A POSSIBILITY OF USING DUCTILE IRON IN THE RAILWAY INFRASTRUCTURE AND TRACK

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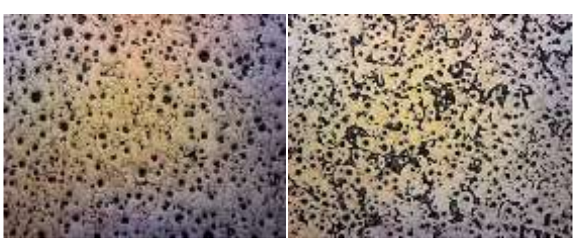
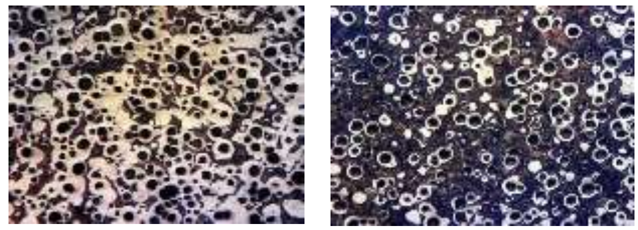
Abstract
The high-strenght complex of the spheroidal graphite cast irons makes them a suitable constructive material ,which can compete with the forged carbon and low-alloy steels. In this article it is considered the possibility of using cast details from ductile iron in the railway transport instead of details made from steel.

KEY WORDS: *DUCTILE CAST IRON, FASTENING IN RAILWAY TRANSPORT*

In recent years there has been a continuous trend of growth of the relative share cast iron with spheroidal graphite (CHSG) in the cast Fe-C alloys. The carried out practical and experimental studies, constantly affirm the superior qualities of this material. Proven its advantages CHSG of years used in the automotive, agricultural machinery, mining, water-supply and sewerage and other industrial areas. The high range of static and dynamic strength characteristics makes it a construction material competing successfully with the forged carbon and low-alloy steels. A similar trend was seen in the highly conservative railway industry. Due to the high requirements to the quality and safety of the products and the assemblies in the railway transport, the entering of new materials and the change of already established ones happens slowly, after numerous tests and trials.The national and company standards change themselves difficult and the innovations must prove their advantages in short terms to be able to get a chance to get into the field of vision of the large companies in the branch. Only they have the potential to force a change in the status quo. Because of this reason ductile cast iron for decades on end gradually proves and shifts steel as a main constructional material in the railway industry.



EN GJS 400-18 LT EN GJS 400-15



EN GJS 500-7 EN GJS-600-3

Figure 1 Typical structures of grades CHSG used in the railway industry

The high strength characteristics of CHSG in comparison with the other cast irons due to the favorable spheroidal shape of the graphite obtained in the course of the primary crystallization of castings. This form provides a lower boundary surface compared to lamellar one of gray cast iron for an equal volume, and reduces stress concentration factor. Spheroidization of graphite is obtained by modification of cast iron in the liquid state. Different alloys with rare earths are often used for improving the properties or obtaining a particular effect.

Depending on their chemical composition and cooling rate CHSG can be with different structure of the metal matrix: ferrite, ferrite-pearlite and pearlite. Figure 1 shows the typical structures of the most common grades of ductile cast iron used in the railway industry.

Ductile cast iron is superior in mechanical indicators gray cast iron and cast irons with vermicular graphite, and is a real alternative of cast and forged steels [1]. The analysis of the nature of the relationship of tensile strength with the other mechanical properties shows that with an increase of strength of CHSG proportionally increases the yield strength. For CHSG the relation Rp0.2 / Rm is within 0.6-0.75, while for the cast steels is 0.55-0.6. As higher is the value of Rm, so higher is the fatigue strength of the material, both harmonic and impact-cyclic loads. This is due to the high reliability of the ductile cast iron, in different operating conditions.

Table. 1 shows the mechanical properties of the most commonly used ductile cast irons in the railway sector.

Table1

Strength characteristics of the most commonly usedductile cast irons in railway transport according EN1563.2012.

Grade	Rm, MPa	Rp 0.2, MPa	A_5 %	HB Kgf/mm^2
EN GJS 400-15	400	250	15	135-180
EN GJS 400-18	400	250	18	130-175
EN GJS 400-18 LT	400	240	18	130-175
EN GJS 500-7	500	320	7	170-230
EN GJS 600-3	600	370	3	190-270
EN GJS 700-2	700	420	2	225-305

The main advantages of CHSG compared to steel are brought to:

- a lower temperature of casting reduces (almost 2 times) the energy costs for its production;
- much better casting properties than these of steels and lower requirements to the mould;
-CHSG have a lower density of 8-10% compared to the steels and this allows to make castings of the same order lighter;
- the lower shrinkage of cast iron - (1.1 -1.2)% against (0.8-2)% of the steels, enables designers to design castings with smaller allowances for machining and in this way to save metal and to reduce the cost of machining;
- as an important advantage of CHSG is improved castability, which is almost two times higher than that of the steel.

Generally CHSG castings used in the railway industry can be classified in two main directions:

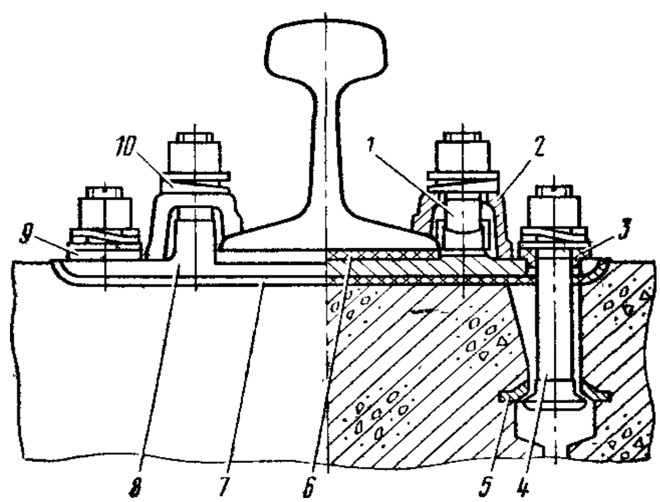
- Railway infrastructure and railway (Railway infrastructure and track);
- And rolling stock (Railway rolling stock).

In the first group - Railway infrastructure and track fall rail clamps for mounting to the sleepers and castings used for arrows and drive mechanisms for them, as well as elements for fixing to the contact system.

The intermediate rail clamp is the most important element of the superstructure of the railway track. It interacts with the rolling stock and ensures the reliability and substantially determines the value in building and costs during the operation. There is a wide variety of rail clamps and numerous patents. But despite this diversity of varieties of rail clamps they can be classified and grouped in several key attributes:

-A rail clamp for sleeper joist (using ribbed pad of steel or cast iron) or a rail clamp without sleeper joist (with a fixed iron anchor or with a polymer pad with an elastic element).
-According to the characteristics of the pressing element (terminal): solid; elastic lamellar; elastic spring.
-According to the type of attachment to the sleeper: bolt; anchor; screw dowel.

Fig.2 Rail clamp type "K".



1. Terminal bolt 2. Terminal 3. Isolating sleeve 4. Connecting bolt, 5.Washer , 6 .Underrail seal 7. Rubber seal 8. Cast iron pad 9. Flat washer, 10. Elastic washer.

In Europe mainly the rail clamps are type "K" with a stiff or elastic clamping element, and pulled taut to the sleepers with anchor bolts and coach screws, or elastic type without sleeper joist [2]. By mid-70s were used mainly steel ribbed pad, made by rolling. With the improvement of foundry technology in developed countries, began production and operation of the cast rib pads of CHSG. In Germany, Deutsche Bahn (DB) accepted a standard defining the production of pads of GJS 600-3, while in France, Belgium and the Netherlands GJS 500-7 has its way.

Figure 2 shows a scheme of a rail clamp type "K" for concrete sleepers. The attachment of the pad is carried out by two or four bolts that are placed in the reinforced concrete sleeper. The metal pad 8 with two high boards is placed on the rubber seal 7 and is attached to the sleeper by the bolts 4. The rail is placed on an underrail seal 6 which also serves as a shock absorber. It is attached to the pad with the solid terminals 2 by clamping bolts 1. Under the nuts are placed flat 9 and elastic washers 10.

The main element of the clamp is the cast iron pad. It takes the load from the rail and distributes forces on the sleeper and the supporting elements. Fig. 3 shows the most commonly used type pad with four holes for fixing and a horizontal underrail site. In building of sections with curves are used inclined underrail sites with ratios 1:20 and 1:40.

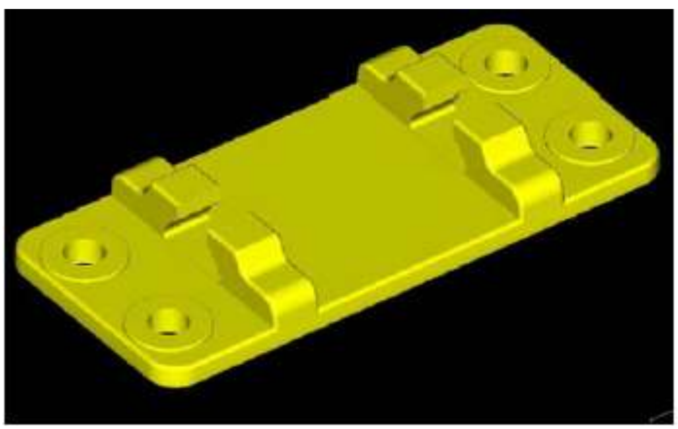


Fig. 3 Cast pad of cast iron for rail clamp “K”.

The main advantages of cast pads of CHSG over the rolled steels consist in the fact that after casting and cleaning the casting of iron is finished state ready for use. The steel pads are cut to a certain width from the rolled profile, after that holes are drilled for connection of the pad to the sleeper and a groove with a complicated shape is milled for the bolt fixing the rail with a clamping element. Namely the need for further machining of steel pads makes them expensive, and makes cast of CHSG pads to be preferred. On the other hand, the specific properties of CHSG provide additional advantages. Within the same range of the tensile strength, CHSG have a higher yield strength. For the steel the compressive strength is practically equal to that of the tensile strength, while for the ductile cast iron the compressive strength is almost twice higher than the tensile strength. In conditions of compressive stresses under which the ribbed pads are put, the advantage of the cast iron becomes apparent. It is essential and the ability of CHSG to extinguish vibrations arising during the operation. That is why cast iron rib pads are preferred in the realization of railway sections in tunnels, bridges and residential areas.

The rail clamp "K" has its disadvantages. The transmission of the lateral forces directly to the screws of the pad that is not fixed in the concrete leads to the breaking of the dowels and mechanical damages of the screws. The width of the track-gauge of the straight sections and especially in the turns is unstable. Rubber pads do not provide the necessary elasticity and vibration damping. The heavy weight and its combination with high costs for routine maintenance lead to high life-cycle cost of the rail clamp.

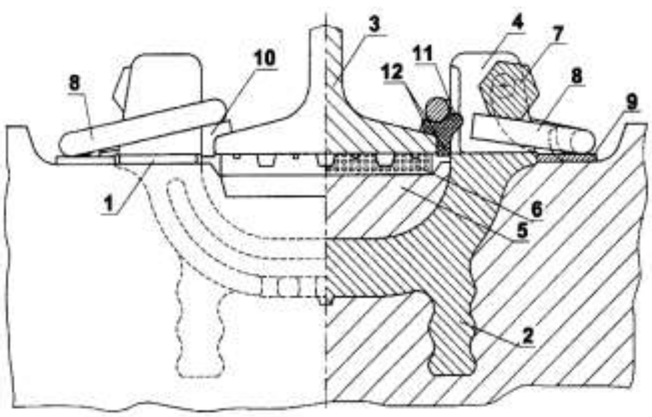
In order to avoid the above mentioned problems the British company "Pandrol" creates a anchor fastening Figure 4) with an elastic element that doesn’t need a ribbed metal pad under the rail.

1. Elastic spring, 2 Isolator, 3. Anchor.

Fig.4 Rail clamp of "Pandrol" company.

The company selects ductile cast iron grade GJS 500-7 for making of the anchor. The anchor 3 is concreted into the sleeper and is clamped in it. The force is taken from the elastic element 1 that is separated from the rail by an insulator 2. The great advantage of this fastening over these with pads is the lack of threaded connections and therefore no need from a periodic maintenance of tightening. The spring is easy for disassembly and replacement, including by fully automated machines. As a major shortcoming of this fastening it is pointed out the breaking and loosening of the anchors in loaded sections such as curves with a small radius (below 300 m).

In order to eliminate the shortcomings of the company "Pandrol" development in the Russian Federation has been created a similar anchor construction of rail fastening ARF - fig.5 [3]. It was tested on a laboratory road route of BNIIZHT and used in many parts of the railway network in Russia. Its construction includes: Anchor 1 and 2 firmly concreted in the sleeper 5, pad 6 under the rail 3, two spring terminals 8 ,rubber pad under the terminal 9, angular electrical insulators 10.



1.and 2. Anchor with corrugated fasteners, 3. Rail 4, Bracket, 5. Concrete sleeper, 6. Underrail seal, 7. Monoregulator of stresses, 8. Spring terminal ,. Terminal seal, 10. Insulating seal, 11. Holder, 12. Spacer

Fig. 5 Anchor rail fastening ARF.

In contrast to the classical "Pandrol" and the other anchor constructions in which there are two light anchors for one assembly, in the ARF a large anchor is used. This solution improves the conditions for interaction of the contact concrete- anchor and increases reliability of the sleeper. On the other hand, the heavy anchor of cast iron GJS 500-7 increases the weight and the cost of the construction.

The position of the rail in height is adjusted by an eccentric monoregulator 7. Rotating it in one of the four possible positions, it provides the standard compression of the terminal depending on the wear of the pad and the other elements of the fastening.

ARF increases reliability and safety of the railway track, providing a much better retention of the track. In the construction of the anchor rail fastening has fewer parts and therefore every kilometer of the way spent 15 tons metal less. ARF allows also better regulation of the way in height. A big disadvantage is the cost of the rail fastening. It is 10% more expensive than the traditional ones. ARF is certified and included in the Register of Federal railway transport since 2005. The rail fastening ARF is recommended for the performance of the high-speed main line Moscow-Saint Petersburg [4].

Over the past decade superstructure time comes a new trend of replacing of the traditional metal rail fastenings with polymer with an elastic element. The main characteristic of these new systems is their low cost and easy installation. The main developments belong to the Vossloh company. After the expiry of their license, they gained popularity in all national railway networks. Naturally, the process of replacement is long and comes across the same difficulties as entered the cast iron in the railway infrastructure in the leading European countries. What is clear, that the cast iron ribbed pads will be the main element of the railway track in the curves with small radius, where the polymers don’t bear the loads and show many defects. The railway security system is much more important than the lower price. Underlay fastenings so far don’t have alternative and in their installation on wooden sleepers, which continue to be used in all countries in Europe. During the construction of the railway track sleepers from plastic and recycled materials increasingly enter. These sleepers also require the use of cast-iron ribbed pads.

Conclusion: Castings of ductile cast iron have their place in the superstructure of the railway track. Their good mechanical properties and their economic advantages over the steel ones ensure their successful implementation over the next decade. The competition from the alternative materials and the

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