A NEW SOLUTION FOR IMPACT ENERGY DISSIPATION DURING COLLISION OF RAILWAY VEHICLES

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1. Introduction

In the railway industry, the necessity of increasing passive safety is a very important task. In order to protect the passengers, train drivers and goods transported on the railway, one of the measures that has to be taken according to the requests of the standard EN 15227:2008+A1:2010 is the controlled absorption of impact energy. In the last 15-20 years, significant progress was noticed on the use of permanent plastic deformation for energy absorption. Witteman [1] showed that the profile with hollow circular section (pipe) should be preferred for energy dissipation, taking into account the energy absorption level and reduced costs. Shakeri et al. [2] described an efficient procedure for impact energy absorption by plastic deformation of a pipe and friction. Another solution, based also on the plastic deformation of a pipe introduced in a tapered ring and on the friction between the pipe and the ring was presented in [3] and [4].

This paper describes the design of a new structural element dedicated to the impact energy absorption for railway vehicles using controlled plastic deformation, as a reliable solution for passive safety during impact of railway cars and locomotives. The energy Q necessary to be dissipated in the plastic collision was established with an average value of 1.1 MJ, for usual maneuvers velocity (10…15 m/s) and for masses between 50 t (cars) and 130 t (heavy locomotives). The relationship used to obtain this energy can be found by writing the equations of conservation of momentum and kinetic energy in plastic collision:

$$m_1\vec{v}_1 + m_2\vec{v}_2 = (m_1 + m_2)\vec{v}\,;\quad \frac{m_1 v_1^2}{2} + \frac{m_2 v_2^2}{2} = \frac{(m_1 + m_2)v^2}{2} + Q$$

where v is the velocity after impact. It should be mentioned also, that a part of the energy Q is absorbed by the buffers and only the remaining part should be dissipated in the newly design absorbers.

2. Design of a new impact energy absorber

A cross section through the new impact energy absorber is shown in Fig. 1. Two absorbers are mounted, one on each buffer. Energy is dissipated in four elements of the structure: 1. The deformable pipe 5 which can expand its diameter with about 24% in case of an impact by being pushed inside the tapered penetrator 6; 2. The penetrator 6 which can absorb energy through friction with the pipe; 3. The support flange 7, on which eight cutting tools are fixed, which cut the deformable pipe and 4. The bending flange used to bend the deformable pipe after cutting.

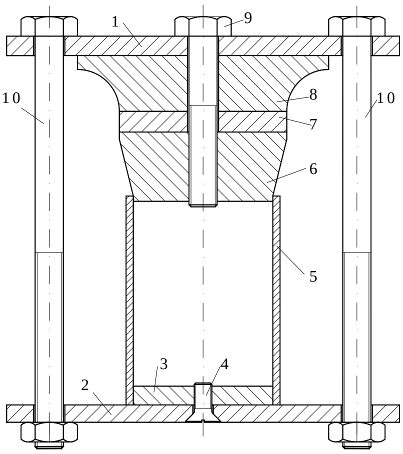

Fig. 1. Section through the impact absorber:
1. Frontal sleeper; 2. Fixing plate; 3. Guiding flange; 4. Fixing screw; 5. Deformable pipe; 6. Tapered penetrator; 7. Cutting support flange; 8 Bending flange; 9. Fixing screw; 10. Pre-stressing screws.

The steel S235JR was used to manufacture the deformable pipe due to its good ductility and toughness. It has a yield limit of 235 MPa and a ultimate strength of 360 MPa. The other elements used to dissipate energy were manufactured from a tougher alloyed steel 45Cr2 (with yield limit 540 MPa and ultimate strength 780 MPa). As indicated in [1], a pipe shaped deformable element was chosen. As stated in standards EN 12663-1/2010 and EN 12663-2/2010, the condition of plastic deformation only for compression loads higher than 2 MN was imposed in the design process. In order to protect the strength structure of the chassis, a value of 2.5 MN (1.25 MN on each absorber) was considered. Consequently, the length of the element can be inferred from the condition that the dissipated energy *U*, considered with the average value of 1.1 MJ (0.55 MJ on each absorber) is equal to the mechanical work of the force $W=F\cdot l$. A value l=0.44 m is thus established.

The total length of the deformable pipe was chosen with the value of 500 mm. It's external diameter is 273mm with a wall thickness of 6.3 mm, resulting thus a cross section area A=5278 mm^2 and thus, a normal stress $\sigma=F/A$=236.8 MPa in compression, slightly higher than the yield limit. One end of the pipe is fixed and the other is deformable through the tapered penetrator.

The penetrator (Fig. 2) was designed with an angle of 60° and with a 24mm diameter threaded central hole. The material 45Cr2 was chosen as to ensure only small elastic deformations during collision.

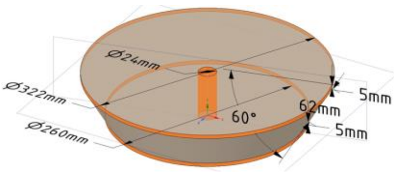

Fig. 2. The tapered penetrator.

The cutting support flange has a radius of 161mm, a height of 10mm and contains eight cutting tools uniformly distributed in the cross section with a 45° angle between them. The width of each tool is 6mm and their length exceeds the maximum diameter of the penetrator with 6mm. Thus, during deformation, they can produce in the pipe eight longitudinal grooves, located symmetrically with respect to the longitudinal axis.

A 3D view of the bending flange, the fourth element used to dissipate the collision energy and which would act in the final stage of the collision if necessary, is shown in Fig. 3.

3. Calculation of the absorbed impact energy

From the entire length of 600 mm, only about 480 mm is the active part of the energy absorber. On this length, a total amount of 1.1 MJ on both elements mounted on the buffers should be dissipated. Based on the dimensions of the elements and the mechanical characteristics of the material, the energy dissipated in each element was calculated as the mechanical work of all forces acting during collision. The results are presented in Table 1.

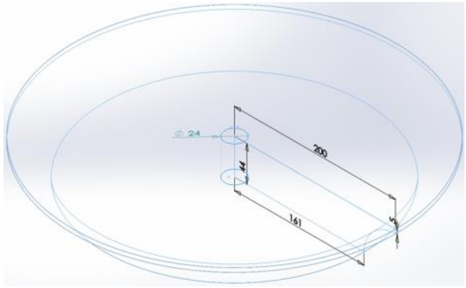

Fig. 3. The bending flange.

Table 1. Energy absorbed in the active elements.

	Expansion of element 5	Friction in element 6	Cutting inside element 7	Bending of element 8	Total
Energy [kJ]	224	252	37.4	47.8	561.2

4. Conclusions

The new energy absorber designed by the authors uses controlled plastic deformation, as a reliable solution for passive safety during impact of cars and locomotives. The calculation of the energy dissipated in all four active elements shows a total amount of 561.2 kJ for each absorber, which is more than the proposed target of 0.55 MN, established based on the common velocities and masses of railway cars and locomotives. Thus, this element can be successfully used as a solution that can diminish the consequences of train collisions. Verification of the obtained results using computer simulations and experiments is to follow as the next step for validation of the proposed structure.

References

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