

# METALLOGRAPHIC ANALYZE OF PARTS FOR BREAKING SYSTEM MADE OF NODULAR CAST IRON EN-GJS-500-7

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**Abstract:** In this research work, metallographic investigation of two parts which are implemented to railway wagons breaking system was performed. Both parts are produced from EN-GJS-500-7 nodular iron. One of delivered parts leading nut (part 1) was broken during the exploitation and the second part working nut (part 2) was new. Metallographic investigation based on standard EN 945-1 was implemented in order to check the quality of the parts. The reason for breaking of part 1 one was analyzed too. After metallographic preparation, the polished specimens they were analyzed under optical microscope in order to determine form, size, density and distribution of graphite per unite area as first graphite nodules were analyzed after that microstructure of nodular iron. Figures from optical microscope were compared with reference images under the same magnification. After etching the specimens their microstructure was analyzed. It was concluded that quality of the part 2 is much better concerning the requirement of the EN 945 -1 standard.

**Keywords:** NODULAR IRON, GRAPHITE, VERMICULAR, MICROSTRUCTURE, METALLOGRAPHY

## 1. Introduction

EN-GJS-500-7 belongs to the middle class of nodular cast irons. Its characteristics are defined with EN 1563 standard [1], which is equivalent with DIN 1693, and has designation GGG50. Mechanical and chemical properties defined according EN-GJS 500-7 [2].

**Table 1** Mechanical properties of nodular cast iron EN-GJS-500-7 standard and measured values for two parts

EN-GJS-500-7	% Stand.	Part 1	Part 2
UTS, MPa	min 500	532	542
Yield strength, MPa	min 320	366	374
Elongation, %	min 7	9	10
Hardness, HB	170-230	227	231

This type of nodular iron don't has defined requirement concerning impact toughness. Its mechanical properties are given in table 1 and concern to the castings with the wall thickness 30-60 mm. Basic parameters which have to be fulfilled are UTS, yield strength and elongation. Hardness is not treated as quality requirement except in special situations. Chemical composition of the nodular iron is given in table 2.

**Table 2** Chemical composition of nodular iron according EN-GJS-500-7 and measured values

Elem..	% Stand	part 1	part 2
C:	2.7-3.7	3.2	3.4
Si:	0.8-2.9	2.4	2.3
Mn:	0.3-0.7	0.5	0.45
P:	≤0.1	0.06	0.05
S:	≤0.02	0.015	0.012

Chemical composition could be different for different standards. International standard gives broad freedom to the producers concerning to the chemical composition in accordance with their experience and production conditions until requirements for mechanical properties are fulfilled. Many foundries in the world can produce this type of nodular iron but always should to select good producer. Quality of this nodular iron is mainly determined by the present graphite nodules, their form size and distribution and their microstructure. Because of that that investigation in this research work was performed.

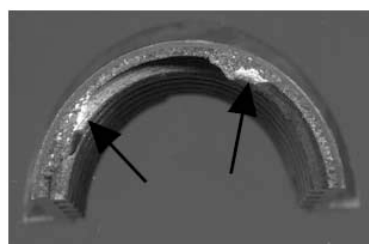
## 2. Material and experimental

Standard metallographic preparation of specimens was performed after grinding on different abrasive papers 100, 220, 280, 400, 600, 800 и 1200 polishing with diamond paste (1 and ¼ μm) was performed. Graphite nodules were analyzed at magnification of x100.

### Part 1- Leading nut

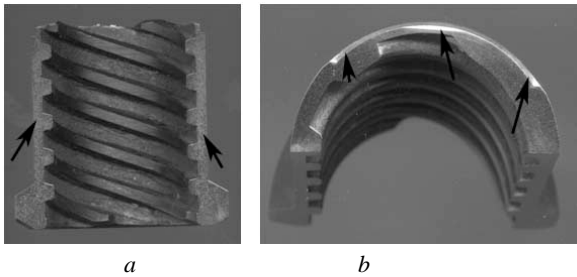
Metallographic specimen from part 1 is given in figures 1 and 2, it is so called leading nut. This part was broken in the exploitation conditions. It has to be point out that this specimen was machined from cast bar φ55x400.

Before to start with metallographic analyses visual control of the part was performed. It was detected light areas on the fractured surface probably segregation of impurities which are the reason for fracture Figure 1. Besides, at the place of the fracture the wall of the leading nut is the thinnest. Metallographic prepared specimen from the broken part is given in the figure 2. Figure show longitudinally prepared specimen. Besides small surface near the broken specimens were prepared too in order to find some suspicious reasons for cracks appearing (Figure 2b). As can be seen from the fig fractured surface is not homogenous i.e. Light areas appear. Marked with arrows probably some segregation of impurities additionally has to be said that fracture location is on the thinnest part of the nut which is additional reason for the fracture.



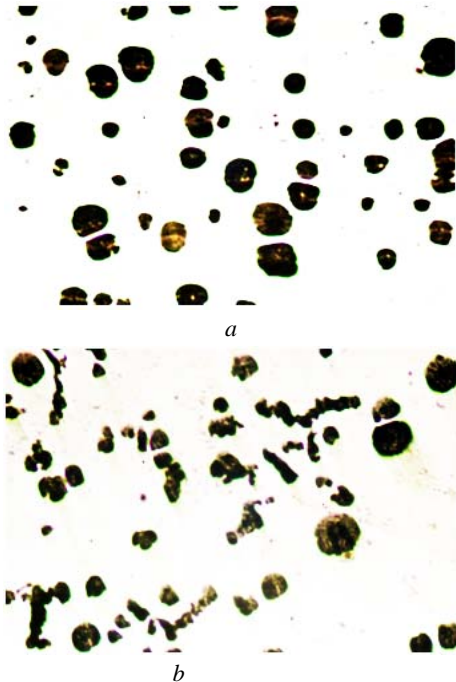
**Figure 1** Broken surface of part 1

After visual control it was started with metallographic preparation. Cylindrical part was cut longitudinally to be obtained two equal parts. One of them was prepared for metallographic investigation (figure 2a). Besides lateral surfaces near the fractured surface were prepared too (figure 2 b), marked with rows.

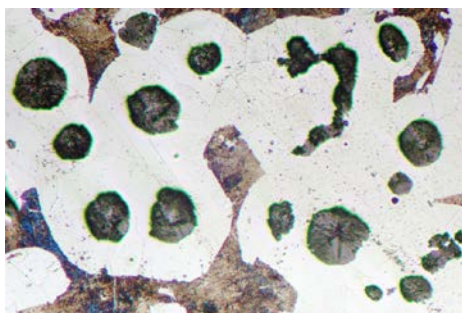


**Figure 2** a longitudinally prepared specimen b laterally prepared surface

Presented nodules in the part 1 are given in the figure 3 (a and b), and its microstructure is given in figure 4.



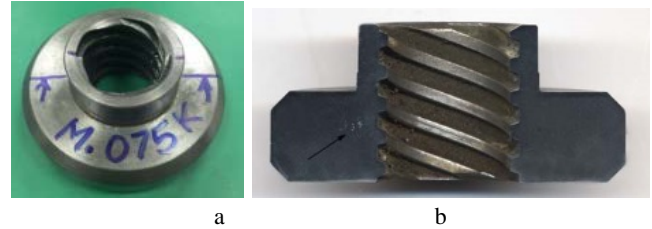
**Figure 3** Polished specimen from part 1, x100



**Figure 4** Microstructure of part 1, etching with Nital

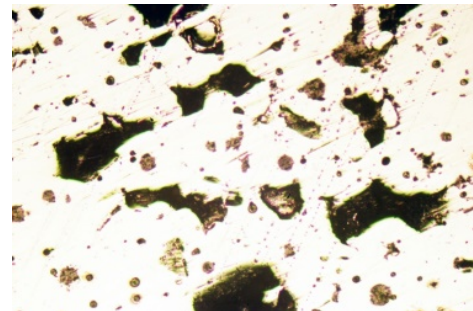
#### Part 2 - working nut

The second investigated part i.e. Working nut is given at figure 5a, and the specimen prepared for metallographic investigation is given at figure 5b. As can be seen from the macro specimen, micro pores are noticed on the specimen (denoted with black arrow). Micro pores can appear in the cast specimen, in the case of very fast cooling when present gases are entrapped inside the specimen. But in this case they can't be serious problem for the quality of the part.

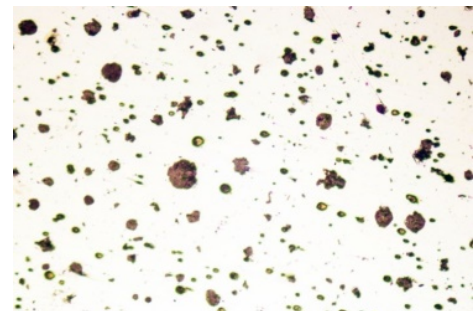


**Figure 5** Investigated part 2 working nut a, prepared specimen b.

At the figure 6 are presented pores at higher magnification x200. It can be seen that they are with irregular shape. Figure 7 presents the nodules of free graphite in the part 2, Graphite nodules are much smaller compared with part 1. And Microstructure of part 2 is given at figure 8

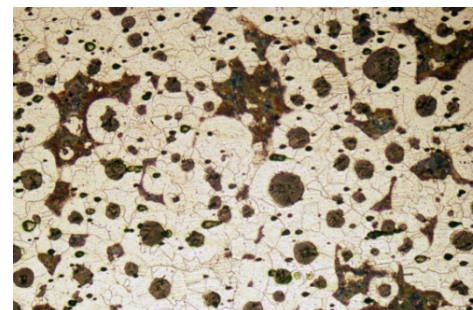


**Figure 6** Micro photo of polished specimen with presented pores, x200



**Figure 7** Micro photo of polished specimen with graphite nodules, x100

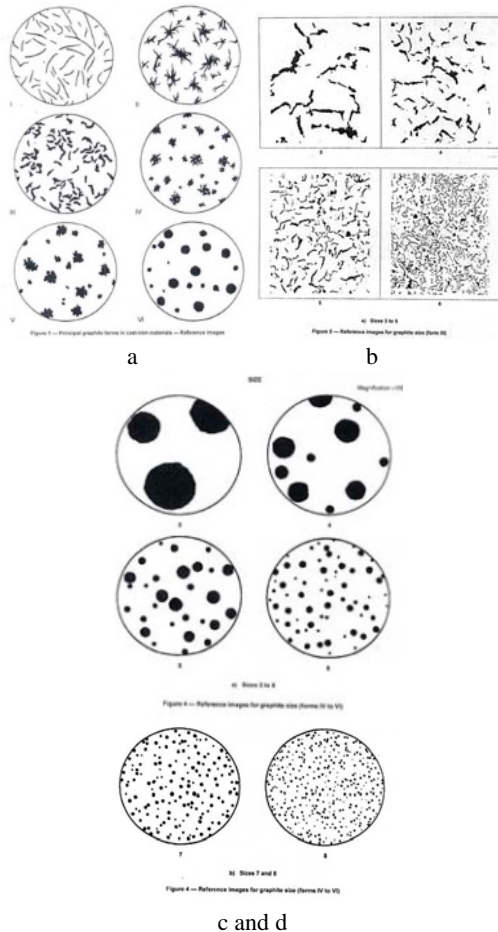
After analyze of graphite nodules, microstructural analyze was performed. Because of that, polished specimen was etched with Nital. Microstructure of part is given at figure 8. It consists of ferrite and perlite.



**Figure 8** Microstructure of part 2

### 3. Discussion

Graphite nodules presented in both specimens were compared with reference pictures from EN 945-1 given in figure 9.



**Figure 9** Reference figures from standard EN 945-1

Graphite forms are presented at figures 9a. They are denoted with Roman numbers I – VI. In both specimens graphite forms V and VI are dominated. Requirement from the purchaser is to be presented 90-95% and the rest form IV. In part 2 these requirement are completely fulfilled. But in the part 1 graphite form III so called Vermicular ferrite is presented too (figure 3b and figure 9b). This form of graphite according its mechanical properties is between form I i.e. lamellar graphite and nodular graphite, form VI Concerning the properties of cast iron, the best solution is presence of form V and VI [3]. The worst situation is presence of the form I, because lamellar graphite gives the highest stress concentration in the iron. Vermicular graphite is something thicker than lamellar ferrite vermicular graphite i.e. forms III. The properties of vermicular graphite are between lamellar and nodular graphite [4]. This form could be required in some special cases but in this case it is not necessary.

Nodular ferrite is the best form compared to all other but finer nodules give the best results. Concentration of free graphite in the nodular iron should be 15-20 % from total investigated surface. Number of nodules per unite should be 200-250 nodules/cm<sup>2</sup>. This requirement is fulfilled for part 2. And the number of nodules is lower than requirement for part 1 [5].

The size of nodules in part 1 is mainly 4 and 5. Nodules in part 2 are much finer and are in range 5-8 (Figure 9c). The size of presented vermicular graphite (figures 3b and 9b) is size 4.

#### 4. Conclusion

Metallographically were investigated two specimens from nodular iron *EN-GJS-500-7*.

It was concluded that specimen 2 completely fulfilled standard requirement. On the contrary specimen 1 was broken in exploratory conditions and form, size and distribution on free graphite is not at appropriate level.

#### 5. Literature

- [1] BS EN 1563:2011 Founding. Spheroidal graphite cast irons
- [2] ISO 945-1:2008 Microstructure of cast irons -- Part 1: Graphite classification by visual analysis
- [3] ELKEM Norway, graphite structures in cast irons
- [4] CLAAS GUS, Technical Information No. 2 Spheroidal cast iron EN-GJS
- [5] Mark Ihm, Automotive Introduction to Gray Cast Iron, Brake Rotor Metallurgy, TRW