MATERIALS USED IN COUPLINGS MECHANICAL FRICTION BRAKING SYSTEM OF HIGH SPEED RAILWAY VEHICLES

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REZUMAT. Lucrarea prezintă un studiu cu privire la materialele utilizate pentru anumite componente ale cuplului de frecare: sabot pe bandajul roţii şi garnitură de frecare pe discul de frnare. Elementele cuplei de frecare prin materialele din care sunt confecţionate, trebuie să asigure o eficacitate sporită a sistemului mecanic de frânare pentru toate gamele de viteze. Direcţiile principale ale cercetărilor si investigaţiilor viitoare în domeniul frânării vehiculelor feroviare de mare viteză sunt: găsirea unor materiale al căror coeficient de frecare să fie independent de viteza şi de condiţiile atmosferice (ploaie, gheaţă etc.); Înlocuirea totală a frânei mecanice cu saboţi cu altă frână a sistemului mecanic (de exemplu: frâna cu disc) care nu solicită suprafaţa de rulare a roţii din punct de vedere mecanic şi termic; găsirea şi cercetarea unor materiale noi pentru cupla de frecare a frânei cu disc din punct de vedere al densităţii lor, pentru reducerea greutăţii nesuspendate a vehiculului.

Cuvinte cheie: materiale, cuplă de frecare, frânare, material rulant de cale ferată.

ABSTRACT. The paper presents a study on the materials used for friction torque components: brake shoe-binding-wheel, that the friction torque components: friction lining-disc brake. Elements of friction torque, the materials are made, to ensure an increased efficiency of mechanical braking system for all ranges of speeds. The main directions of future research and investigations in high-speed rail vehicle braking are: finding materials whose coefficient of friction is independent of speed and weather conditions (rain, ice etc); total replacement of mechanical brake blocks with different mechanical brake system (brake disk) which does not require the wheel tread of the mechanically and thermally; find and research new materials for friction torque of brake disc in terms of their density, to reduce unsuspended vehicle weight.

Key words: materials, friction coupling, braking, railway vehicles.

1. GENERALITIES

Of all the known braking systems, mechanical braking system, based on tribological principles, is the oldest and the only one able to stop a vehicle or a train of railway vehicles within an area of deceleration and braking space required.

The main modes of mechanical braking (physical phenomenon which gives rise brake force = friction) of railway vehicles are:

− brake shoe on the wheel bandage;
− friction lining on disc brake.

Braking force generated by the element's friction of the friction couplings presented (brake shoe-wheel bandage and friction lining – disc brake) is limited by the adhesion between wheel and rail:

$$F_{f\,max} < 1000\psi Gr \quad [\text{daN}]$$

where: F_{fmax} is the maximum braking force; ψ - the adhesion coefficient; Gr – the wheel load and own weight.

Also mentioned that the relationship has been written without taking into account the force of inertia and rolling resistance(which are small in relation to the braking force).

Thus, this relationship is the condition of rolling the wheel even at maximum braking force.

At the high-speed rail vehicle braking, when the braking system used at elevated speeds, this condition can be met only by means of antilock devices involved in referral trends to zero of the angular velocity of the wheel (intervention materialized by decreasing the pressure in the brake cylinder).

Physical phenomena (friction) underlying the formation of braking force can be explained as the result of the irregularities of surfaces in contact (Coulomb) or as the result of molecular attraction theory (Tomlinson-Bowden).

Thus, friction arises from „engaging" rough surfaces in contact and corresponds to the work of pulling the particles to prevent relative sliding of those two surfaces.

After molecular attraction theory developed by Tomlinson-Bowden, between molecules of the contact surfaces are produced forces of attraction and rejection depending on the distance, forces which are represented in Figure 1.

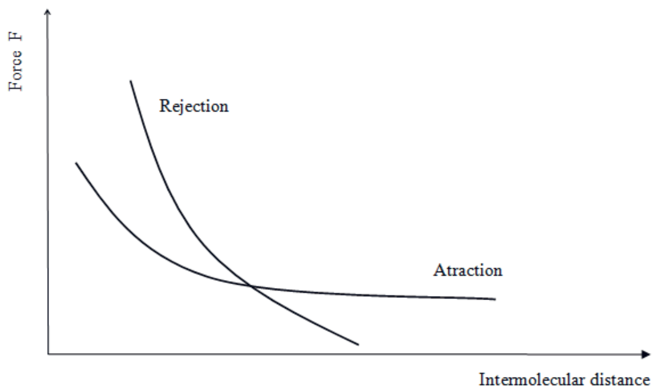

Fig. 1

Assuming contact surfaces clean at high contact pressure, result the fact that at smaller intermolecular distances predominate the forces of rejection and with the increasing of the intermolecular distances predominate forces of attraction (changing the molecular structure).

It follows from these theories that the actual area of contact between the two bodies is very small and breaking the work of these irregularities ("mountains" and „valleys") is transformed into heat which then produces the temperature increase of friction torques components along with increasing of actual surface contact.

2. MATERIALS USED FOR FRICTION TORQUE ELEMENTS BRAKE SHOE-BANDAGE-WHEEL

Current trends in the development of railway vehicles (high speed, low weight, high capacity etc.) leads to decrease even at suppressing the use of the wheel (running surface) for the braking function.

Some railway administrations are also using the railway friction torque brake shoe - wheel for braking high speed vehicles but in combination with an system independent of adhesion able to reduce speed to a limit gave by thermal regime of the friction torque components (especially running surface of the wheel).

The first material used to manufacture brake blocks were wood of certain essences, which gave a good friction coefficient. Due to reduced life time of this material was passed to alloys or composite materials.

Thus, in 1938 was found the solution for brake shoe of trains which circulated up to 140 km / h, from the iron reinforced with carbon into the brake shoe block to eliminate specific sparks corresponding to high speeds.

Then, they managed the production of cast iron blocks hardened by placing the tellurium in the composition, who showed the greater influence sustainability without diminishing the effort at brake shoe (at the same effort on brake shoe a longer life time of those).

Iron is a friction material used to manufacture brake blocks, because it is easily prepared and put into shape, very inexpensive and has no harmful influence on the wheel running surface.

Research conducted by the Subcommittee of the International Union of Railways Brake Shoes Standardization of iron led to a rate not exceeding 1% P (phosphorus) in the composition of iron.

It is known that phosphorus increases the fragility of iron and thus diminishing its area of use (have tried P10, P14, P30).

Research regarding the friction material from which will be made the brake shoes not stopped at the iron, but have spread and to other materials namely composite materials (metal matrix, non-metallic or ceramic).

The conditions that were imposed on these materials are:

- high levels of friction coefficient;
- changes of the coefficient of friction with speed very low or even zero;
- maintaining the characteristics at high temperature;
- high efficiency .

Thus, there are many composite materials that have been experimented and which have succeeded to comply with conditions imposed at a rate of 75%.

From those, Table 1 it shows 5 (five) materials used in Europe.

Table 1

Material (symbol) code	Friction coefficient	Maximum temperature	Using domain	Components
NECTO C100	0.35	370	Renault, Mercedes	Iron particles, agglutinate organic (resin, synthetic rubber), carbon
NECTO C100	0.15	480	Railways and auto vehicules	Iron particles, agglutinate organic (resin, synthetic rubber), carbon (concentration difference)
V.I.P.	0.35	900	Douglas DC8, Boeing 707	Nonmetallic composition, steel liquid (mixture)
K	0.25	450	Railways vehicles SNCF, TGV-PSE	Organic matter (5 ... 50%), mineral material (50 ... 95%)
L	0.17	500	Railways vehicles SNCF, TGV-PSE	Organic matter (5 .. 50%), mineral (50 .. 95%) (difference of concentration)

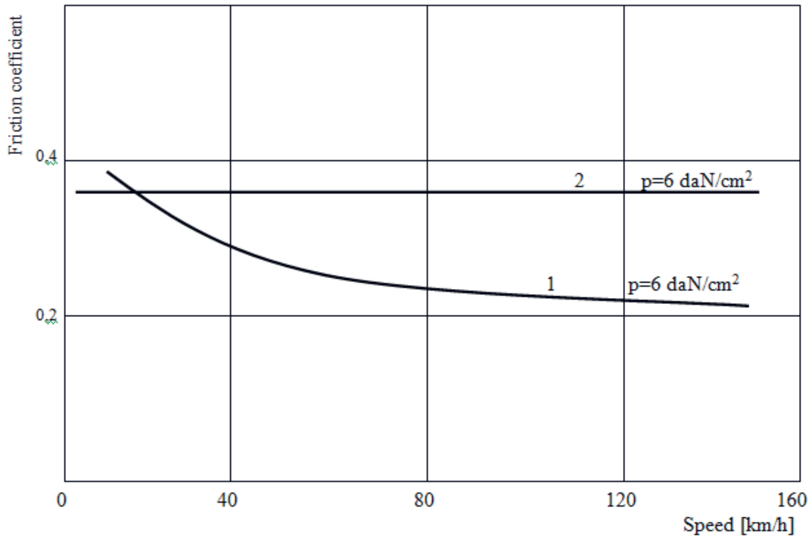

Fig. 2

In our country, research and experimentation in the manufacture of railway brake shoes from composite materials were made since 1962 by a team of researchers and specialists from the center of welding and fatigue tests, Polytechnic Institute of Timisoara, Arad wagons plant etc.

They found solutions that have been patented in the country and abroad and the experiments gave satisfactory results.

3. MATERIALS USED FOR FRICTION TORQUE ELEMENTS: FRICTION LINING - DISC BRAKE

Braking function assigned to the wheel of railway vehicles (running surface) can be considered secondary in view of its main functions: supporting and guiding the rail vehicle.

Using the running surfaces of wheels as friction surfaces, effects of other element of friction torque (brake shoe) regardless of the material it is made are negative(degradation of running surface, thermal and mechanical stresses etc.).

Thus, it was considered necessary to find the friction coupling whose elements have better contacts, a high value of friction coefficient and a low (or zero) speed variation.

A friction torque which meets the above is: friction lining - disc brake.

Figure 2 presents for comparison the variation of friction coefficient with speed for brake shoes (by plastic) and disc brake.

We observed an exceeding variation with the speed (a decrease) of the friction coefficient for brake shoes while for the disc brake, at the same specific pressure (6 daN/cm^2), friction coefficient is constant with speed.

In order to describe in terms of manufacture materials for friction torque of disc brake, Figure 3 provides the schedule of a disc brake equipment, being made the following notations: *1* – disc brake; *2* – friction lining; *3* – brake cylinder; *4* – wheelhouse brake; *5* – vehicle's axle; *6* – cross end of the bogie frame; *7* – the hung support of the wheelhouse.

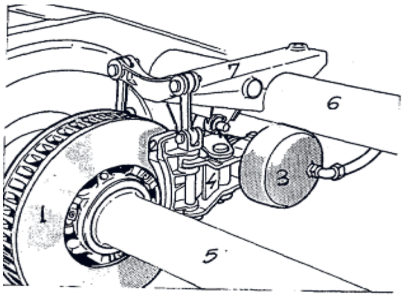

Fig 3

Braking capacity of the disc brake depends on the quality, material properties and friction torque components and in particular by friction lining material.

Therefore, to achieve these sets are imposed very stringent conditions, namely:

− friction coefficient regardless of speed, the specific pressure, temperature, humidity etc;

− to bear temperatures up to 400 ^{o}C without structural changes;

− to not damage the disc brake;

− be resistant to wear,

− throughout the braking (and to a maximum braking power) to stop, the value of friction coefficient must remain between 0,30..0,40.

Friction lining has a special form (see Figure 4), friction surface is flat and attachment port-lining is usually done through swallow tail.

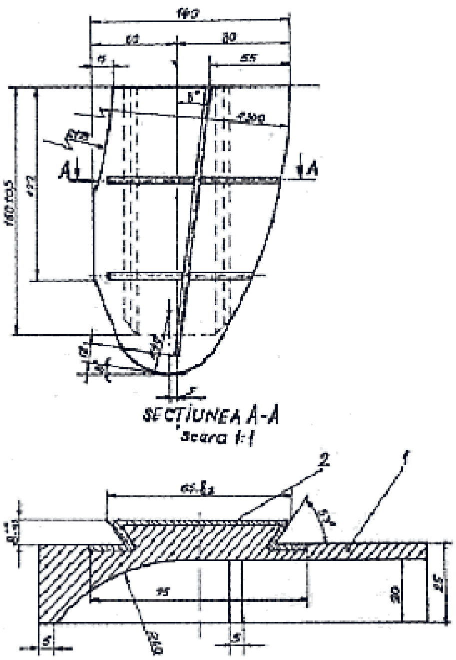

Fig. 4

For friction linings are used non-metallic materials based on asbestos in the form of flakes or powder and constituents to ensure as high wear resistance and a stable friction coefficient. Material components are: novolac, hexametilenteramina, kaolin, flakes of synthetic rubber, graphite concentrate.

Armature foot of friction lining usually made of steel sheet (OL37).

Table 2 presents some friction lining materials that are used in our country and through the world.

Table 2

Material (symbol, code, manufacturing company)		**Friction coefficient**	**Maximum allowable temperature**
CR	England		175
BA			260
AS10			260
AN11 Ferodou			260
VM41		0,25...0,30	290
RC			250
MP			175
Jurid440 Jurid 441	Jurid	0,25…0,30	230..250
Jurid445			250
Jurid446	Germany		300
Bremskerl B5 / C	Germany	0,38	450
Bremskerl B5 / E		0,35	450
RT99/4		0,35	500
COSID - 3000	COSID Germany	0,25…0,30	250
NCG 23/12/26(SC Vagoane ASTRA - Arad) (Brevet OSIM)		0,30	200
GKV 10, GVK56	C.S.I	0,25…0,30	200
COBRA	USA	0,25…0,30	250
FD 140 Timisoara	Romania	0,25…0,30	200

It notes a definite period of friction coefficient and material of the German company Bremskerl (B5 / C) has a very good friction coefficient and also a very high maximum allowable temperature, which leads to the use of this material by several railway administrations.

Regarding disc brake, materials that are use for manufacture are alloys of iron with carbon, irons and steels.

From the irons used distinguished themselves by good mechanical properties and wear resistance nodular cast iron (Fgn 400-10) and gray cast iron (Fc 250 STAS 568-82) whose structures are shown in Figure 5.

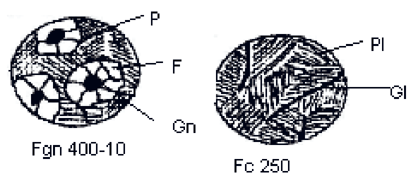

Fig. 5

The process of manufacturing technology is casting material.

For making discs brake are used frequently gray cast iron with lamellar graphite and nodular cast iron matrix „ferito-perlitică” (see previous figure).

These cast irons (especially gray cast iron) has a good thermal conductivity (necessary for the proper discharge of heat due to friction), good mechanical properties, good wear resistance.

The main elements of its chemical composition have the following percentages:

$$C = 3\%,\ Si = 1.7\%,\ Mn = 0.6\%$$

and mechanical properties fall within the intervals corresponding to the desired purpose (hardness 170 to 230 HB, A ~ 0%, KCU~0) .

For high-speed railway vehicles it use two types of brake discs, namely:

– auto-ventilated discs;

– non-ventilated discs.

Current trends converge towards for equipping the railway vehicles (wagons) with non-ventilated discs brake with small thickness ~ 45mm.

Justification for choosing this solution is made by calculating the power absorbed by auto-ventilated disc which is very high at high speed (about 3.5 ... 4.5 kW on each disc to 300 km / h) and through reducing the unsuspended weight of the vehicle.

By increasing the number of discs on the area ($n_d > 8$) obtain a better overall thermal regime of friction torque friction lining - disc brake but more unsuspended weight of the vehicle.

Some railway administrations(eg. SNCF) already use an increasing number of discs per axle (TGV - Atlantique) made from special steel and are not ventilated.

4. PROSPECTS OF THE USE OF MATERIALS FOR HIGH-SPEED RAIL VEHICLE BRAKE

Commercial speeds which are currently used in the world are very high (~ 250…300 km / h) and require stringent measures for traffic safety, both in traction’s domain and especially regarding braking railway vehicles.

Objectives, in terms of materials for friction couplings of rail vehicles, are:

− the suppression of braking through friction between brake shoe-wheel, by placing into service of compact brake blocks with little weight (about 63 kg) but effective, which great acting on other elements of another friction torque;

− the use of effective braking system less influenced by weather conditions (humidity, snow etc.);

− reduction to cancel the power absorbed by ventilation of the auto-ventilated discs brake, which becomes very large at high speeds (3.5 to 4.5 kW per disk to 300 km / h);

− very high energy dissipation using discs brake with small mass but very good dissipation properties.

Calculations showed that the braking onto the alignment and landing from speed of 300 km / h in each elementary discs dissipates energy arround 13,5 MJ.

This is possible if:

− are used discs brake made from more efficient materials than gray cast iron, namely a high-limit elastic steel;

− change the form of discs from auto-ventilated in full non-ventilated discs;

− are used friction linings with a special geometric configuration from very competitive materials in terms of coefficient of friction and the maximum allowable temperature;

The steel used for making non-ventilated discs brake have the following qualities:

− very good mechanical characteristics at high and low temperature *(R_m, R_{po2}, A* >10%, KCU >23J, *HB* = 331-388);

− a good resistance to hot deformation;

− a good ductility;

− a good resistance to wear (have very elevated hardness);

− a good conduct in service (at thermal fatigue).

SNCF used a steel discs brake with following chemical composition: C%: 0.24-0,31, Cr%: 1.2-1,6; Mo%: 0,6-0,9; We 0.2-0.4%.

Also, is trying to adapt the mechanical brake system with disc brake and friction linings of carbon, which is currently used in Formula 1 machinery equipment and airplanes.

The solution of the future carbon / carbon, has the advantage of high capacity to absorb energy. Also, carbon having a density of 1.75 gives an unsuspended weight reduction of the bogie and at the same time a very elevated maximum permissible temperature of 1000 ^{o}C.

5. CONCLUSIONS

Elements of friction torque, through the materials are made, must ensure an increased efficiency of mechanical braking system for all ranges of speeds.

The main directions of future research and investigations of braking the high-speed rail vehicle are:

– finding materials whose coefficient of friction is independent of speed and weather conditions (rain, ice etc..)

– total replacement of the mechanical brake blocks with different mechanical brake system (eg. brake disc) which not request running surface of the wheel in terms of mechanical and thermal;

– finding and research new materials for friction torque of brake disc in terms of their density, to reduce unsuspended weight of the vehicle.

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