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CONSIDERATIONS REGARDING ELASTIC ELEMENTS FROM SUSPENSION OF RAILWAY VEHICLES

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Abstract**: This paper summarizes some aspects of railway vehicle suspension and presents a new type of primary suspension (the link between the bogie frame and the running part) in which the vibration damper is of special construction. The liquid inside the vibration damper is a liquid whith shape memory, in this way, the damper comes into operation only when the device is disturbed during running on the tread.*Keywords**: railway vehicle suspension, shape memory liquid, vibration damper.*

1. General considerations

Railway transportation is in constant competition with other means of transport and has an important share in most countries in the world. It is visible the tendency to increase transport capacity linked to increased traffic speeds and competitive prices offered. Along with the increasing speeds it is required direct approach to road safety problems of railway vehicles. This imposes a thorough study of elastic elements in this case of metal springs that are used in suspension and shock absorbers fitted in vehicles. Railway vehicles most elastic elements can be found at suspension bogies. The bogies provides the running and are made of rigid metal frames where are mounted two or more axles that support the vehicle chassis rail (locomotive, freight or passenger car).

Rail vehicles suspension must meet some technical and economic requirements like high operational safety, reduced weight and volume, low cost, easily accessible location on the vehicle and easy access to the parts that require constant care. The suspension is composed of elastic elements, connecting elements and dampers. These elements are mounted, depending on the construction of the vehicle, between the bogie and running part, between the bogie and the vehicle box. The whole suspension is composed of two subassemblies: primary suspension (between the running part and the bogie frame) and secondary suspension (between bogie and wagon box). In figure 1.1 is presented a type of primary suspension made of two coil springs mounted in parallel.

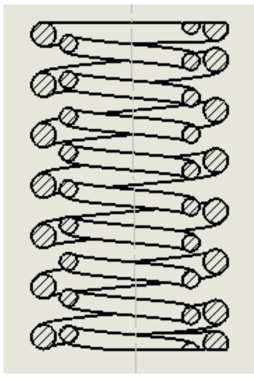

Fig. 1.1 Primary suspension. Double coil spring

During running, the vehicle is subjected to the action of pulses which are generating vibrations with adverse effects on the quality of the running. The vehicle responds to vibration pulses generated in the process of running through suspension, which is designed to reduce the gallop to acceptable values.

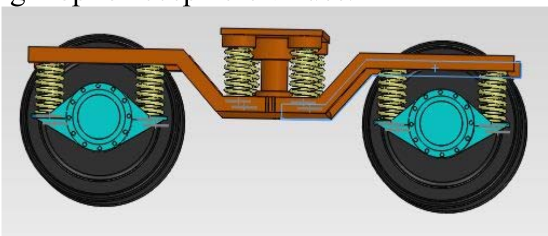

Fig. 1.2 Bogie scheme - suspension with coil springs

Schematically represented in Figure 1.2 is a railway vehicle bogie equipped with suspension consisting of coil springs.

Another source of vibration at railway vehicles is represented by vertical and transverse unevenness of the thread and its discontinuities at joints. An important advantage of coil springs is that their transversal elasticity can be used to provide booster across the wagon box. Lacking the friction this springs do not dampens oscillations and therefore necessary that such suspension contains springs and dampers.

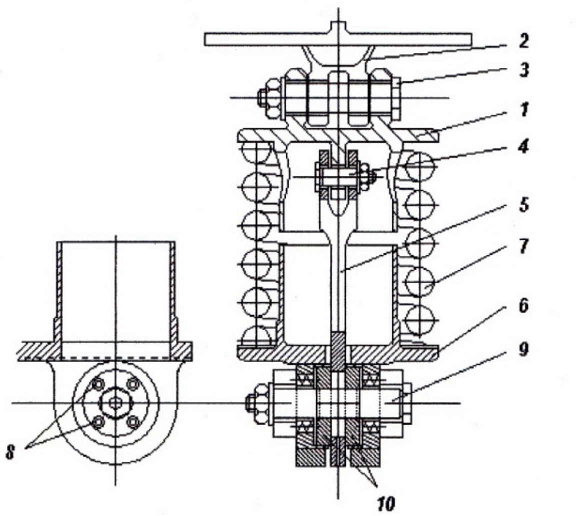

Fig 1.3 friction dampers

One of the most common material used in the rolling stock is friction shock damper shown in Figure 1.3.

Friction damper is composed of a friction rod 5 articulated through the peg 4, at upper pan of a suspension spring 7, the friction plates 10 (made of a friction material) with holes for bolt 9, attached by the lower pan 6, on both sides of the friction rod. Friction plates are pressed on the rod by two groups of four coil springs 8, each group developing a pressing force on the friction rod 5. The damper is placed between the axle box and the wagon box and the bogie frame 2, by which the upper pan of the suspension spring via peg 3. A disadvantage of this damper is the uneven wear of the rod, leading to damper characteristic changes and friction is not a stable value, due to dust and moisture from the atmosphere on the coefficient of friction, damper not being protected. To remove this disadvantage tubular dampers were designed, sealed, represented in Figure 1.4 (used in rolling stock in Germany).

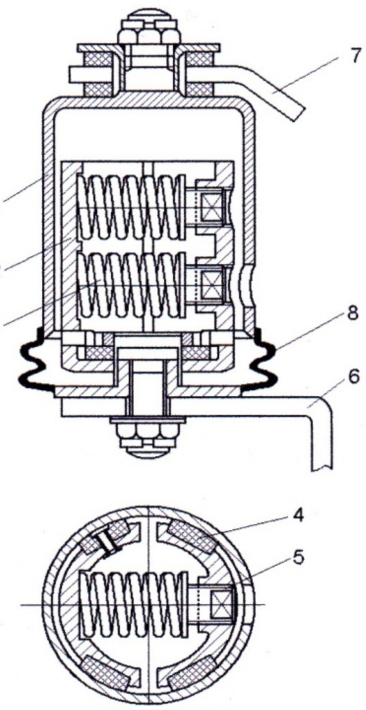

Fig. 1.4 telescopic shock absorbers with constant resistance force

This type of damper consists of the following main parts: a cylinder 1, mounted on the top of the bogie by support 7 and lower cylinder 2, attached to the support of the axle box 9. Amortization is achieved by friction produced in the cylinder and friction linings 4, fixed to the two half cylinders comprising piston damper. The tension of the coil springs 3, on which depends the friction force can be set using adjustment parts 5. The interior is isolated from the outside enviroment via protective bellows 8. The design will be considered to take springs with relatively low stiffnes and relatively high strain to obtain the necessary contact pressure. This is necessary for dampers properties to be influenced as little as possible by contact surfaces movement.

2. Damping characteristics

Vehicles riding on the rails is accompanied by the forced vibration of the masses suspended on springs, which can have large amplitudes, even dangerous to produce the phenomenon of resonance. To avoid this danger vibration dampers are used, these are necessary especially in modern vehicles which are using frictionless elastic elements. The adoption of appropriate damping characteristics is important both in terms of achievement of driving quality of the vehicle and for reducing dynamic overloads at acceptable values. Railways vehicles are generally using hydraulic shock absorbers and friction dampers (referred to as dry friction dampers).

Hydraulic shock absorbers have the advantage that the value of amortization is controllable and can be maintained within the limits set by the study and practical determination of the vehicle vibration. Bitubulare telescopic hydraulic dampers are most used constructive option in railway vehicles. It converts a portion of kinetic energy into thermal energy vibratory movement (which is then dissipated to the outside), the transformation is achieved by viscous friction that occurs when passing through the damper fluid by single section lamellar holes or through holes provided with constant valve whose opening is determined by the pressure of shock. It converts a portion of vibratorys movement kinetic energy into thhermal energy (which is then disipated to the outside), the transformation is achieved by viscous friction that occurs when the liquid in the damper is passing through the single section lamellar holes provided with valves whose opening is determined by the pressure in the damper.

A hydraulic damper is achieving the resistance force (the damping) Fr which is opposing the motion and that depends on the speed of the damper piston.

$$F=\rho\ \dot{z}_r^{i}$$

where: ρ is the damping coefficient and i - the index of power.

Depending on the values of the i index, Fr ($\dot{z}_r$) damper characteristic can be linear, if i=1 , progressive if i>1 (called quadratic if i=2) an regressive if i<1. The characteristic is progressive, in the small zr speeds, low resistance forces which increase with increasing zr speed. In the field of high zr speeds for reducing at acceptable values of the resistance force, regressive characteristic is prefered.

When the damper piston stroke through relaxation or compression, adequate resistance forces will be Frd and Frc (Figure 2.1). Frd and Frc forces at the same absolute speed of zr can be equa or different. Thus, the ratio between damping coefficients at compression stroke respectively rebound, damping effect can be simple (ρ_c=0) and symmetric doube effect ($\rho_c = \rho_d$) or asymmetric ($\rho_c < \rho_d$).

At railways vehicles are used hydraulic dampers with dual symmetric or asymmetric effect. Symmetric characteristic dampers are used for central suspension for both the central vibration damping and of the cross. Asymmetric characteristic dampers are usually used at suspension axles to reduce the effect of shocks produced by the action of joints.

The energy dissipated by hidraulic damper in a compression-relaxation cycle is equal to the surface area delimited by the hysteresis curve force-displacement, this energy depending on the damper characteristic and on the type of load.

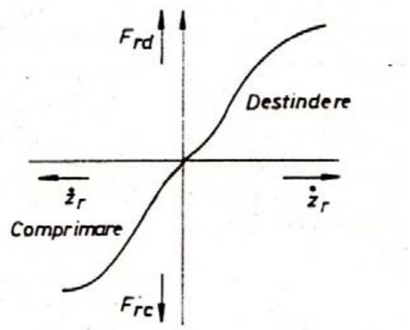

Fig. 2.1 hydraulic damper characteristic

Thus we consider the ideal case of a linear damper subjected to harmonic displacements $zr = z = Z_0 \sin \omega t$, amplitude z0 and pulse ω. In this case the damper is acting with the force

F=Fr=ρż= $\rho \omega_0 \cos \omega t$ =±ρω $\sqrt{z_0^2 - z^2}$ (1)

The energy dissipated by the hidraulic damper in a cycle compresion-relaxation equals the surface area delimited by the force-displacement hysteresis curve, this energy depending on the damper characteristic and the type of load whose variation depending on the z displacement is represented by the ellipse in Figure 2.2.

The energy dissipated by the damper during a period of movement is equal to the mechanical work of the damping force. If the damper is parallel to a linea elastic element whose stiffness is c (Figure 2.2 b), the force transmitted to the sprung masses of the vehicle is

F=cz+ $\rho \dot{z}$ = cz $\pm \rho \omega \sqrt{z_0^2 - z^2}$ (3)

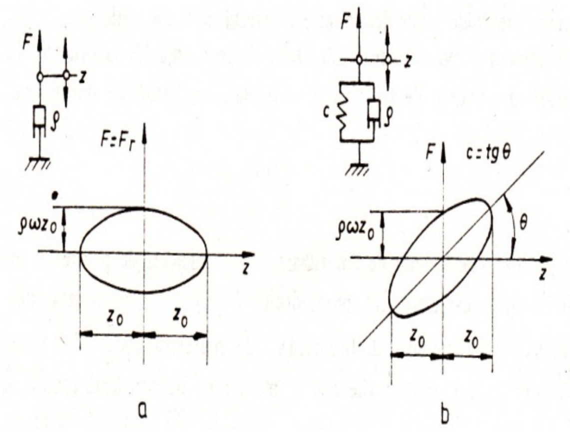

Fig. 2.2 The theoretical characteristics (Fz) for linear harmonic displacement a) for simple damper, b) for a damper in parallel with a spring with stiffnes c.

$$W = \int_0^{\frac{2\pi}{\omega}} F_r \dot{z} dt = \rho \int_0^{\frac{2\pi}{\omega}} \dot{z}^2 dt = \pi \rho \omega z_0^2 \qquad (2)$$

3. A new assembly coil spring - damper

In the following will be presented new thinking about the primary suspension of railway vehicles to replace the primary suspension above. Thus in Figure 3.1 is presented an assembly consisting of a coil spring and a damper of a special construction, which is a liquid agent operating with shape memory.

This assembly serves as a primary suspension for a railway vehicle and is mounted in the place of the springs on the bogie (Figure 1.2), the operating principle is as follows: pan 1 is fixed to the axle box and the pan 11 is secured to the bogie. During operation, the spring 2 is compressed and if we come across some unevennesses on the tread the contact sensors 4 are closing an electrical contact between wires 9 thus magnetizing the fluid (shape memory), which if it is magnetized, its viscosity increases six times, the vibrations being much attenuated.

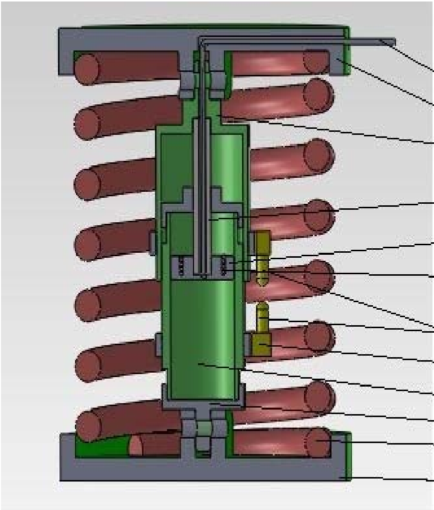

Fig. 3.1 Spring - damper assembly

4. Magnetorheological materials

Magnetorheological materials (MRs) are ferromagnetic ultrafine particles stable suspension with 0.05 to 10 um dimensions in a carrier fluid, insulator.

General characterization of RM materials

When applying a magnetic field, MR materials have the ability to change viscosity by up to six orders of magnitude, due to the formation of particle chains aligned. The phenomenon is illustrated in Figure 4.1

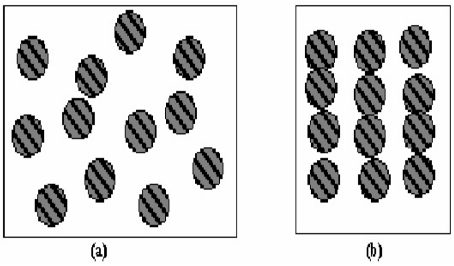

Fig. 4.1 Schematic ilustration of the reversible behaviour of the RM materials. a) disordered arrangement in the absence of external magnetic field; b) alignment after a single direction when applyng magnetic field.

Formation of the MR particles sequences, in the figure, is accompanied by modification of rheological (elasticity, plasticity, viscosity), magnetical, electrical, thermical, acustical properties etc. But the main effect is to increase the apparent viscosity. When the manetic field is removed, the particles return to disordered state shown in Figure 4.1, a. In the MR material structure can be found three major components: ferromagnetic particles, the fluid carrier and the stabilizer. *1. Dispersed ferromagnetic partices.* Spherical in shape and occupies approximately 20-50% of the MR material. Currently are used soft magnetic material powder such as carbonyl iron (FeCO). The chemical composition of particles is Fe, - max. 1% C, - max. 0.7% O, - max. 1% Ni. 2. *Carrier fluid* serves as insulation and must have a viscosity between 0.01 - 1 Pa * s at 400 ^{0}C. Carrier fluids commonly used are: water, gycol, kerosene and mineral or synthetic oil. 3. *The stabilizer* is designed to keep particles suspended in fluid, preventing them to gather together or to deposit because of gravity. The stabilization is done differently depending on the concentration of particles: a) at low concentrations around 10%, stabilization consists of formation of a gel that favor dispersion and lubrication, modify viscosity and inhibit wear. An example of such a stabilizer is silica gel, consisting of ultrafine and porous silica particles, which have the capacity to absorb large amounts of liquid; b) at high concentrations up to 50%, stabilization is done with surfactants, neutral or ionic adhering to the surface of the particles, favoring their arrangement finely dispersed structure, space branched.

MR materials are obtained by grinding in ball mills were are introduced all the components and materials including carrier fluid, mixing occurs under the effect of fragmentation and balls collision at speeds of the order of 2000 r / min.

The behavior of MR materials in space tension-speed-shear deformation is similar to that shown in Figure 4.2. In Figure 4.3 is shown the influence of magnetic field applied to the tension variation with speed shear deformation.

MR material is characterized by: a) low initial viscosity; b) high values of shear stress at certain values of applied magnetic field; c) negligible temperature dependence; d) high stability.

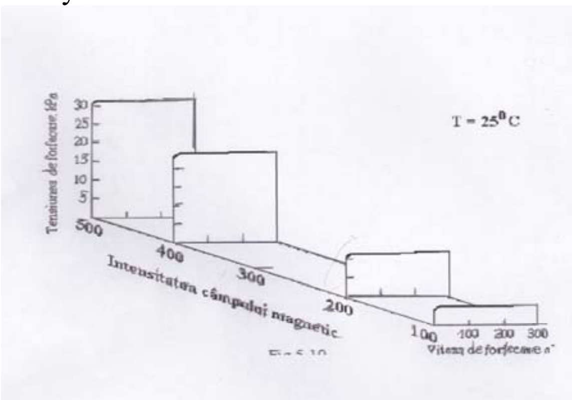

Fig.4.2 Influence of magnetic field intensity on tension variation depending on the speed of shear at the MR material

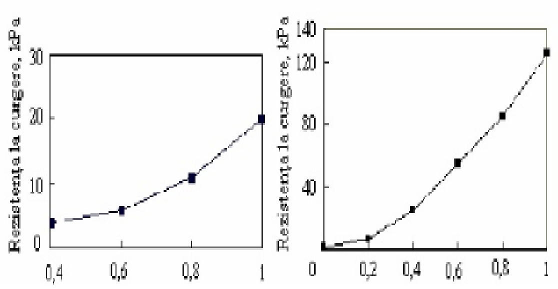

Fig. 4.3 Influence of material particle on MR properties: (a) iron oxide, (b) to a suspension of 40% pure iron

It is noted that the flow resistance of MR pure iron suspension figure is about six times higher than the suspension based on iron oxide.

It must be said that the MR materials have superior properties ER materials (electrorheological) of the following ways:

a) have higher yield stress as shown when comparing Figure 4.2 a to Figure 4.2, b;

b) have greater stability to impurities and contamination elements, usually occurring during the production and use of material;

c) energy consumption is low (necessary powers below 50 W , can be provided at voltages of 12-24 V and 1-2 A intensities even from electric batteries).

Due to their superiority over the ER materials and their easily controllable rheological properties, MR materials are used successfully in applications to control shock and vibrations.

5. References

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CONSIDERA II PRIVIND ELEMENTELE ELASTICE DE LA SUSPENSIA VEHICULELOR FEROVIARE

Rezumat: Lucrarea sintetizează unele aspecte privind suspensia vehiculelor feroviare □i prezintă un nou tip de suspensie primară (legătura dintre partea de rulare □i rama boghiului) în care amortizorul de vibra□ii este de o construc□ie specială. Lichidul din interiorul amortizorului de vibra□ii este un lichid cu memoria formei, în acest fel, amortizorul intră în func□iune doar atunci când aparatul de rulare este perturbat în timpul mersului pe calea de rulare.

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