Rubber Suspension, a Solution of the future for Railway Vehicles

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Rubber is widely used in railway infrastructure and in rolling stock. Rubber pads are used in fastening systems of rail to sleepers and rubber elements are used in the primary suspension of Romanian (and foreign) electric locomotives, in freight and passengers railway cars, metro trains and trams; the trams wheels are built with rubber insertion in order to reduce the vehicle unsprung mass. Also, rubber elastic elements are used in railway vehicles buffers. From these examples it can be seen that the rubber elements are used in the construction of parts which are directly contributing to traffic safety.

Keywords: rubber, railway car, suspension, railway safety

Nowadays, when there is a tendency of using vehicles with high transport capacity and able to run at high speeds, the problem of suspension optimization is of particular importance. During its runtime, a railway vehicle is subject to vibration generating pulses, which have negative effects on the ride quality. The vehicle responds to these pulses generated during the rolling process by its suspension, which has to reduce their effect to acceptable levels.

A source of vibration for railway vehicles is represented by vertical and transversal track irregularities and by rail discontinuities at the joints. The rigid fastening of the wheels to the axle and the reversed conicities of the rolling surfaces of the wheels of the same axle produce the hunting motion of the wheelset, which is transmitted to the sprung mass of the vehicle. Wheel defects such as eccentricity and tread flats are also important sources of vibration. Ensuring passenger vibration comfort, the integrity of the transported freight and of the structure itself of the vehicle depends essentially on the quality of the vehicle suspension. The suspension of the vehicle must ensure stable dynamic behaviour while running in straight line and in curves, in the latter case being required also to ensure low guiding forces. Suspension must contribute to the reduction of mutual forces between vehicle and track, keeping them within the limits determined by traffic safety and by the necessity to ensure the protection of both wheelset and track. The suspension consists of elastic elements (springs), shock absorbers (dampers) and connection elements (links, joints, etc.). These elements are mounted, depending on the vehicle type, between the wheelset and the bogie frame, between the wheelset and the vehicle body, between the bogie frame and the vehicle body. The elastic elements of the suspension may be metallic (made of steel), of rubber or pneumatic. Their role is to accumulate a part of the vibration energy and then to return it over time, thus contributing to the reduction of the dynamic loads acting on the sprung and unsprung masses of the vehicle.

Rubber emerged as a material with technical application in 1839, when *Charles Goodyear* discovered and developed the process of vulcanization, by which the plastic rubber can be turned into an elastic material, with proper characteristics to be used in different fields.

The interest for this material, justified by its properties, initiated a series of researches and experiments, which led to the establishment of recipes, mixtures and execution technologies for rubber parts of different shapes and sizes, with characteristics specific to a wide range of applications (rubber resistant within a wide range of temperatures, resistant to oil products, with electrical insulation properties, rubber bonded on metal armatures, etc.). The basic characteristic of rubber is its great elasticity, i.e. the ability to support large deformations under the action of external forces and to recover its original shape when the action of these forces ceases. Rubber elasticity is an intrinsic property, which does not depend on the shape of the part, in contradistinction to steel, which, in order to have an appreciable elasticity, must be manufactured with special shapes (coil springs, leaf springs) i.e. the elasticity is a property of the form. The rubber as a material is incompressible, i.e. a volume of rubber subject to a compressive stress in an enclosed space behaves as an undeformable material so, in order to provide elasticity the rubber part must have the possibility of modify its shape.

The suspension system of many modern railway vehicles uses rubber elastic elements instead of conventional steel springs. In figure 1 is shown schematically a metro train bogie using rubber in both suspension stages.

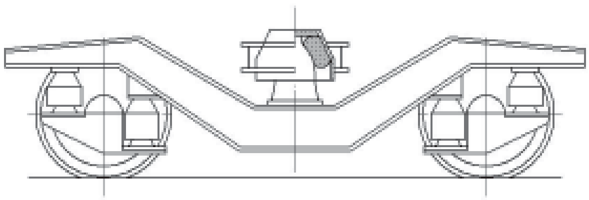

Fig. 1. DT type bogie used in metro cars in Hamburg

Y25 freight bogie

In Europe, after the first half of the last century, as a result of the enhancement of the unification trends for railway components, the bogie Y25 (fig. 2) has been standardized for freight cars. The structure of this type of bogie is virtually unchanged even nowadays. From the point of view of the suspension, the bogie is fitted with metal coil springs.

As a result of the frame-type construction and of the suspension made of metallic elements (fig. 2), the bogie has a high longitudinal and transversal stiffness, which can be detrimental to the ride quality of freight cars in some operating circumstances.

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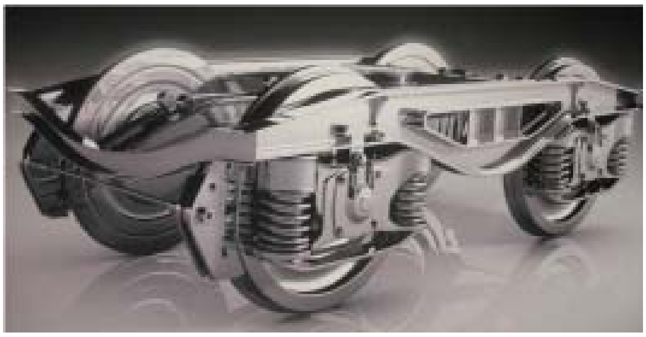

Fig. 2. Y25 bogie used in Europe
in freight cars

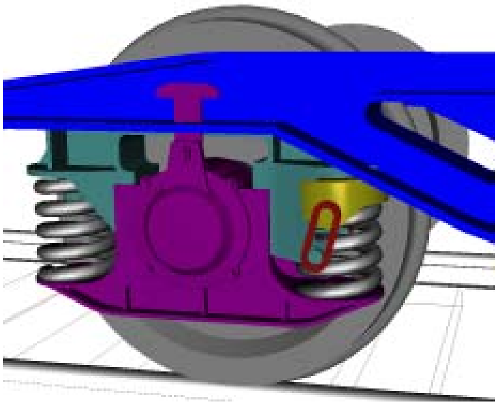

Fig. 3. Y25 bogie suspension

Fig. 4. Y25 freight bogie with rubber suspension [7]

Fig. 5. Y 25 bogie axlebox with cu rubber
suspension [7]

Y25 freight bogie with Continental rubber suspension

In order to eliminate the previously presented disadvantages of Y25 bogie with metal coil springs suspension and to meet the requirements of railway operators, the manufacturer Continental has patented the

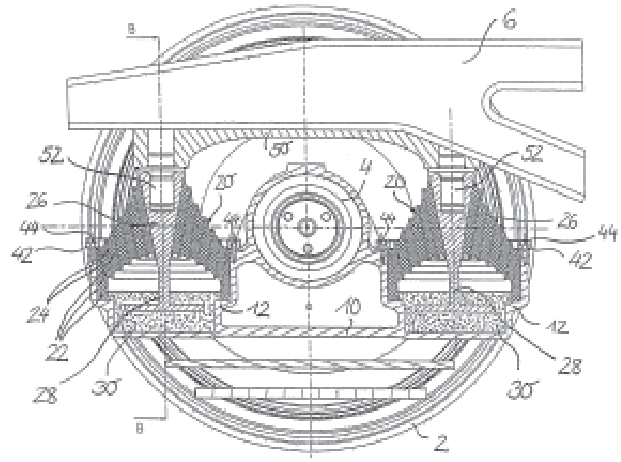

Fig. 6. Rubber springs used in Y25 bogie suspension [8]

rubber suspension for Y25 freight bogie. In figures 4 – 6 is presented this rubber suspension used in Y25 bogie.

Taking into account the changes made to the bogie by introducing rubber springs, it can be seen that it is not affected the mechanical resistance of the bogie structure and the constructive modifications are minor.

The pictured section of the bogie comprises an axlebox **10** with a rolling bearing **4** mounted in a middle region of the axlebox**10**. The rolling bearing **4** supports one end of one of the two axles of the bogie. A base of the axlebox **10** is extended to the left and the right side forming a cup shaped region **12** at each of the sides. Each of the hydraulic springs comprises a spring element **20** which is attached to each of the cup shaped regions **12** of the axlebox **10**. A metallic centerpiece **26** is located in the center of each of the spring elements **20**. These two centerpieces **26** are attached to one bridging adapter **50**. Therefore the centerpieces **26** and the bridging adapter **50** have bores for connecting the centerpieces **26** with the bridging adapter **50** via two bolts **52** pictured uncut in figures 1 and 2. In other embodiments, the bolts **52** can be integral parts of the centerpieces **26** or of the bridging adapter **50** or the centerpieces **26** can be connected to the bridging adapter **50** by any other connecting means. The bridging adapter **50** is attached to a longeron of a frame **6** of the bogie. This longeron extends in a longitudinal direction parallel to the rails and is pictured uncut in figure1. Preferably the bridging adapter **50** is connected to the bogie frame **6** by welding. In the following description, just the left cup shaped region **12** in connection with the left spring element **20** is described in detail, because the same applies to the right cup shaped region **12** in connection with the right spring element **20**. Figure 2shows a sectional view along the line B-B of figure1. The spring element **20** comprises sleeve shaped elastomeric elements **22** and intermediate sleeve shaped metallic elements **24** in an alternating succession, whereby the elastomeric and the metallic elements **22** and **24** are connected by way of vulcanization. Also the centerpiece **26** is connected by way of vulcanization to its adjacent elastomeric element **22**. The spring element **20** is secured to the respective cup shaped region **12** of the axlebox **10** via a sealing ring **42**, which is attached to the axlebox **10** via screws **44**. In other embodiments the spring element **20** also can be directly vulcanized to the cup shaped region **12**. The spring elements **20** forms together with the respective cup shaped region **12** of the

Fig. 7. DRRS25 bogie [9]

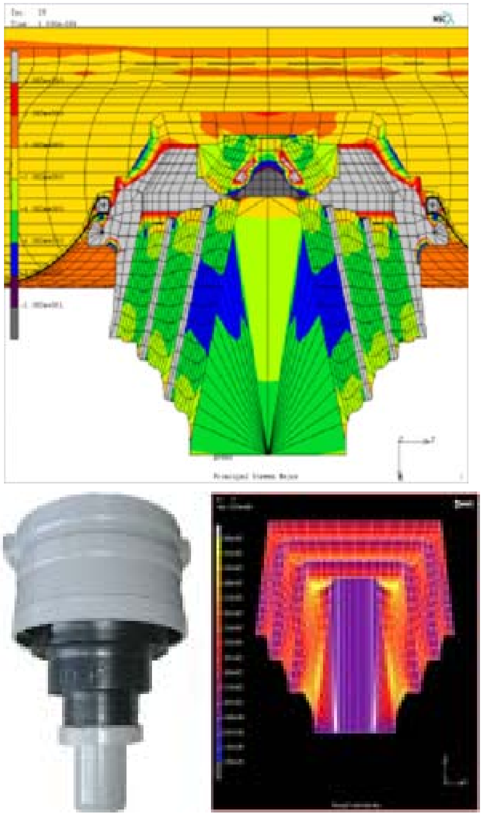

Fig. 8. Studies performed on rubber suspension [10]

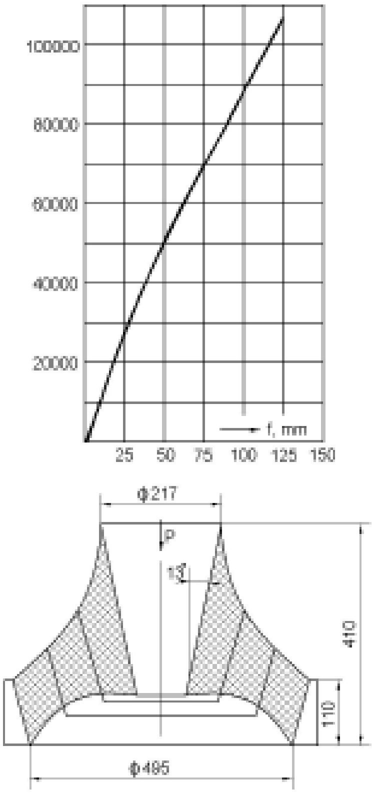

Fig. 9. Rubber conical spring and its load/deflection characteristic curve [3]
Fig. 9. Clouth-type spring

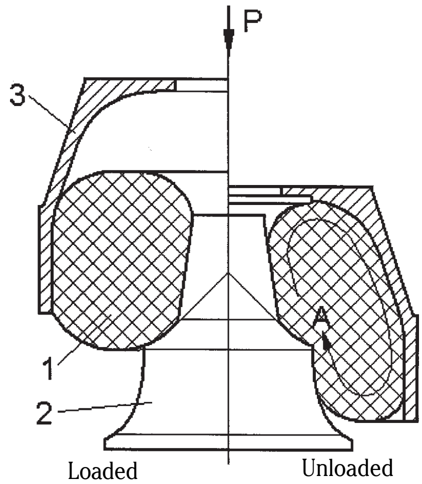

Fig. 10. Clouth - type sspring

axlebox **10** a volume for a fluid **30**, particularly a hydraulic fluid. This volume is at least partly filled with the fluid **30**. The centerpiece **26** is prolonged into the volume forming a plunger shaped region **28**. Thereby at least a disk shaped region at the end of the plunger shaped region **28** is dipped into the fluid **30**, so that this arrangement fulfils the function of a damper. The cup shaped region**12** of the axlebox **10** together with the respective spring element **20** and the fluid **30** form together the hydraulic spring [8].

Bogie DDRS25

GERMAN Rail (DB) wagon producer DB Waggonbau Niesky has developed a new range of bogies for freight wagons which aim to reduce noise and lower long-term maintenance costs (fig. 7).

The DRRS25 can be fitted with conventional, compact or disc brakes, and all configurations use double rubber rolling springs instead of standard steel springs to help reduce noise resulting from the condition of the track. The disc-braked version reduces noise to 6dB(A) below the TSI Noise standard, and more crucially reduces the perceived noise level by 30% compared with a conventional wagon. Noise-based track access charges will be introduced in Germany by DB Networks from next year and other countries, notably Switzerland, require wagon noise to be managed and reduced. This means the market for quieter bogies could be very large in the future. DB claims disc brakes will reduce maintenance costs by 35% because wheel rims are not worn down by braking, nor is there the risk of wheels overheating due to brakes not releasing properly. DB Schenker has tested the bogies as part of a DB project to develop low-noise freight trains and the bogies meet the relevant TSI standards for freight wagons. The DRRS25 bogie is designed to comply with UIC standard UIC 510-1, meaning it is interchangeable with the standard Y25 type. Swiss intermodal operator Hupac is planning to test the new bogie under its wagons [9].

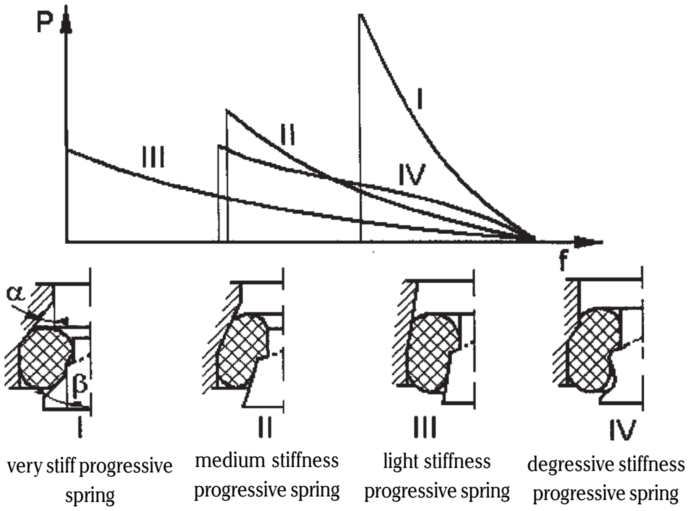

Fig. 11. Influence of the metal housing shape on clouth-type springs stiffness characteristics

Other studies performed at present

Studies concerning the behaviour (fig. 8) of rubber suspension are presented on the website [10].

At the present time, when the trend is to use vehicles with high transport capacity and able to run at high speeds, the problem of suspension optimization is of particular importance for railway engineers [3].

Load/deflection diagrams

The shape and the dimensions of rubber conical springs make them suitable for a large variety of applications, such as suspension elements for sprung parts (compressor, electric traction motors) or elements of the primary and secondary suspension of railway cars. In the following figures are presented the load/defection characteristics of the rubber springs used of bogies shown in figures 4, 7.

For the spring shown in figure 9, the stiffness diagram is obtained for a vertical (axial) load of 80000 N.

The clouth-type springs (fig. 10) are based on the elasticity of compression-extension and torsion of a rubber ring (torus shaped elastic element) forced to roll between two conical surfaces. The rubber torus 1 is mounted between the central pin 2 and the metal housing 3. The load P, axially applied, moves the housing towards the pin, causing the rubber to roll as shown by arrow A in figure 10. At manufacturing, the rubber ring has a circular section of diameter d, as indicated in figure 9 in dashed line, section that deforms when it is mounted and, under load, takes the form shown in solid line. The deformation of torus section between manufacturing and the situation where it is under a load is defined by the coefficient

$$\Psi = [(d-h)/d]100\ [\%] \qquad (1)$$

which must not to exceed 45 ÷ 50%.

As regards the functioning characteristic of this type of spring, i.e. the relation between the load and the deflection, it should be noted that the shape of the two rolling surfaces, the deformation coefficient ψ and the rubber part hardness are elements which can modify this characteristic within wide limits, which makes the mentioned type of spring conveniently adaptable to any required functioning conditions. Thus, the shape of rolling surfaces may result in progressive, regressive or progressive-regressive characteristics. In figure 11 is shown the influence of rolling surfaces shape on the spring functioning characteristics, namely on the axial stiffness characteristic. Inclination α of the housing and pin inclination β are in the range of 10°-30°, so that various combinations can be achieved within these ranges of values. Obviously, high values of inclination result in high stiffness of the spring.

Besides the stiffness in axial direction, the clouth-type springs have also a radial (transversal) elasticity, which is depending on the axial load. This feature increases the field of use of clouth-type springs, as it eliminates the necessity of some guiding systems or links which are required in other systems.

Conclusions

Noise is regarded as the "Achilles heel" of European railways. European Commission is aware of this issue and that is why it desires the reduction of noise, without jeopardizing the competitiveness of rail transport. The main goal is to reduce noise inconveniences caused by vehicles to people living near railway tracks. As the renewal of the rolling stock fleet is slow, the European Commission reached the conclusion that further measures are necessary on existing freight wagons. Since metal suspensions are producing and transmitting noise, a solution would be to replace metal suspension of bogies for freight cars with rubber suspension.

Taking into account also the above mentioned characteristics and performances of rubber suspension, it can be stated that it represents an effective and reliable alternative to metal suspension and constitutes a solution of the future for railway vehicles.

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