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THE TREND OF TRAIN COUPLING FAILURE ON SERBIAN RAILWAYS IN 10 YEAR PERIOD

Marija VUKŠIĆ POPOVIĆ[1]
Jovan TANASKOVIĆ[2]
Zorica STARČEVIĆ[3]
Nebojša MEĐEDOVIĆ[4]

Abstract *– This paper presents an analysis of train coupling failure on the Serbian Railways and displays a trend of characteristics over 10 year period. The impact of changes in the organization of exploitation and maintenance and led by the introduction of Entity in Charge of Maintenance (ECM) and reconstruction of Serbian railway company into 3 separate entities as well as some differences and aging in rolling stock induce certain changes in the parameters of train coupling failure. The analysis is done based on parameters of train configuration and driving specifications. Only freight trains with single traction locomotives are considered. The distribution of coupling failure along the train, driving regime and velocity is comparatively discussed related to the values from the previous period. Load status, as well as the length and mass of the trains in the extended collection, correspond to a certain distribution. Causes of failure and damages to coupling and draw gear indicate specific conditions leading to failure. Analysis significance helps the systematization of failure features and sets the ground for defining the parameters that impact failure and determining their quantification.*

Keywords – railway, train, screw coupling, draw gear, couplers failure, train breaks apart.

1. INTRODUCTION

The analysis of train coupling failure (that includes coupler and draw gear) on Serbian railways public network aims to:

- classify coupling failure cases and systematize causes, circumstances and consequences;
- quantify the structure, place and conditions of coupling failure to determine what leads to failure increase;
- take into consideration the impact of coupling failure on railway traffic safety,
- predict the coupling failure and propose measures to reduce them.

Rolling stock of railway operator "Serbia Cargo" partially includes rolling stock of previous national operator "Serbian Railways", whereby their number was reduced from approx. 330 from 2011. to about 230 in 2020. Number of freight wagons were reduced from almost 8500 in use of "Serbian Railways" in 2011. to approx. 4000 wagons in use of "Serbia Cargo" in 2020. with almost 1900 wagons in daily operation. Rolling stock in "Serbia Cargo" are over 40 years old, while only new locomotives (16 engines Vectron) were procured in 2020. "Serbia Cargo" also rents a number of vehicles from other railway operators in Europe and a certain number of foreign vehicles, according to the GCU (General Contract of Use for Wagons), also operate on the Serbian railways. Therefore, the analysis of train coupling failure does not have a purely national character and is not unambiguously defined.

Only relevant cases of train coupling failure were analyzed, therefore uncoupling of semi-automatic couplers was not taken into account, as well as other special cases (3,3%).

There were only a few train coupling failures on passenger trains, so this analysis excludes them. From 2007 to 2011 the average number of coupling failures on "Serbian Railways" freight trains was 40,2 cases [1] per year (Fig.1). That number didn't decrease significantly from 2016 to 2020 and for "Serbia Cargo" freight trains the average number of coupling failure was 36,4 cases per year [2]. Reduction of the

[1] Belgrade Academy of Technical and Art Applied Studies, College of Railway Engineering, Serbia, marija.vuksic.popovic@vzs.edu.rs
[2] University of Belgrade, Faculty of Mechanical Engineering, Belgrade, Serbia, jtanaskovic@mas.bg.ac.rs
[3] Serbia Cargo, Belgrade, Serbia, zorica.starcevic@gmail.com
[4] Serbia Cargo, Belgrade, Serbia, nebojsa.medjedovic@srbcargo.rs

total number of accidents and incidents in the period 2016-2020. increase train coupling failure (on average) to 13,9% per year.

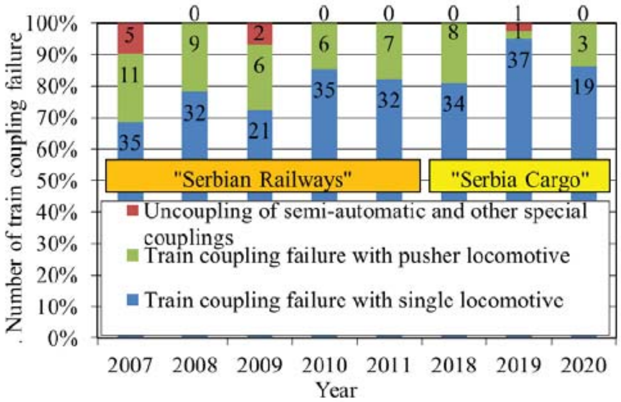

Fig.1. Number of train coupling failure of freight trains of the operators "Serbian Railways" and "Serbia Cargo"

2. COUPLING FAILURE CHARACTERISTICS

There has been an increase in the number of damaged foreign wagons due to coupling failure from 35,4% to 46,6% in the period from 2018 to 2020 [3], compared to 10 years ago (Fig.2). This is primarily a consequence of more foreign wagons operating on the Serbian railway infrastructure.

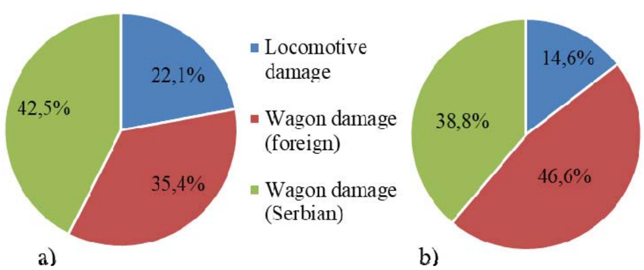

Fig.2. Frequency of damaged railway vehicles in case of coupling failure, a) from 2007 to 2011, b) from 2018 to 2020

The frequency of locomotives damage has decreased from 22,1% (Fig.2a) to 14,6% (Fig.2b) in observed 10 years period. This indicates that a large number of coupling failures occur between the locomotive and the first wagon in the train. Also, over 50% of damaged locomotives must be repaired in workshops (Fig.3), which further increase the expenses of the incident and can lead to traffic closure.

Ten years ago, as many as 59,1% of cases of coupling failure on freight trains were on the first third of the train length (Fig.4.a) of which 26,2% are coupling failures between the locomotive and the first wagon, and 32,9% between the first wagon and the first third of the train length [1]. Only about 17,7% of train coupling failures were between the first and second third of the train length. A slightly different distribution of coupling failure was in recent years, where in 38,3% of cases coupling failures were on the first third of the train length (Fig.4.b), of which 16,0% are coupling failures between the locomotive and the first wagon. Almost 40,4% of coupling failures were on the second third of the train length compared to just 10,6% on the last third.

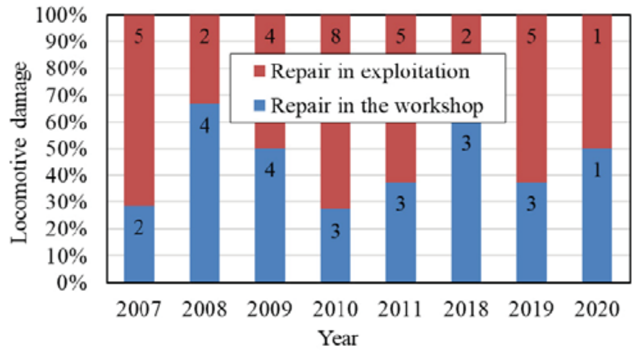

Fig.3. Locomotives damage in case of coupling failure

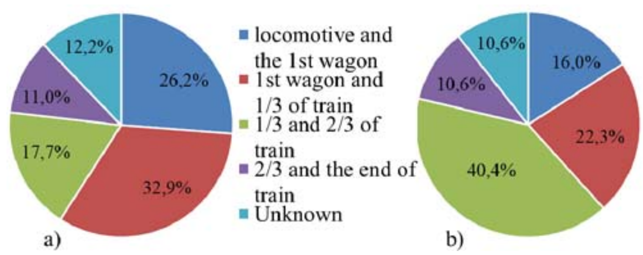

Fig.4. The distribution of coupling failure along the train, a) from 2007 to 2011, b) from 2018 to 2020

Coupling failure between the locomotive and the first wagon mostly occurs during traction, while other cases mainly occur during braking or changing of direction. From 2018 to 2020 decrease in the number of coupling failures in the front part of the train, and increasing in the middle of the train (Fig.4), was caused by a larger number of coupling failures during maneuvers (pushing) that were taken into account.

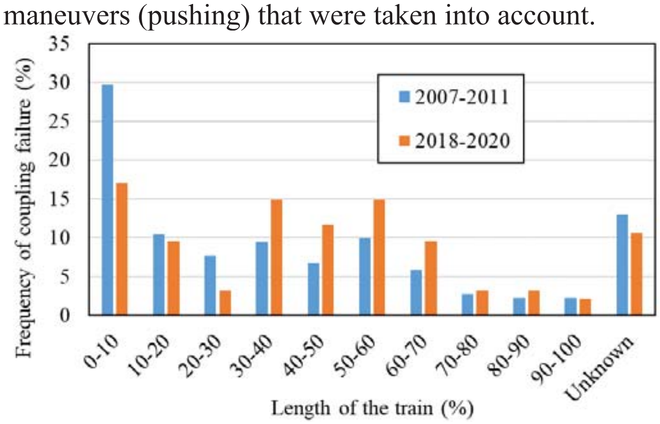

Fig.5. Frequency of coupling failure in the train

Most coupling failures occur during braking, due to large longitudinal forces, even 56,1% 10 years ago and 41,0% recently (Fig.6). Pulling regime had a similar effect on coupling failure 20% to 23% in both periods, while maneuvering has significantly more influence on coupling failure recently than before

(Fig.6).

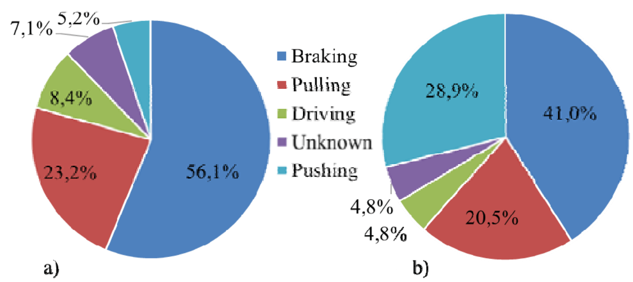

Fig.6. Driving mode before coupling failure, a) from 2007 to 2011, b) from 2018 to 2020

Ten years ago coupling failure mostly occurred at train speed between 10 and 20 km/h (34,2% cases - Fig.7) [3], while recently most coupling failures occurred at speeds up to 10 km/h (38,6%). The number of coupling failures decreases with increasing speed, so as many as 58 ÷ 65% of coupling failures occur at speeds less than 20 km/h (Fig.7).

As low speeds and the number of starts and stops (traction and braking) are more frequent in stations and nearby, so 50% to 70% of train coupling failures occur in the station area or switchyards.

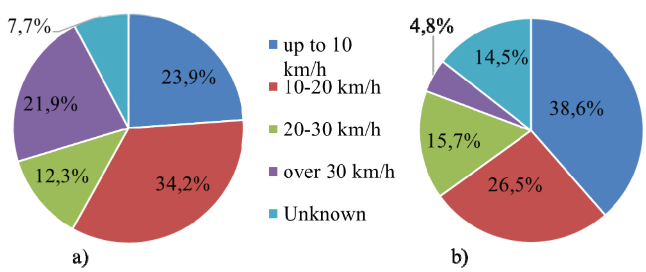

Fig.7. Train speed before coupling failure, a) from 2007 to 2011, b) from 2018 to 2020

The train characteristics that can influence the frequency of coupling failure are the number of wagons, the length, and weight of the train, the state of loading, the schedule of loaded and empty wagons in the train, and others. The smallest number of wagons on freight trains that have coupling failure is 8 to 15 and the largest number of wagons is 43 to 51, while in the last three years the number was between 9 and wagons (Fig.8).

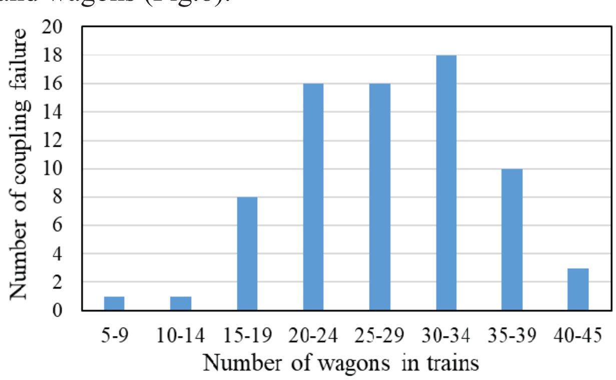

Fig.8. Number of wagons in trains with coupling failure from 2018 to 2020

Consequently, as average freight train in the last ten years had 26 to 27 wagons [4], length of broken trains ranged from 152 m to 720 m. The average length of trains breaking apart was about 400 m. It can be concluded that the frequency of train coupling failure increases with train length over 500 m (Fig.9).

The masses of trains that have coupling failure range from 336 t to 2333 t (Fig.10). The average gross weight of one train in 2009 was 926 t [3], and of a train that break apart 1354 t, similar to the last few years.

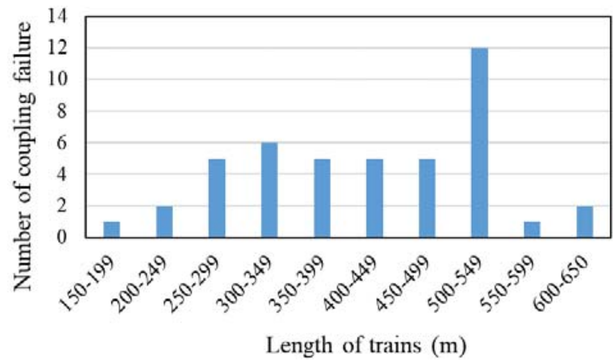

Fig.9. Length of trains with coupling failure from 2018 to 2020

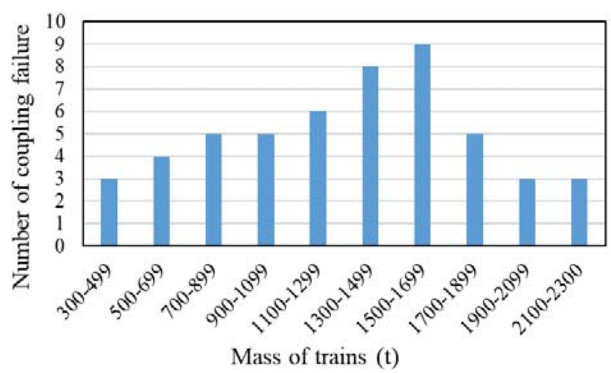

Fig.10. Mass of trains with coupling failure from 2018 to 2020

The frequency of coupling failure is somewhat higher for trains with all loaded wagons (26,6%) related to 16,5% for trains with all empty wagons. Trains with diverse lodes (both loaded and empty wagons) have 25,3% frequency of coupling failure, but in almost a third of cases loading data were not available.

The official analysis of train coupling failure on Serbian railway, states that the cause of failure, in over 50% of cases, was the fatigue of material (Fig.11), such as changed material structure, loss of connection parts, and other irregularities related to the material of failed parts. Irregularities in driving are listed in 15% to 18% of cases as the cause of coupling failure. Variations of train composition, tightness of screw coupling, as well as the vehicle condition (technically in order) make 9% to 20% of coupling failure causes. The increase of the material in the last ten years, as the main cause of coupling failures from 50,8% to 59,6% cases, indicates that there has been a decrease in the quality of diagnostics in the maintenance of coupling systems (including draw gear).

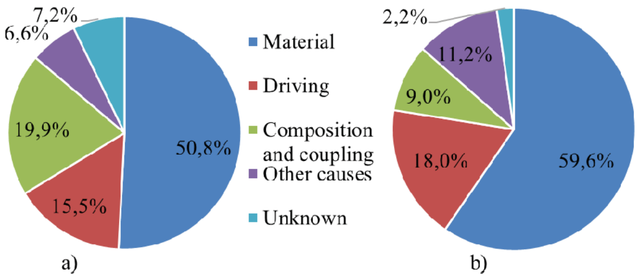

Fig.11. Causes of coupling failure, a) from 2007 to 2011, b) from 2018 to 2020

The consequences of the coupling failure and train breaking apart could be direct costs of the material (spare parts and repair), but also include indirect costs (delay of a broken train and other trains on the the line). They also include costs related to traffic disruption and organizational change. From 2007 to 2011, the direct material costs of breaking trains apart were up to 1000 euro, [1] and the traffic closure on the rail line section lasted on average 3 to 4 hours. Similar was from 2018 to 2020, with direct material costs between 400 and 900 euros, and the traffic closure between 4 and 5 hours (Fig.12) [5]. These consequences do not include the total costs of keeping trains and the engaged train route, which do not happen at every break, but can amount to 3000 euro and higher.

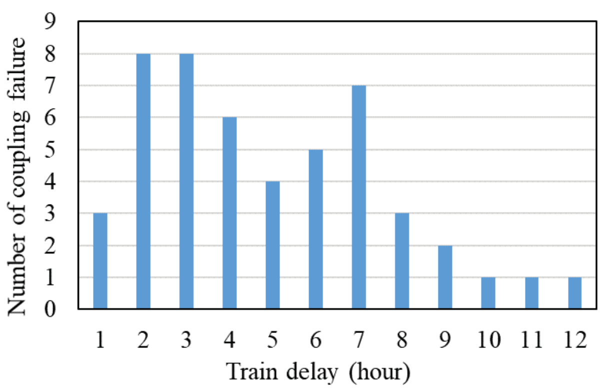

Fig.12. Train delay after the break from 2018 to 2020

The conditions of technical inspection and the level of the technical quality of wagons in the exchange between railways in Europe are defined in Annex 9 of GCU. It attributes all the damage caused by the accident (not wear and tear), with a recent breakdown, without signs of fatigue, to inadequate handling of freight wagons by the railway company of vehicle users. Thus coupling failure can have significant financial consequences as all fractures during breaks, in which there are no clear traces of fatigue, or wear on broken parts, are considered the responsibility of the user's railway operator.

During the coupling failure, in majority of cases the reason were parts of draw gear in 55,0% of cases and coupler in 36,7% of cases (Fig.13). The failure of other parts was significantly less - about 8,3%. In the last three years, the failure of draw gear elements has increased to as much as 63,9%, while the failure of coupler elements has decreased to 26,9% (Fig.13).

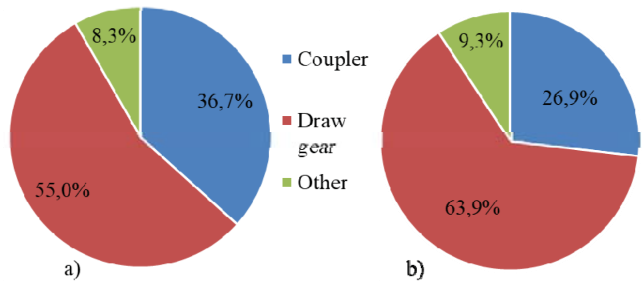

Fig.13. Coupling failure parts, a) from 2007 to 2011, b) from 2018 to 2020

3. CONCLUSION

The characteristics of train coupling failure over 10 years show a decrease of locomotive damage and frequency of coupling failure in the front part of a train, as well as an increase of coupler and draw gear fatigue. Since coupling and draw gear are standard constructions, and also inspected with regular maintenance, the percentage of failure caused by material fatigue is extensive. Significantly, the frequency of coupling failure due to train driving has not decreased.

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