



CALCULATION OF SELECTED PARAMETERS OF A SCREW COUPLER AND BUFFERS OF A LOCOMOTIVE SCALED MODEL

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Abstract – Railway and railway vehicles are often not only a favorite kind of transport, or favorite kind of a transport means, but also a subject of personal hobby of many people. Efforts to be as near as possible to railways force people to develop scaled models of railway vehicles together with the needed infrastructure. The presented study is focused on determination of selected parameters of a chosen components of a scaled model of a shunting locomotive. It is a shunting locomotive of older design, but due to its availability, it was chosen for creating of the scaled model. Performed calculations are based on an analytical approach. The dimensional calculation comes from the strength and plasticity theory. There are calculated parameters of the screw coupler and the buffers. These structural units are important mainly during acceleration and deceleration of the vehicle during operation.

Keywords – calculation, locomotive, scaled model, screw coupler, buffer.

1. INTRODUCTION

Railway modelling is a long-standing activity that combines technology and creativity. It is an activity in which people with a passion for railways strive to create functional, realistic scale models of real railway systems. In addition to the vehicles themselves, their operating environments are also created, such as tracks, landscapes, buildings, station buildings and various infrastructure accessories. According to the National Modelling Association (NMRA), it also includes a lot of work from planning to subgrade construction, electrical installation, environment construction, to the detailed creation of vehicles and their technical elements.

When designing the structural parts of the vehicle, it was necessary to base the design on a real existing locomotive. When making the selection, it was necessary to consider several factors that significantly influence the design solutions when creating the

model. Since it is a 1:8 scale model, the resulting model will be reduced by 8-times compared to the real locomotive. The main criteria are the manufacturability of individual components, economic and efficient production and structural simplicity of the proposed solution, the availability of technical documentation, as well as the possibility of a physical inspection of the locomotive. Based on these input conditions, the shunting locomotive R799 was selected (Fig. 1). Fig. 2 depicts a compositive view to the chosen locomotive.

A screw coupler and buffers device located on the front ends of the main frame serves to connect the individual rail vehicles (i.e. a locomotive and wagons) in a train and to transfer longitudinal forces between the vehicles. With its spring device, it is able to absorb a significant part of the dynamic longitudinal forces that arise during the operation of railway vehicles, especially during starting and braking, and mainly during shunting movement. Most railway vehicles on

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the European standard gauge railway network use a coupling device with separate functions for the transfer of push and pull forces as standard. A screw coupler in the form of a hook and a screw is used to transfer the pull forces, and two buffers mounted symmetrically to transfer the pressure forces [1, 2].



Fig.1. A locomotive R799 class

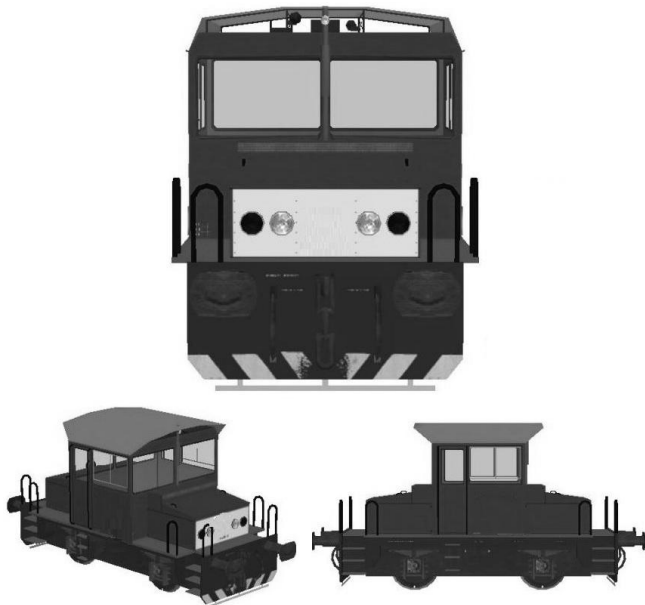


Fig.2. A compositive view of the chosen locomotive

The main objective of the presented work is to calculate the selected parameters of the screw coupler and buffers, which will be mounted on a scaled model of the chosen shunting locomotive.

2. CALCULATION OF PARAMETERS OF THE SCREW COUPLER

The suspension of the screw coupler hook is an important part of the screw coupler of a railway vehicle. Its main function is to reduce the dynamic shocks associated with starting. The elastic element in the screw coupler allows partial deformation of the system when longitudinal forces are applied, thereby absorbing and gradually transferring energy [3]. This reduces the stress on individual structural parts and at the same time improves the operational properties of the vehicles. The calculation of the suspension is

based on the requirements for damping the longitudinal forces acting in the drawbar.

Fig. 3 shows the assembly of the screw coupler. It consists of a hook, guide, pin, tie bolt and a spring-loaded body with an annular spring. The tow hook forms an external functional member for capturing the coupled vehicle. It transfers the load to the internal towing mechanism via the pin. The design is based on the principle of two mutually sliding tubes. The external tube performs the function of supporting and guiding casing, and the internal tube is connected to the moving part of the mechanism. A tie bolt is located in the rear part of the assembly, which serves to connect, adjust and transfer force to the elastic system. The annular spring ensures elastic shock absorption. When the towing force is applied, the internal parts in the guide move longitudinally, the spring is compressed and the load is smoothly transferred. The location of the drawbar hook also allows to be rotated in a horizontal plane, which is especially necessary when passing through curves in the track, when their relative position changes.

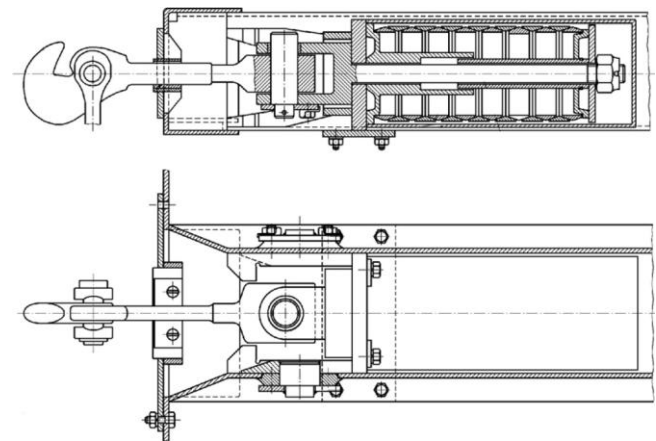


Fig.3. A conceptual view to the screw coupler

The basic assumption for the design of the spring and ensuring its proper operation is the loading force. This force was defined when calculating the resistances, i.e. 79.2 N. It is assumed that a situation may arise where the load increases due to the action of a dynamic shock [4]. Therefore, the dynamic safety coefficient $k_d = 2$ was chosen:

$$F_{pt} = F_o \cdot k_d = 79.2 \cdot 2 = 158.4 \text{ N} \quad (1)$$

Thus, the maximum force F_{pt} that was considered in the calculation is 158.4 N. The maximum stroke considered is 20 mm. After determining these two parameters, it was possible to calculate the required spring stiffness k :

$$k = \frac{F_{pt}}{x} = \frac{158.4}{20} = 7.92 \text{ N} \cdot \text{mm}^{-1} \quad (2)$$

Since the design of the locomotive model is based on the use of standardized components, the screw

coupler spring will also be selected as a standardized element. In the previous section, the required functional parameters of the spring, design force, working stroke and required stiffness were determined by calculation. These values represent the basic criteria for selecting a suitable spring [5]. Other geometric parameters of the spring, such as wire diameter, number of turns, free length, inner and outer diameter, will be selected from the range of standardized springs. In CAD modeling, a specific standardized spring will then be selected, which will satisfy the spatial and geometric conditions in terms of geometry and will also meet the calculated stiffness and working stroke. Fig. 4. shows a 3D model of the designed screw coupler of the locomotive scaled model.

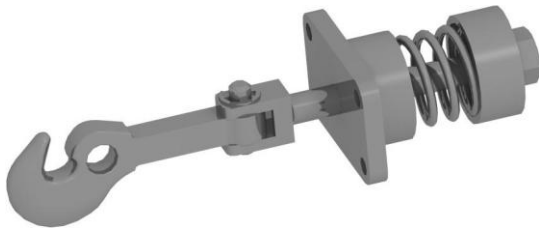


Fig.4. The three-dimensional model of the screw coupler

The concept of the screw coupler was chosen from Fig. 3, which shows the connection of the screw coupler hook to the screw coupler bolt using a pin. The screw coupler hook is rotated around this pin. At the same time, it is subjected to double shear stress during the transfer of forces. Therefore, it was necessary to design its diameter using dimensional calculation [9]:

$$\tau_s = \frac{F}{S} = \frac{F_{pt}}{2 \cdot \frac{\pi \cdot d^2}{4}} = \frac{2 \cdot F_{pt}}{\pi \cdot d^2} \quad (3)$$

Formula (3) shows the basic relationship for shear stress. The area S must be multiplied by 2 because it is a double shear. To calculate the minimum diameter d of the pin, it is necessary to include the material properties in the calculation. C45 steel was chosen as the material.

C45 steel is an unalloyed structural carbon steel with a medium carbon content, which is commonly used to produce machine parts stressed for strength, such as pins and shafts. It is characterized by a good ratio of strength, toughness and is also suitable for heat treatment. The permissible shear stress is stated as 80 to 120 MPa. The average value, i.e. 100 MPa, is taken for the calculation [14]:

$$\tau_D \leq \tau_s \Rightarrow \tau_D \leq \frac{2 \cdot F_{pt}}{\pi \cdot d_{min}^2} \quad (3)$$

Then:

$$d_{min} = \sqrt{\frac{2 \cdot 140}{\pi \cdot 100}} = 0.94 \text{ mm} \quad (4)$$

By expressing the diameter d_{min} from the strength condition, the minimum value of the pin diameter was determined. However, this value cannot be the final value and must be adjusted by the safety factor k_s . The value of the safety factor was chosen to be 3. Therefore, the final value for the pin diameter is calculated as follows:

$$d = d_{min} \cdot k = 0.94 \cdot 3 = 2.82 \text{ mm} \quad (5)$$

Thus, the final value of the pin diameter is of 2.82 mm. The calculated value serves as an indicative basis for the structural design and subsequent CAD modeling of the drawbar. When creating the 3D model, the pin diameter will be adapted to the normalized dimensions and design requirements, while the nearest larger normalized diameter will be selected.

3. CALCULATION OF PARAMETERS OF BUFFERS

Buffers on locomotives serve to absorb impacts during vehicle contact, especially when coupling or when transmitting longitudinal forces during travel. Their role is to reduce the magnitude of impacts, protect the vehicle frame and other parts from damage, and at the same time contribute to a smoother transfer of forces between vehicles [6].

The buffer (Fig. 5) consists of a buffer plate, a base plate for attachment to the vehicle frame, a basket tube and a buffer tube as a guide sleeve. The inner part consists of a rod guided in a flexible member, which is usually in the form of an annular spring. The assembly is supplemented with washers and guide elements, and a screw for adjusting the preload [6].

Forces act on the buffers, just like the screw coupler. The calculation of the buffer spring is based on determining the magnitude of the load acting on the buffer and the required stroke when compressed. For the model under consideration, the load caused by the deceleration of the system, i.e. the braking force, is considered [7]. When braking, the force of the towed system is transferred to the locomotive. This force depends on the mass of the set and the braking deceleration. A 3D model of the designed buffer is shown in Fig. 6.

The braking deceleration considered is $0.15 \text{ m} \cdot \text{s}^{-2}$. That is, the deceleration for normal operation.

$$F_b = m \cdot a_b = 300 \cdot 0.15 = 45 \text{ N} \quad (6)$$

The braking force transmitted to the front of the locomotive is 45 N. This force must be absorbed by the two bumpers that will be mounted on the fronts of the locomotive.

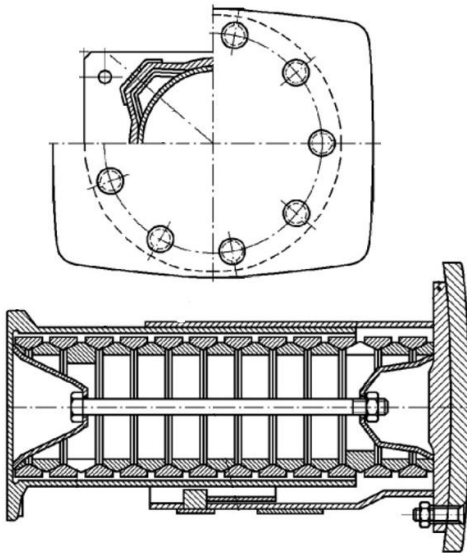


Fig.5. A conceptional view of the buffer

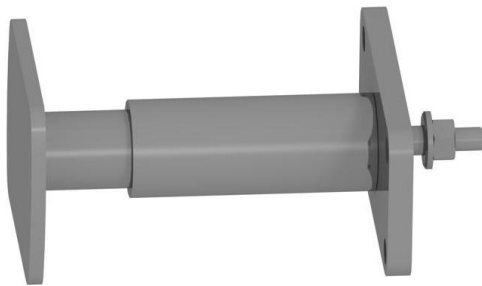


Fig.6. A three-dimensional model of the buffer

As a result, the force is ideally distributed evenly, i.e. 22.5 N per a buffer. Due to the occurrence of dynamic shocks, sudden braking with high intensity, it was necessary to increase this force by a safety margin. Therefore, the load was increased to 35 N per a buffer. The working pressure was determined to be 5 mm:

$$k_b = \frac{F_b}{x} = \frac{35}{5} = 7 \text{ N} \cdot \text{mm}^{-1} \quad (4)$$

Both the screw coupler and the buffers will contain a coiled compression spring. Since this is a standardized part, it will be necessary to choose a spring with the closest parameters. An important parameter will be the closest stiffness while compromising with the dimensional conditions of the frame. Therefore, the buffers are designed primarily as an element for transmitting operating forces with a limited ability to absorb minor impacts, not as a full-fledged system for absorbing kinetic energy in a frontal impact of the entire set.

4. CONCLUSION

The presented research was focused on calculation of the selected parameters of the screw coupler and

buffers, which will be mounted in a scaled mode of the shunting locomotive. These calculations were performed by an analytical approach. There are calculated forces, stiffnesses and deflections of the chosen components. The chapter Conclusion which summarizes the paper is obligatory. The future research will be focused on calculation, analysis and dimensioning all important components of the locomotive, which are necessary to launch the locomotive to a real operation.

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REFERENCES

- [1] Kalinčák, D., *Rail vehicles I* (in Slovak), University of Žilina, Žilina, Slovak Republic, 2008.
- [2] Zošiak, M., *Design of selected structural elements of the travel of a two-axle locomotive in a scale of 1:8* (in Slovak), Qualification thesis, University of Žilina, Žilina, Slovak Republic, 2026.
- [3] Serajian, R., Mohammadi, S., Nasr, A., *Influence of train length on in-train longitudinal forces during brake application*, Vehicle System Dynamics, 57, 2, 192–206, 2019.
- [4] Wu, H., Luo, S., Fu, B., Wang, L., Wang, L., *Research on adaptability of diesel locomotive in plateau railway based on dynamics*, Proceedings of the SPIE conference, Seventh International Conference on Electromechanical Control Technology and Transportation (ICECTT 2022), 123020E, 2022.
- [5] Xu, P., Qu, C., Yao, S., Yang, C., Wang, A., *Numerical optimization for the impact performance of a rubber ring buffer of a train coupler*, Energies, 9, 10, 225, 2021.
- [6] Zhang, Z., Chu, G., Lv, K., Wang, F., Zhang, Y., *Experimental investigation on the dynamic performance of a heavy haul locomotive and its coupler and buffer system under longitudinal forces*, Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit, 240, 4, 465–476, 2026.
- [7] Musayev, J., Zhauyt, A., Solonenko, V., Alipbayev, K., Kaliyeva, N., Smailova, G., Kurmangaliyeva, N., *Modeling the interaction of the rolling stock and the track in the emergency braking mode of a passenger train*, Engineered Science, 40, 2026.