Risk management of friction liner welding reconditioning technology change

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Abstract: The paper presents the authors’ work in identifying the main risks that may arise if pursuing the change of the reconditioning technology through welding the friction liner of the passenger car disc brake based on the technical hazard identification, and the authors analysis and management of these risks by carrying out a risk management system. Their work is based on the specifications of the Commission implementing regulation (EU) No 402/2013 on the common safety method for risk evaluation and assessment (EU Regulation 402/2013) [1], which is compulsory for any technical, operational and/or organizational change in the railway field that has an impact on railway safety. Also the purpose is that the modified technology does not affect railway safety.

The friction liner from the passenger cars disc brake is a part that ensures the grip of the friction pad, which applies the braking force to the brake disc to realize the braking of the rolling stock. The new reconditioning welding technology can affect the friction liner clamping function, making it possible for the friction pad to fall from the friction liner, resulting in losing braking power on the vehicle, which leads to the occurrence of rail events, thus affecting rail safety.

1. European and national rail legislation on risk management in the event of a change with an impact on railway safety

Railway transportation has always represented both a strategic sector of national interest and an important service for the population.

Railway safety is the concept that governs all railway activities.

Any technical, operational and/or organizational change in the railways that has an impact on railway safety is compulsorily analyzed in accordance with EU Regulation 402/2013[1] thus, this regulation [1] establishes a revised common safety method (MSC) for assessing and evaluating risks in the event of described-above changes to a railway system.

When, based on an assessment made on the criteria established by this Regulation, the change is considered significant, the risk management process is applied following the steps described in Annex I of EU Regulation 402/2013[1], figure 1.
2. Risk management process application in case of a change in the railway system.
When during the railway activity (repair, in this case) we have a technical, operational and / or organizational change that has an impact on railway safety, it is mandatory to analyze this change in accordance with the EU Regulation 402/2013 [1]. If, based on the criteria mentioned in the regulation, it is found that the change is significant, the risk management process relative to change hazards will be applied—as described in Annex I of this same Regulation.

2.1 Carrying out the analysis of the change in welding reconditioning technology
Assesing whether the change of the welding reconditioning technology is important and affects the railway safety will be made compulsory in accordance with Article 4 point (2) of EU Regulation 402/2013[1], based on the criteria in this article table 1.

Figure 1. Stages of risk management process in the railways [2].

Figure 2. Analysis of the change based on its significance [2].
In accordance with the provisions of EU Regulation 402/2013[1], in order to decide the importance degree of the change, the analysis and evaluation team formed by the internal experts takes into account the criteria found in table 1 and they will follow the steps from figure 2.

Table 1. Change assessment according to the criteria of EU Regulation 402/2013.

| No. | Criterias | Description |
|-----|-----------|-------------|
| 1.  | Impact in case of failure: credible pessimistic scenario in case the evaluated system suffers a failure, taking into account the existence of safety barriers outside this system; | After modifying the welding technology, defects can result, and can affect the railcar part so that it does not ensure the functions for which it is designed. Once the railcar is back into circulation, incidents with consequences on the railway system can occur (example: friction pad dropping from the friction liner, resulting in lack of braking force on the brake disc) - major importance |
| 2.  | New elements used in achieving the change: this concerns both the innovative aspects of the railway sector and the elements that represent a novelty only for the organization that makes the change; | New elements introduced through the change: - new clamping system in mobile welding bench (advantage - different positioning degrees, easy to modify, easy handling, compared to the old clamping device which was massive and difficult to handle) - mechanized welding instead of manual welding (advantage - constant welding speed, constant linear energy, uniform base material melting) - major importance |
| 3.  | The change complexity; | The change complexity degree is major because the welding process changes from manual to mechanized, plus it requires different welding equipment; different qualifications of welding personnel; different materials (wire instead of electrode) - major importance |
| 4.  | Monitoring: the inability to monitor the change made throughout the entire life cycle of the system and to take appropriate measures; | Monitoring is also complex because the entire process and the execution personnel is changed, so the monitoring modality is also completely changed - major importance |
| 5.  | Reversibility: the system’s ability to return to the pre-change situation; | The change is reversible, allowing the ability to return to manual welding with electrodes and to the initial device attachment - reduced importance |
| 6.  | Additionality: assessing the importance degree of change, taking into account all the recent safety modifications to which the target system was subjected (not considered significant). | The change is not additional to other changes in relation to its importance degree |

Considering the arguments already presented, we consider that changing the welding technology represents an important and significant technical, operational, and organizational change that has a potential impact on railway safety based on the criteria of Art. 4, point 2 of EU Regulation 402/2013[1].

The change consists in the modification of the welding reconditioning technology of the friction liner found on the disc brake, on passenger cars type 2180, figure 3.
The friction liner is provided constructively with a swallow tail profile, which ensures the grip of the friction pad that performs the disc braking on the passenger cars.

Over time, the forces that appear during braking lead to the wear of the swallow tail profile and to diminished clamping capacity, towards the total loss and eventually the fall of the friction pad from the friction liner, thus causing accidents due to the lack of braking.

Wear repair is done by replacing this part with a new one, in accordance with the repair technology. In the absence of new parts, as they are no longer manufactured, the repair has been addressed through manual welding reconditioning.

Figure 3. Friction liner [3]: (a) frontal view, (b) lateral view, (c) FL-BP swallow tail clamping detail FL-friction liner, BP brake pad, BD brake disc.

For optimization, analyzing the advantages and disadvantages of each technology, we evaluate the risk of switching from manual welding to MIG / MAG mechanized welding.

Since, due to the reconditioning technology, any defects in the part could result in loss of braking capacity of the vehicle and obviously affect the railway safety, the change should be evaluated, taking into account the criteria imposed by EU Regulation 402/2013[1].

2.2 The Risk Management System in case of changing the technology of welding reconditioning

When concluded that the change is significant and has effects on railway safety as in the present case, the hazards and risks generated must be identified and analyzed, and a risk management system developed for this change of welding reconditioning technology. Conformity for this change is evaluated in relation to the Implementing EU Regulation 402/2013[1], figure 4.

The objective of risk management is to reduce risks from activities carried out. Also, the changes in activities are not accepted if they will induce unwanted or unacceptable risks.

The main objective of the safety risks assessment, resulting from the described change, is to identify the following aspects:
- the associated hazards, probable causes and potential consequences / systemic assumptions that they present, which are necessary for the proper risks classification;
- railway safety methods for reducing the risk severity to an acceptable level.

The process to create the risk management system for managing the risks generated by the change is achieved in accordance with EU Regulation 402/2013[1] Annex I, figure 1.

2.2.1 Preliminary definition of the system. The preliminary definition of the system, prior to the change, must also be set-up in accordance with EU Regulation 402/2013, point 2.1.2 from Annex I [1], which implies to approach the following aspects:
- system objective;
- system functions;
- system boundaries;
The issues listed above refer to:

a) system objective: restore the friction lining to the nominal dimensions of the railcar technical specification during the periodic or general repair, in accordance with the maintenance and operation instructions, eliminating the wear by welding reconditioning. The repair activity aims to remove the failures and to restore the railcar parts to the nominal parameters, provided by the technical book, accompanying the type of railcar as well as the instructions regarding the modalities, conditions, and repair times of the rolling stock.

b) system functions: ensuring the secure grip of the friction pad

c) system boundaries: the railcar rolling system.

d) physical system interfaces: the friction pad on one side and the elements of the wheelhouse on the opposite side.

e) system environment: vibrations caused by running the railcar on the rail, actions of the braking forces.

Figure 4. Implementation of a risk management system in case of significant changes affecting railway safety [2].

According to the documentation of the railcar technical book, the friction liner, being a railcar part, repairing the brake lining is done through replacing it with a new part. Because over time, spare parts were no longer manufactured by any supplier, it became necessary to find a new method for their repair, and it was the welding reconditioning of the existing part.

The current analyzed change consists in modifying the welding technology used in the reconditioning in order to optimize it, in table 2.
The common elements of the two technologies are: the initial and final mechanical preparation of the piece, and the final results (i.e., the shape and dimensions of the piece, ensuring the friction pad is attached); cleaning between cords and checking with penetrating liquids when welding ends.

An important common element of the two technologies is linear energy [3-5].

The elements identified by the analysis team, elements that can be found in table 3, represent the foundation of the decision to seek optimization of the current welding technology.

Table 2. Comparison of current welding to modified welding technology.

| Current welding technology | Modified welding technology |
|---------------------------|-----------------------------|
| Mechanical preparation by removing swallowtail profile | Mechanical preparation by removing swallowtail profile |
| Clamping in mobile clamping device with inclination degree at only 90° or 45° | Clamping in the welding bench with multiple inclination degrees |
| Manual welding—first flank with 180° return for the second flank | MIG / MAG welding and mechanized, with a 180° turn clockwise |
| After each welding operation of a cord, the slag is removed with the hammer and slag brush. | After each welding operation of a cord, the slag is removed with the hammer and slag brush. |
| Penetrant Liquid Control (PL) | Penetrant Liquid Control (PL) |
| Mechanical machining, milling with log milling for the production of swamp profile at nominal dimensions | Mechanical machining, milling with log milling for the production of swamp profile at nominal dimensions |

Table 3. Comparison of current welding to modified welding technology from the point of view of the elements chosen by the analysis team.

| Current welding technology | Modified welding technology |
|---------------------------|-----------------------------|
| Detection of irregular melting of the base material (in various sections) due to the variable speed of manual welding | The mechanization will give a perfectly constant speed, consequently, the uniform melting of the base material along the entire length of the welding cord |
| Clamping in mobile device with inclination degree at only 90° or 45°, difficult handling due to the weight of the device (7 kg) | Fastening in the welding bench with multiple inclination degrees will allow easy handling, without forcing the operator to lift the part. |
| Lack of penetration in certain sections of the cord, at the 90° angle | Positioning at certain angles through the welding bench allows a very good penetration up to the base of the 90° angle |

2.2.2 The process of hazards identification and risk analysis. All the risks that may arise due to the change of the welding reconditioning technology must be presented as acceptable. The modification of the welding reconditioning technology is not allowed if it induces undesirable or unacceptable risks for rolling stock in rail traffic.

Consequently, in order to identify the hazards and to correctly assess the associated risks, it was necessary to go through the steps in table 4.

With help from the designated team of experts, using the brainstorming identification and evaluation technique, the possible ways of failure and the associated hazards, we identified generated risks and the measures to deal with these risks. We identified all the hazards that can be reasonably foreseen for the entire technical system under evaluation, for its functions and interfaces. These have
been classified according to severity, taking into account the classification of accidents and incidents in GD. 117/2010 [6], for the approval of the Regulation of accidents and incidents investigation, and for the development and improvement of safety on the railways and the metro network.

In order to focus the risk assessment activities on the most important risks, the hazards are classified according to the estimated risk they generate. Based on the opinion of the commission's experts, the dangers associated with a generally acceptable risk should not be analyzed in detail as they are kept under control by codes of practice, but they are recorded in the hazards records evidence.

As a criterion, the hazards generated risk can be classified as generally acceptable, when the risk is so low that it is not reasonable to implement any additional safety measures. The opinion of the internal experts takes into account that the contribution of all generally acceptable risks should not exceed a defined proportion of the overall risk. [1]

Loss of function caused by functional failure generates a negative impact on railways safety. The nature of the hazards and their number depend on the technical and functional characteristics of the analyzed technical system.

Table 4. Steps for identifying hazards and assessing associated risks.

| No | Name of the stage | Description of the analyzed change |
|----|-------------------|-----------------------------------|
| 1  | team building     | the team will consist of employees with proven skills in the analyzed area (in this case: welding and rolling stock construction) |
|    |                   | Analysis will be performed on the system before the change, on the change itself, and on the system after the change; |
|    |                   | a) the system before the change - the used part, disassembled from the passenger car and brought to reconditioning, |
|    |                   | b) change - modified welding technology |
|    |                   | c) the system after modification - the part reconditioned to the nominal dimensions through the new welding technology |
| 2  | defining the system to be analyzed; | a designated team, trough Brainstorming, will identify the hazards and enter them in table 6., hazards evidence register, together with the origin of the hazards, systemic assumptions, safety measures, acceptance principles and the person responsible for the measures, according to article 4.1.2 of Annex I of the EU Regulation 402/2013 [1] |
| 3  | identifying the system hazards by analyzing the activity as well as the technical documents; | the classification of hazards, according to the associated risk table 5. |
|    | risk evaluation   | risk hierarchy and the establishment of the reduction / prevention priorities; |
|    |                   | the hierarchy of risks is achieved |
| 6  | establishing additional safety measures. | safety measures are established for each risk so that it is managed at an acceptable level |

Assumptions that determine the limits of risk assessment:
- accidents and incidents foreseen in the "Regulation for the investigation of accidents and
incidents, for the development and improvement of the railway safety on the railways and the metro
transportation network in Romania” approved by GD no. 117/2010 [6].
-all identified hazards and associated risks are kept under control at an acceptable level through
security measures based on codes of practice, as well as internal processes and procedures.
-the railway safety management system complies with all the legal safety requirements, necessary
to accept the risks related to the identified hazards, limiting us to the risks that may cause
accidents or incidents.

2.2.3 Selecting the risk acceptance principle. During the working session concerning the change
evaluation and the application of the risk management process, the working team established that, for
the risk assessment in the analyzed system, they have to apply the risk control and acceptability
through codes of practice.

As a risk acceptance principle, the evaluation team decided to use codes of practice, because there
is no relevant information regarding the movement safety of similar systems, and because, in the case
of railway processes, the distinction between frequency and consequence is not very clearly defined
and cannot be assured by an explicit risk assessment, which is why the codes of practice were
established.

As notified legal requirements, the codes of practice, have also been used in defining the railway
safety management system and are used as acceptable criteria for all railway safety risks.

The application of this risk acceptance principle has identified possible safety measures, which
make the related risks acceptable and keep them under control. Of these safety measures, those
selected to control the risks become the minimum safety requirements to be met. Whenever a code of
practice is used to control a risk, hazards identification has been limited to:
- checking the relevance of the code of practice
- identification of deviations from the code of practice.

Codes of practice meet at least the following three requirements:
- they are widely recognized in the field of railway activity.
- they are relevant to the control of dangers considered in the case of the system under evaluation;
- are available to all actors from the railway field, who want to use them [1]

If Directive 2008/57/EC[7] requires compliance with technical specifications for interoperability
(TSI), and the relevant TSI does not require the risk management process established by this analysis,
TSLs may be considered as codes of practice for hazard control, provided that the requirement of EU
Regulation 402/2013, point 2.3.2 (c) [1] is fulfilled, namely, to be available for the evaluation bodies,
upon their request.

National rules notified in accordance with Article 8 of Directive 2004/49/EC [8] and Article 17 (3)
of Directive 2008/57/EC[7] may be considered as codes of practice, provided that the requirements of
paragraph 2.3.2, of EU Regulation 402/2013 [1] are met.

If one or more perils are controlled by codes of practice that meet the above requirements, then the
risks associated with those perils are considered acceptable. This means that:
- these risks should not be analyzed in more detail;
- the use of the codes of practice is recorded in the perils records evidence as safety requirements
for the hazards in question.

When all hazards are controlled through codes of practice, the risk management process can be
limited to:
- identification of the related hazards;
- the registration of the use of codes of practice in the danger register within the applicant;
- documentation of the application of the risk management process, by drawing up specific
documents[1].

2.2.4 Hazard management process. Starting with the evaluation phase, as well as in the implementation
phase, until the acceptance of the significant change taken into account, the repair company keeps and
updates a record of the hazards related to it. Hazard evidence recording follows the progress of monitoring the risks associated with the identified hazards. All identified hazards are classified according to the estimated risk, table 5. They are recorded and kept under control, through safety measures, as mentioned in the Register of hazards evidence, table 6.

Table 5. Hazard classification according to the generated risk.

| No | Hazard description | Associated risk (estimated risk generated by the hazard) | General acceptable (yes/no) |
|----|--------------------|----------------------------------------------------------|-----------------------------|
| 1  | Deviations in the values of the welding technology parameters | Defects in the welding cord that can lead to the failure of the clamping function and to the fall of the friction pad from the friction liner | no |
| 2  | Locking in operation of the welding equipment | Piece refuse due to an irrecoverable fault | no |
| 3  | Welding filler with inadequate chemical composition | Defects in the welding cord that can lead to the failure of the clamping function and to the failure of the friction pad from the friction liner (inadequate hardness and wear resistance) | no |
| 4  | Inaccurate mechanical processing | Piece rejected due to irrecoverable default | no |
| 5  | Insufficient testing to detect defects | Undetected defects in the welding cord which, can lead to the failure of the clamping function and the fall of the friction pad from the friction liner | no |
| 6  | Testing that does not detect defects due to deficiencies in the testing failure of the clamping function and the fall of the friction pad from the friction liner | Undetectable defects in the welding cord that can develop later and can lead to the failure of the clamping function and the fall of the friction pad from the friction liner | no |

Table 6. Hazard evidence register in the repair activity by welding reconditioning of the frictionlinings on passenger cars type 2180.

| No | Hazard description | Hazard origin | Safety measure / safety requirement | The principle of risk acceptance | Responsible |
|----|--------------------|---------------|-------------------------------------|-------------------------------|-------------|
| 1  | Deviations in the values of the welding technology parameters | Poor training of the execution personnel, checking the welding equipment before starting the welding operation | Personnel’s qualification testing, equipment verification | Use of codes of practice / Safety rules | Welder |
| 2  | Locking in operation of the welding equipment | Not verifying the welding equipment before starting the welding operation | Personnel’s qualification testing, equipment verification | Use of codes of practice / Safety rules | Welder |
|   | Description                                                                 | Responsible Party                |
|---|-----------------------------------------------------------------------------|----------------------------------|
| 3 | Welding filler with inadequate chemical composition                         | Non compliant supply verification |
|   | Use of codes of practice / Safety rules                                      | Head of supply service            |
| 4 | Inaccurate mechanical processing                                             | Non-calibrated measuring devices  |
|   | Periodic checks of measuring devices                                         | Use of codes of practice / Safety rules |
|   | Qualified personnel in charge of mechanical processing                       | Qualified personnel               |
| 5 | Insufficient testing to detect defects in operation                          | Insufficient data from previous exploitation on similar defects (at what number of hours, km, brakes, braking force, speed) |
|   | Enlargement of the data search area, performing simulations in the laboratory of the possible extreme conditions | Use of codes of practice / Safety rules |
|   | Designer                                                                    |                                   |
| 6 | Testing that does not detect defects due to deficiencies in the testing equipment or personnel qualification | Unprepared personnel, unfulfilled criteria, decalibrated test equipment |
|   | Equipment verification, testing, personnel’s qualification                   | Use of codes of practice / Safety rules |
|   | Personnel execution, laboratory tests                                        |                                   |

### 3. Conclusions regarding the hazards and risks generated by the change of welding technology

Following the identification of the hazards in the case of the new welding technology and the risk analysis carried out, the railway safety risk analysis and assessment team concludes that the risk level for the proposed change is acceptable, and the technical and operational risks are kept under control by applying the specified codes of practice and through the proposed risk management system. This allows the change to be carried out and the switch to the new reconditioning welding technology which has advantages over the previous one and whose risks are kept under control.

The advantages of this new technology are the creation of a welding cord with very good properties and the minimization towards the exclusion of the defects detected in the case of cords deposited by the old technology.

Although the new welding technology has obvious advantages, and the risks induced by the possible hazards identified are managed through the risk management process, the process of modifying the technology is long lasting and will require the application of a standard approval process by accredited bodies.

### 4. References

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