Standards and new design of absorbing devices for automatic SA-3 couplers

Differences in operating conditions of coupler devices of the European railroads' 1435 mm standard track gauge and the Russian 1520 mm track gauge with SA-3 automatic couplers were examined. Design, performance and testing results of hydro gas draw gear for 1520 mm track gauge developed by experts of the UK and Russia for use in passenger rolling stock are evaluated.

1 Working conditions of couplers

Practically all trains consist of wagons or coaches, joined with various coupler devices for mechanical connection between the vehicles. In this area special absorbing devices should be placed that provide energy absorption of the vehicles between each other when the train formation is going on and during the braking phase when an uneven deceleration causes longitudinal accelerations or decelerations.

The parameters of the absorbing devices have the greatest impact on the acceleration arising from the longitudinal oscillations in the train set, as well as they determine the level of protection at shock influences. However, the generally recognised, internationally harmonised requirements for the design and parameters of these devices do not exist. And the greatest differences are determined by a variety of coupler devices' structures of which the rolling stock is equipped with.

The European standard for screw couplers for the 1435 mm track gauge railways includes a draw gear which serves to absorb tensile forces. The absorption of energy in the collision of railway vehicles and the amortisation of compressive forces is performed by side buffers. It is their power consumption which is regulated by normative documents to ensure safety.

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The standard for rail 1520 mm gauge automatic coupler device (with model SA-3 automatic coupler), as well as the American standard automatic coupler device AAR, is a draw-buffing gear and includes a draw gear and a yoke. This design allows absorbing devices to receive both tensile and compressive loads. Its parameters provide safety and comfort of passengers. Side buffers installed on coaches with 1520 mm track gauge are only for backlash adjustment in automatic coupler device and its attachment point on the rolling stock.

Thus, the work of absorbing devices in different types of coupler devices and regulatory requirements for them are significantly different. However, in the last century, there were few cases of interaction of rolling stock with different coupler devices, mostly concerning a small number of locomotive-hauled passenger trains between USSR and European countries, which were provided for replacement of the automatic couplers with screw couplers and back.

In recent years the penetration of foreign rail technology to the markets of countries with a 1520 mm gauge has grown considerably. In particular, there should be mentioned the appearance of high-speed trains and their components on the Russian railways, designed and manufactured abroad, and some conflicts are detected between the technical facilities and the current regulations.

2 Basic requirements for draw gears

At present, the Russian railways' most significant and binding standard is named "Safety Standards of the Federal Railway Transport". Herewith, the standards of railway products are certified. Due to the fact that the railways of the CIS (Community of Independent States) and the Baltic countries operate a corporate fleet of vehicles, their requirements are identical.

One way to solve the conflict for Russian Railways is to provide certification bases – it is quite justified in cases where the existing "Safety Standards" set based on the experience of the previously known designs cannot be applied to some entirely new designs. However, the products that meet current standards without any compromise on their requirements have the greatest demand in the market of the countries with the 1520 mm gauge railways.

Regarding the topic of this article, the "Safety Standards" for automatic coupler device (НБ ЖТ ЦВ-ЦЛ 022-2000) establish the requirements just to four parameters of draw gears of coach coupler devices, which require confirmation by certification tests. These requirements are quite reasonable, and non-compliance with them (even legalised with the certification basis) are giving noticeably negative quality, reducing interest in this to the design.

Among the requirements are the following:

- Nominal power consumption should be at least:
  - 35 kJ for locomotive hauled vehicles (at a maximum force of 1.5 MN)
  - 20 kJ for multiple units and high-speed trains (at a maximum force not more than 1.0 MN).

Of course, calculations and mathematical simulation can easily show that at the normalised speeds of collision of vehicles (3 km/h) the set values of energy are high. If we take into account crash scenarios as described in the TSI Rolling Stock, the power consumption is a hundred times higher than the value set here. Certainly collisions with speeds slightly above standard values have a significantly higher probability than accidental collisions, in which you must have a crash system.

- Reduction of capacity of draw gears under extreme operating temperatures, for which the rolling stock using the given absorbing device was designed, should not exceed 30%.

This requirement is, of course, necessary for Russia, given the severe climatic operation conditions. However, it is not mandatory for non-automatic couplers of cars of high-speed trains in the presence of emergency buffers (which must provide the required capacity at extreme temperatures).

▷ The resource of draw gear (defined for reducing capacity by no more than 10% of the original nominal value) must be provided after the introduction of 25 MJ of energy.

This requirement provides preservation of the function of the draw gear between scheduled repairs of rolling stock.

▷ The strain of the preload (minimum force that must be applied to the draw gear at quasi-static loading, so it starts to shrink) must be in the range of 0.025 to 0.08 MN.

It's necessary to look at this requirement in greater detail, since this measure has the greatest impact on the longitudinal acceleration during transition conditions of the train.

3. The influence of the strains of preload of draw gears on passenger comfort

Within the 1435 mm track gauge railway system, for locomotive-hauled trains the strain of preload of the draw gear is limited, mainly on the basis of other factors. There, side buffers are the main energy-absorbing devices. The buffers of vehicles of the 1520 mm track gauge system have greater rigidity.

While negotiating a tight track curve the centre distance between the vehicles increases, so that the tensile forces cause stress at the draw hooks. High level of primary strain preloaded will hamper it, thus the wheels cling to the inner flange of the rail and it might cause a derailment in extreme conditions, but mostly it results in extra wear of the wheel and rail flanges.

On the 1520 mm gauge railways the lower limit of the required range of strains of preload is set to increase the capacity of the draw gear. In absence of such a compression the stroke of the gear will occur at low power, almost with no absorption of energy.

The upper limit of standard range of strains of preload of the draw gear is determined by the condition of comfort and safety of passengers during the action of longitudinal accelerations of varying level. These accelerations are caused by changes in the longitudinal forces that occur in all modes of the train movement: starting off, braking, and when the train moves on different line gradients.

To reduce the longitudinal acceleration in the train movement the draw gear should have gentle power characteristic - without failures and jumps of power. Because of the presence of such jumps it is unacceptable to use friction draw gears. Each failure of force occurs on the value of its level ΔP from one end of the vehicle while maintaining the same level of force on the other end. This causes a jump in the middle of the longitudinal acceleration on value ΔP/MT, where MT is the effective tare-mass of the vehicle.

However, the impact on the comfort is provided not only by failures of power. Adversely affected by the high level of strain of preload of the draw gears, as in the steady state of motion (when the longitudinal forces in the train are lower than of the preload strains of gear) even minimal external influence causes an abrupt increase and subsequent decline of force in the gear with little energy absorption. At a change of acceleration occurs vibration with a frequency depending only on the rigidity of the carbody and that is most unfavourable for the passengers.

When the preload of the draw gear is reduced or total excluded, the rigidity of the vehicle-to-vehicle connection is equal to the rigidity of the draw gears, i.e. next lower order. This provides a corresponding reduction in the frequency of the oscillations. At the same time the amplitude of a longitudinal acceleration is also reduced. This is due to the following: When the strain of preload is below the level of longitudinal forces in the train, the compression and unloading of the draw gear takes place. At the same time its rigidity is significantly lower than the rigidity of the carbody. Therefore the rate of change of power and differential force in the draw gears at opposite ends of the vehicle decreases, which determines the longitudinal acceleration acting on the body of the vehicle (it is defined as the ratio of forces of the opposite ends of the coupler of the vehicle divided to its mass) . As a result reducing of strain of the preload of the draw gear causes significant improvement of comfort under the action of longitudinal vibrations. All existing methods for evaluating the vibration comfort of passengers (e.g. in accordance with UIC Code 513 OR "Guidelines for evaluating of vibration comfort of passengers in railway vehicles") take into account the frequency and amplitude of the vibration, so that the positive effect of reducing the preload strain will be confirmed by all existing methods of assessment.

To illustrate this, there is given a mathematical model of the movement of a locomotive-hauled passenger train in the full service brake. Fig. 1 shows a graph of the power characteristics of the vehicle-to-vehicle communications standard for 1520 mm gauge railways including model SA-3 coupler, draw gears and side buffers.

This power characteristic includes: the line of loading and unloading of buffers (3), the line of loading (1) and unloading (2) of the vehicle-to-vehicle communication (including buffers and draw gear) under the action of tension and compression forces, the line of elastic deformation of the vehicle (4) in tension and compression, and takes into account the gaps in the automatic coupler de-

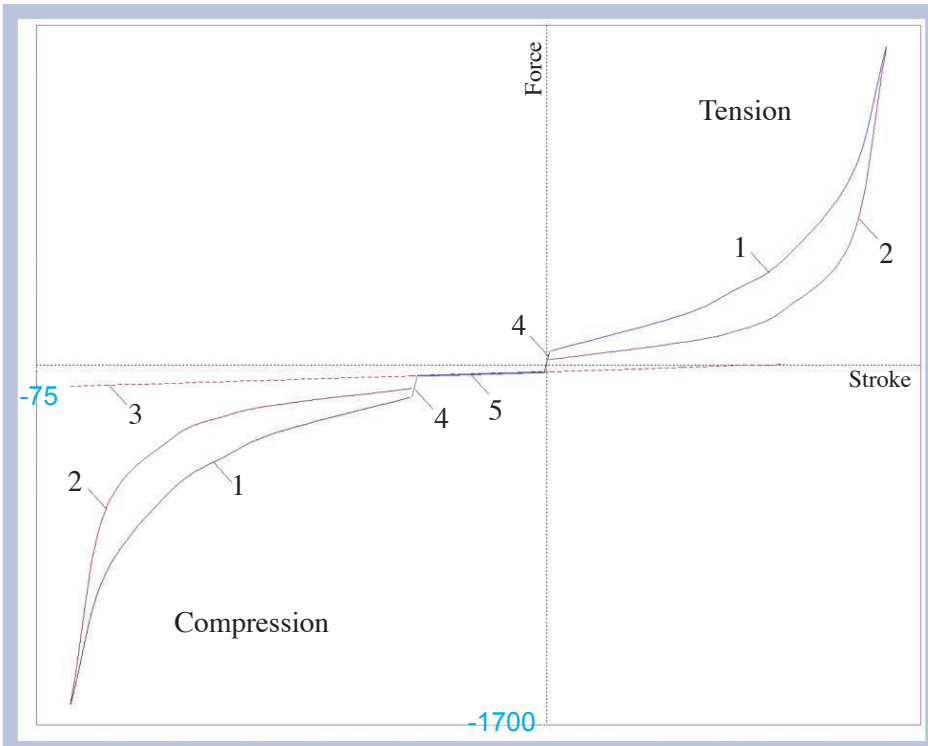


Fig. 1: Power characteristic of vehicle-to-vehicle connection with draw gears and buffers

vice, within which the acting force is equal to the strain of buffers (5).

The modelling of the train movement was performed for three values of preload strain P_0 = 50, 25 and 0 kN. The results of the mathematical modelling of the movement of locomotive-hauled passenger trains during full service braking for these cases are shown in Fig. 2.

The obtained results show that with a reduction in strain of the draft gear's preload the frequency of the longitudinal oscillations of the vehicle and its amplitude also decrease. Both of these factors have a positive impact on passenger comfort.

However, as mentioned earlier, the low level of preload causes reduction of the capacity of the draw gear and, consequently, reduces the protection degree of the rolling stock and passengers in case of emergency.

4 New hydro gas draw gears for coaches

One of the few exceptions are hydro gas draw gears. In train operation modes almost quasi-static loading occurs, in which the flow of liquid is almost without resistance and the strain of preload is determined only by the pressure in the gas chamber. But in collisions (both shunting and emergency), a rapid increase in strain takes place, at the same time the draw gear has a large capacity.

However, the Russian Railways (RZD), as the other 1520 mm gauge railways, traditionally didn't have any experience of use of hydro gas draw gears for passenger trains. Unlike wagon draw gears of RZD rolling stock (long separated into classes with different capacity, depending on the specials of wagons by type of transported goods), passenger vehicles' draw gears didn't have the classification and it did not stimulate the creation of new models with higher capacity. But there is the need for such gears: for passenger cars operating in conditions of high dynamic loads, as well as for mainline locomotives for passenger trains.

The first case enclose passenger cars included in freight trains and head vehicles of electric trains, providing the possibility of coupling two complete trains with each other, as well as EMUs and DMUs consisting of articulated vehicles. All these options lead to high demands on the capacity of draw gears.

Draw gears of high capacity are fitted on locomotives. Locomotives for passenger trains weigh more than 120 tons and a double locomotive weigh more than 170 tons. At the same time, because of the high preload strain of these draw gears the longitudinal vibration and, correspondingly, the comfort of passengers in the first coach after the locomotive is significantly worse than in other coaches, which shows the usefulness of a high capacity draw gear, but with a reduced level of longitudinal accelerations.

And so, in this area an example of successful cooperation of European and Russian organisations has appeared – creating of hydro gas passenger vehicle draw gear by British companies "ADPO Couplers" and "OLEO International" with Russian companies, "Zircon service" (producer of luxury coaches) and the All-Russian Scientific Research Institute of Railroad Transport "VNIIZhT". Mainly in its laboratory of couplers were created: automatic coupler SA-3 and the system of its maintenance, and almost all the regulatory documents on the design, construction, testing and maintenance of coupler devices and their components.

In a short time and thanks to this integration of efforts two models of draw gears of increased capacity were created: AO-80 (for coaches) and AO-100 (for locomotives hauling passenger trains). Along with the development of these gears the production in Russia took place. Not only assembly, but also all of the most metal-intensive items will be made by "Zircon service" in Russia.

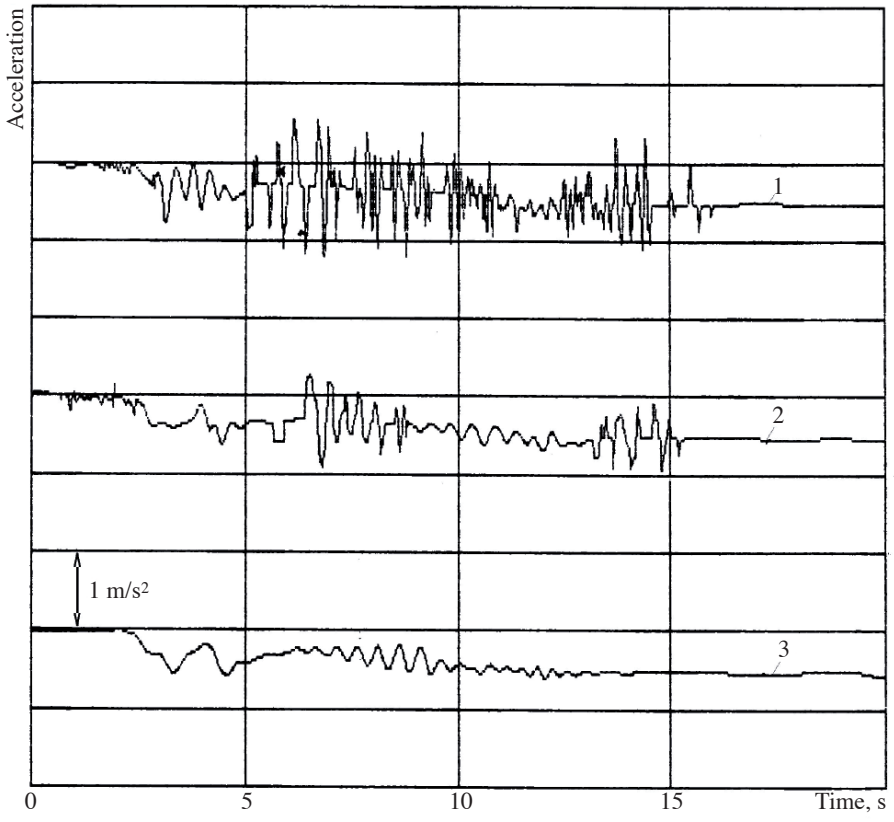
Both models of gear contain a hydro gas capsule and emergency absorber of honeycomb structure, but as the locomotive draw gear AO-100 requires some modification of space to place it, the model AO-80 is fully interchangeable with all passenger cars' gears, operated on the railways with 1520 mm gauge, and that certainly extends the possibilities of the use of this gear.

General view of draw gear AO-80, located in a standard yoke, is shown in Fig. 3, and its power characteristics in Fig. 4.

The tests carried out confirmed that this gear has the following characteristics:

Capacity at a force not more than 1500 kN	≥ 70 kJ
Maximal stroke	80 mm
Preload strain under quasi-static load	25–80 kN
Variation of the capacity at temperatures –40°C and +50°C with respect to +20°C	≤ 10 %
Variation of the capacity after loading at –60°C	≤ 10 %
Coefficient of irreversible energy absorption at quasi-static load	≥ 0.3

The emergency honeycomb energy-absorb-



Legend
1 - P_0 = 50 kN, 2 - P_0 = 25 kN, 3 - P_0 = 0 kN

Fig. 2: Graphics of the longitudinal accelerations occurring in the middle part of a train with full service brake acting

ing element has the following characteristics:

Strain of initial deformation	1700 kN
Capacity	≥ 30 kJ
Stroke	30 mm

As seen from the provided characteristics the positive quality of this design was the preservation of the dynamic capacity in the whole temperature range, confirmed by certification tests at temperatures of 50° and -40° C.

When the temperature decreases, the fluid viscosity increase and correspondingly the strains of its overflow. This is compensated by decreasing the pressure in the gas chamber. At higher temperatures the increase of the pressure is compensated by lower fluid viscosity. While testing there was recorded a reduction capacity in extreme temperatures not exceeding 4 % of the value obtained at + 20 ° C. After loading at -60 ° C the draw gear also didn't get any damage and the reduction of its capacity was only 2%. All these values completely meet the standards, according to the guideline that the reduction shall not exceed 30 %.

5 Conclusion

Hydro gas draw gears for automatic couplers of rolling stock for passenger transport meet the standards for railways with 1520 mm track gauge, and the capacity (the main index that determines the safety of passengers) exceeds the potential of all other draw gears in use. Recently the draw gear models AO-80 and AO-100 obtained certification from the Certification Register of the Federal Railroad Service in Russia and can be installed and operated on all rolling stock for passenger transport within the SA-3-fittet 1520 mm track gauge railway system as well as in other couplings.

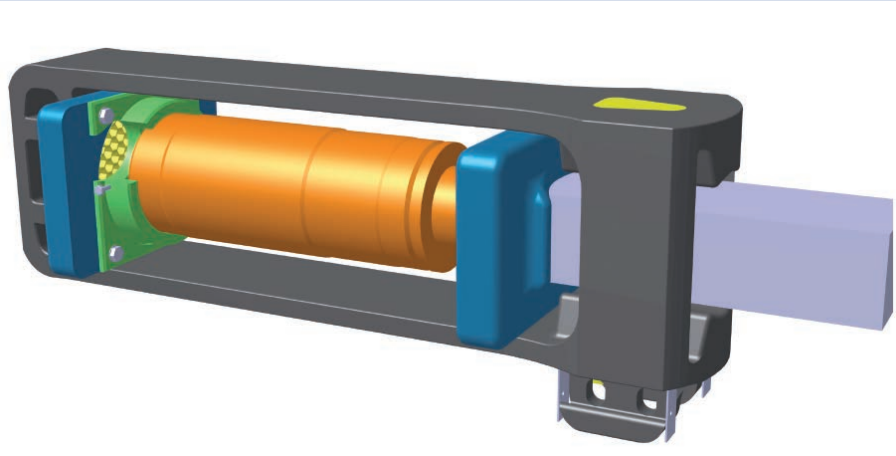
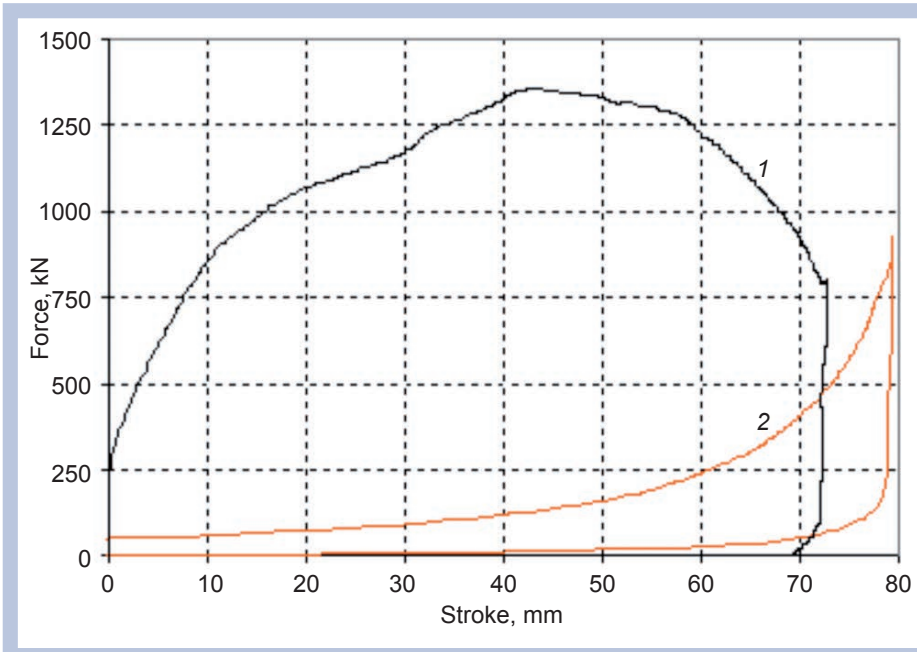


Fig. 3: Hydro gas draw gear AO-80 in a yoke



Legend
1- dynamic, 2 – quasi-static

Fig. 4: power characteristics of the draw gear AO-80