticed (Tables 1 and 2).

Table 1 - Breakage of the suspension elements of the Fbd wagons

Breakage	Number of occurrences	%
Springs	400	67.34
Spring hanger	125	21.04
Spring shackle	35	5.89
Centre bolt	30	5.05
Σ	590	100

Table 2 - Breakage of the suspension elements by axles of one wagon Fbd

Axle	Number of breakages
I	148
II	144
III	142
IV	160

The most frequent breakages are related to the breakage of the main spring leaves (*Figure 3*). In approximately 70% of cases, leaves were broken in the middle which is closer to the spring buckle, but in approximately 30% of cases the occurrence can be noticed on the other half of the spring. Observed per axles (*Table 2*) we can conclude that the breakages of elements of the spring of Fbd wagons are equable per axles.

Figure 3 - Break of the main leaf of the spring

Upon primary analyses, large research of the quality of railway tracks, operation loads, static and dynamic features of springs and the quality of embedded springs has been done. The final results of this research can be found in [21–23], and here are the conclusions:

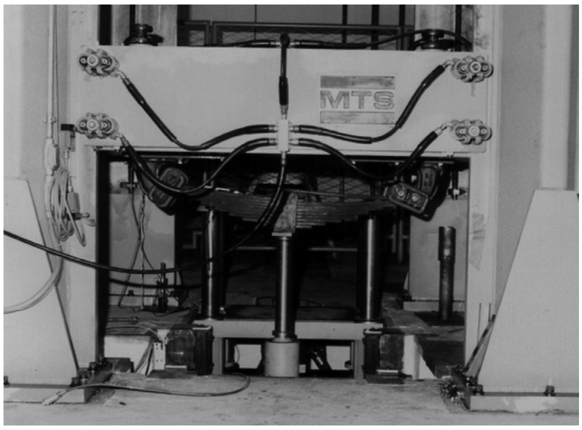

Figure 4 - Examination of leaf spring fatigue

- on the railway track unstable parts in horizontal and vertical direction have been observed; this can qualify the occurrence of impact load;
- unequal load assignment on the wheel has been registered, and that occurrence has influence on the static and dynamic strength, but also on the life-cycle of suspension elements;
- research of the fatigue of spring from different producers (*Figure 4*) has shown that the springs do not feature regular durability;
- based on the carried out research it has been determined that, apart from the above remarks neither the quality of spring production was reliable.

Considering wagon exploitation for car transport DDam, the popping of an average of one spring per wagon yearly has been noticed. Nevertheless, the average withdrawal of wagons from traffic because of suspension exchange, lasts one month. With the aim of minimizing breakage of suspension elements, the weight of loaded cars was reduced from 200kN to180 kN. Meanwhile, not even that caused reduction of spring breakages, so it was decided to take all DDam wagons (about 100) out of service, and to carry out any necessary research in order to remove the mentioned defects.

The Faculty of Mechanical Engineering Kraljevo has made research of load assignment per wheel and axle and the research of torsion stiffness. Based on the results that have been given in *Table 3*, we have noticed that the torsion stiffness is greater than usual. Based on the analysis of torsion stiffness CtA of DDam wagon, we concluded that in ultra causes, the slip of other (middle) wheelset can also be noticed.

Moreover, the values of stress amplitude and displacement also exceed the permitted values. On the diagram that shows amplitude changes of spring stress (*Figure 5*), we can notice the frequent appearance of rigid impact of spring buckle on the limiter of motion flat places on peaks). This appearance can cause the

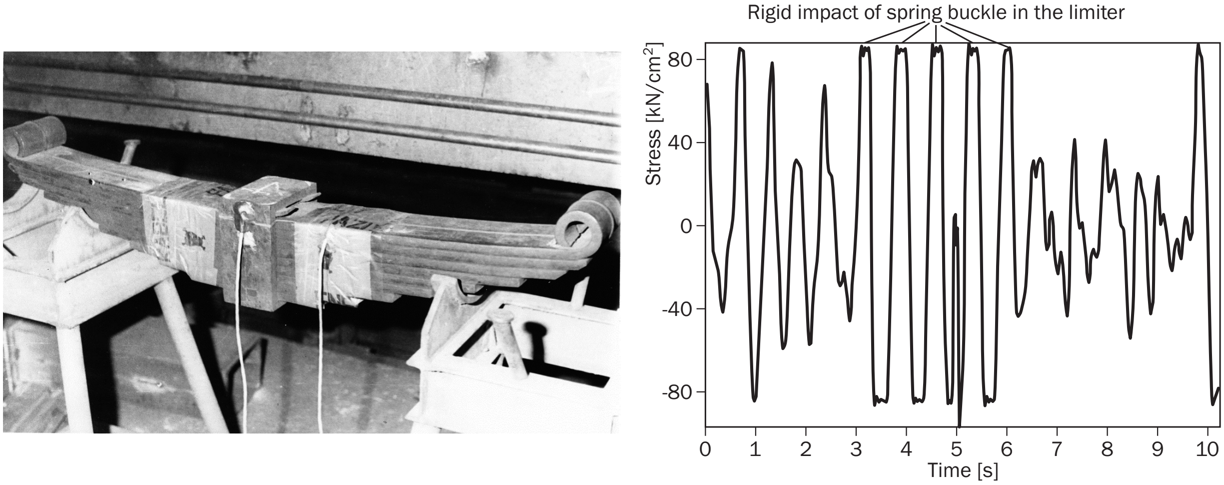

Figure 5 - Examination of spring of Fbd wagons; Left: Examined spring, Right: Diagram of spring stress

Table 3 - Torsion stiffness of DDam wagon

	$C_{tA}\,[kN/‰]$		
	I axle	II axle	III axle
Limit	3.87	2.17	3.87
Experiment	2.43	3.50	2.34

remission of durable dynamic spring strength that is the remission of the life-cycle of the spring.

4. SOLUTIONS TO REDUCE SUSPENSION BREAKAGES

4.1 Fbd wagon for coal transport

In order to resolve the problem of frequent spring breakages, the starting basis was the experimental and exploitation identification of all the parameters that affect the spring fatigue. The named effects, above all expanded loads and stresses, but also unsafe quality of spring products, are the main reasons for the occurrence of breakages. Based on the obtained experimental and exploitation data, improved suspensions were designed with the basic aim to remove the load from the spring.

A lot of conceptual ideas for reduction of spring breakages of wagons have been considered. Regarding Fbd wagons, one of the solutions is to install parabolic springs, but in two versions:

- gap between spring eyes is 1,100mm, and
- gap between spring eyes is 1,200mm.

The first version is built into Fbd wagon, but because of reduced gap and bad production in our factories, this version did not provide the expected results. The second version in exploitation has shown excellent results, that is, in perennial usage, there were no suspension breakages of wagons. Anyway, this variant requires important investments in reconstruction of the under-wagon platform, but also investments in the reconstruction of entire suspension, which is economically impracticable. Having respected adequate perseverance in the existent spring, the resolution with Ferro-rubber elastic element has been designed (*Figure 6*).

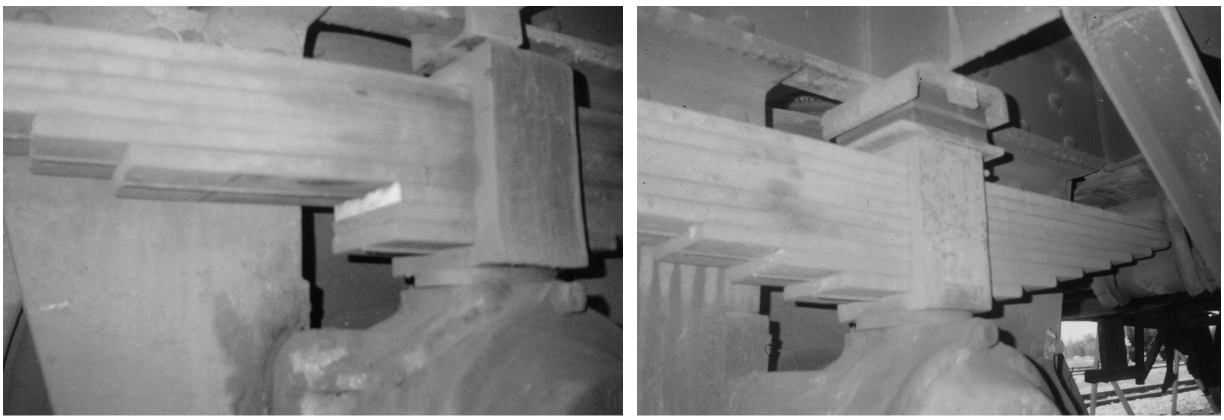

Figure 6 - Suspension of Fbd wagon;
Left: Suspension without elastic element, Right: Suspension with elastic element

Instead of the existent metal limiter (*Figure 6* – left) the tire-metal elastic element is embedded (*Figure 6* – right). This element should have features of stiffness and rigidity, because it has to accept a part of load and disburden the present spring. Additionally, the dimension of elastic elements has to be projected on that way, that in case of empty wagon the elastic element does not touch the spring buckle by its under reef. The elastic element is used only in case when the wagon is loaded. Exceptions are springs, whose spring arrow loses the projected height, owing to fatigue, that results from long exploitation and irregular repair. In that case (and also when the wagon is empty), the elastic element and the spring buckle rub each other. This kind of wagon should be taken out of service, but also the spring should be repaired. The designed solution of Fbd wagon suspension requires the production of trial samples of elastic elements and monitoring of the behaviour in conditions.

Parallel with the development of the elastic element for protecting the spring from overloading, research was done to repair the main spring leaf by welding. As mentioned, the frequent breakages of the main spring leaves, their price, and complicated supply, have significantly reduced the efficiency of regular coal transport. All this requires research of repair possibilities of springs by welding of the main spring leaves and comparative research of the welded and unwelded springs in laboratory and in exploitation conditions.

Comparative research has been carried out on the unwelded spring, welded spring which was repaired at the "Zelvoz" Factory, Smederevo and on the welded spring which was repaired at the "Gibnjara" Factory, Kraljevo. The program of research was based on the UIC rule, and comprises the following activities: research of geometric accuracy, identification of static stiffness, research for rating of durability (dynamic research of fatigue) and results analysis.

Dynamic research has been made with amplitude ±15mm and frequency of 2Hz. Based on the carried out research, it may be concluded that in no sample did the breakage occur in the place of the welded splice, that is, in the heat affected zone (*Figure 7*). The expected spring durability of Fbd wagon to fatigue in laboratory research has not been attained, because of unsafe quality of the embedded material. Unsafe quality of material had been affirmed in earlier research. It is caused by the presence of chemical impurities in the material.

4.2 DDam wagon for car transport

In DDam wagons for car transport, the way of installing the elastic elements in the suspension has not been found. It is because of the spring high arrow remission. However, the suspension of DDam wagons provides the possibility of exchanging of the existent springs by parabolic springs. The static feature of the parabolic spring can be noticed in *Figure 8*.

The feature of the spring has been chosen in that way; to submit all loads that the wagon for car transport has in exploitation. Moreover, these springs have better property of stiffness, and that property can influence a more favourable quality and safety of the wagon movement.

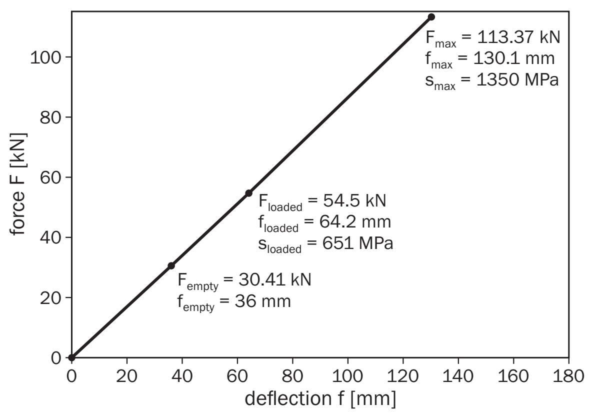

Figure 8 - Static characteristic of parabolic spring

Figure 7 - Welded main leaf of the spring

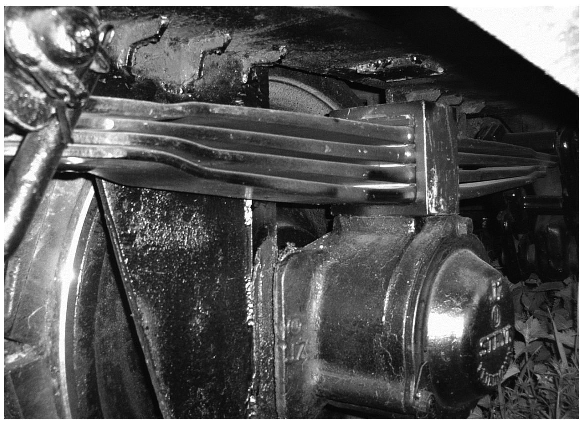

Figure 9 - Parabolic spring

5. CONCLUSION

According to the three-year exploitation monitoring of behaviour of the designed improvements it has been determined that:

- there was no cracking in the parabolic leaf springs that are embedded in Ddam wagons for transportation of cars nor was there the appearance of slippage of the wagon from railway tracks;
- not at any moment was there the break of welded main leaf spring of Fbd wagon for coal transport;
- there was a decrease in the breaking of suspension elements of Fbd wagons with built-in elastic elements by 84%. Although the elastic element fully protects the suspension elements, the appearance of minor fractures explains the unreliable quality of the delivered elements suspension.

From the previous, we conclude as follows:

- The carried out theoretical and experimental studies of wagons for transportation of coal, with and without the designed improvements in the laboratory and in exploitation conditions have proven the validity of elastic mounting elements in the suspension of the wagon;
- The methodology of welding does not have influence on the exploitation spring ability, that in freight wagons, which transport coal, repaired springs, in which the main leaf has been welded according to the stipulated and attested technology can be installed.
- Parabolic springs, built in DDam wagons for car transport, have static feature that can accept exploitation loads. In this case torsion stiffness of wagons is better than the preliminary solution.

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REZIME

POVEĆANJE EFIKASNOSTI ŽELEZNIČKOG TRANSPORTA POBOLJŠANJEM OGIBLJENJA TERETNIH VAGONA

Železnički transport ima veoma važnu ulogu u privredi svake zemlje. Efikasnost železničkog transporta zavisi kako od kvaliteta organizacije saobraćaja, tako i od tehničke pouzdanosti vozila. Prilikom eksploatacije teretnih vagona na železnici uočena je pojava pucanja elemenata vešajnih sistema. Ova pojava je naročito izražena kod četvoroosovinskog vagona za prevoz uglja (oznaka Fbd) i troosovinskog vagona za prevoz automobila (oznaka DDam). Česti lomoovi elemenata vešajnog sistema, na ovim i drugim vagonima, znatno smanjuju efikasnost redovnog transporta, a pored toga u nekim slučajevima dovode i do iskliznuća vagona sa koloseka što uzrokuje velike materijalne štete. U ovom radu su analizirani uzroci pojave pucanja elemenata vešajnih sistema kod oba vagona i mogućnosti poboljšanja kojima bi se lomovi sanirali, sveli na najmanju moguću meru ili u potpunosti izbegli.

KLJUČNE REČI

železnički transport, teretni vagoni, sistem ogibljenja, povećanje efikasnosti

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