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Study of the Characteristics of Large-Diameter Iron Bars Obtained by Rolling at the ODHAV Foundry in the Republic of Guinea

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Abstract

This work consists of evaluating the quality of the mechanical parameters of large-diameter steels, *i.e.* 20, 25, 28 and 32, through a process of recycling scrap metal that fills garages, rubbish dumps, gutters and other abandoned sites, as well as imported concrete reinforcing steel sold in the Republic of Guinea. To carry out this important work, a number of mechanical tensile and bending tests and a microscopic analysis combining two devices, an electron microscope and a photographic camera, were carried out. The samples were taken from sampling areas in the major communes of Conakry, namely: Casse Sonfonia, Matoto and Kagbélen. The tensile strength values of the large dimensions 20, 25, 28 and 32 are given in the tables.

Keywords

Recycled Scrap, Large Diameter, Rolling, Tensile Testing, Bending

1. Introduction

With the availability of material and human resources in the Republic of Guinea, it is inconceivable that major construction projects should be a major preoccupation. Numerous catastrophic situations have been observed throughout the country. These disasters are related either to the load-bearing soil, the structure of the works or the quality of the construction materials [1]. In fact, the construction of a stable and durable quality structure requires a solid construction made up of steel reinforcements and concrete of the highest quality, depending on the performance of the materials used in the structures [2]. Unfortunately, this requirement is rarely met in most developing countries, particularly in the Republic of Guinea [3]. In the Republic of Guinea, there are many structures built with low mechanical and physico-chemical resistance of the materials used in construction, which often results in reduced durability, warping, deflection or even failure or collapse of the structures, particularly in the special zone of Conakry (capital of the Republic of Guinea) where rainfall is very abundant [4]. In 2023, on Tuesday 11 July, a six-storey building under construction between two other residential and office blocks in a quiet district of Matoto collapsed, killing six people, including a child. The construction work was being carried out by a local company, MAK BTP, which is responsible for building social housing in this part of Conakry [5]. In recent years, a large number of non-professional family construction companies and companies close to government officials have been set up in Guinea. This sector of the Ministry of Urban Planning and Housing, which is responsible for issuing building permits, is negligent [5]. However, the construction of large structures requires quality materials such as large-diameter steel bars, which contribute to the reinforced concrete structure's resistance to corrosion, stability and plasticity [6] [7] [8]. For some time now, the ODHAV industrial unit has been recycling old scrap metal discarded in the streets of towns and villages, which is collected by small groups of sellers and bought to be remelted in high-temperature iron and steel furnaces using casting and rolling techniques. After production, these bars are sold on the local market without any prior verification of their characteristics. This sector of scrap and waste recycling is now one of the priorities of the manufacturing industries to be improved, which could be an alternative for reducing the production costs of steel bars and other by-products obtained from ores [8]. Of the many materials used in the construction of bridges and dwellings, steel is the most important in the programming chain. It provides a wide range of mechanical parameters, such as the resistance factor [9]. To this end, we researchers and those in charge of urban planning and housing must monitor and set up a technical structure for monitoring and evaluating the conditions of production, import and use of construction materials. Recently, we reported on the study of the characteristics of steels with diameters of 10, 12, 14 and 14 mm obtained by recycling old scrap metal manufactured by the same ODHAV industrial unit (Republic of Guinea). As an extension of these studies, we propose in the present work an evaluation of the quality of irons with diameters of 20, 25, 28 and 32 produced by the company ODHAV-multi industrie, stored and sold in Guinean markets (**Figure 1**) [9].

Figure 1. Showing a point of sale for iron bars with diameters of 20, 25, 28 and 32 mm.

2. Matériel et Methods

2.1. Presentation of the Study Area

This study took place in the same area as our previous article [10].

2.2. Study Framework

The analysis of the mechanical parameters of large-diameter steels was carried out in the CBITEC Laboratories located in Kagbélén (Dubréka Urban Community), which served as the study framework [10].

2.3. Iron Bar Manufacturing Processes at the ODHAV Plant

- Technical Description.

Steel production in the ODHAV industry (**Figure 2**) involves two main processes: ingot production and continuous casting. The molten liquid masses, which are then poured into moulds previously made from cast iron, solidify according to the weight of the ingot moulds, which range from a few kilos to more in the case of large mechanical forging parts. After demoulding, the ingots are again heated to a temperature of 1200˚C to be crushed in the rolling mills and transformed into semi-finished products.

2.4. Sampling

The rebars used in this study were purchased in the markets of three (3) different most populated Communes of the Capital Conakry (Matoto, Sonfonia, and kagbelen) on 12/03/2024. Thirty-two iron sample bars were purchased (diameter 20, 25, 28 and 32 mm). These bars were cut into pieces of 500 mm each. The bars were then scrubbed with a wire brush to remove the corrosive material (**Figure 3**).

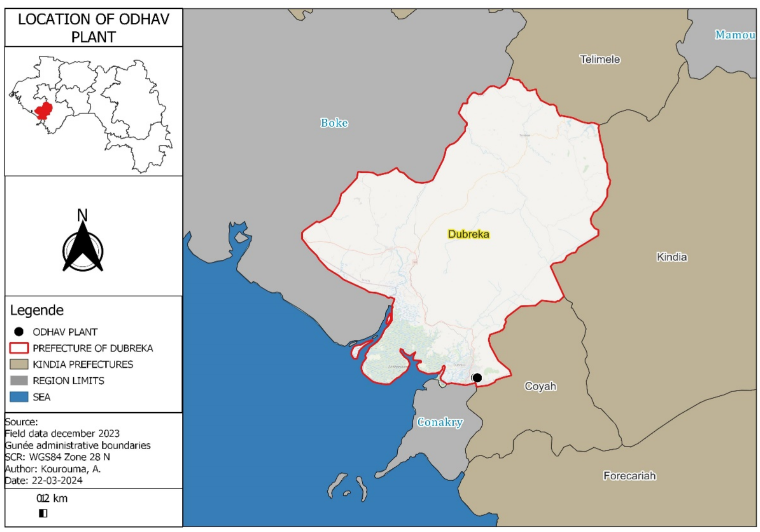

Figure 2. Showing the map of the ODHAV factory (Quartier Kindiasi in Kénendén, urban district of Dubréka) on the right and on the far left the map of the Republic of Guinea showing the prefecture of Dubréka inside.

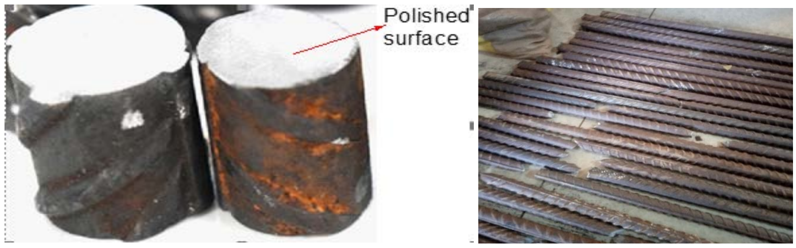

Figure 3. Pieces of rebar cut for testing.

2.5. Equipment and Solvents

- Hacksaw
- Clamping vice
- Vernier caliper
- Graduated ruler
- Wire comb
- Double decimeter
- Testing machine (WES-1000B)
- Testing machine (WES-300B)
- 69% nitric acid, with a density of 1.49
- Electrical optical microscope (Model: Max II 1202.3530 M RATING 220 V 50/60 Hz FUSE 250 mA; HALOGEN LAMP 6 V 20 WN0 1500189)

2.6. Methods

2.6.1. Traction Unit Operation

We used the same unit [10]. Before using the machine, check that the hydraulic oil in the storage tank is full, the oil hose connection is loose and the machine power supply is normal. Then switch on the machine and press the start button. As the pressure value rises, the carriage carrying the test piece moves vertically and the armature is subjected to tension. But first, the specimen to be tensile tested is clamped between the upper and lower clamps. Then, using a digital control unit, the specimens are clamped. The device is then switched on until the specimens break. Parameters are displayed and read out on a screen. The values for yield strength, ultimate tensile strength and elongation ratio were calculatedusing the following formulas: $Re = \frac{F}{S} \times 1000$. $Rm = \frac{F}{S} \times 1000$; $A\% = \frac{Lu - Lo}{Lo} \times 100$, Where: Re = conventional yield strength (MPa); Rm = ultimate tensile strength in (MPa); $A\%$ = aspect ratio; F = conventional yield load (kN); S = cross-sectional area (mm^2); Lu = initial size; Lo = dimension after tension [9].

2.6.2. Device Operation for Bending

Operation of the machine for bending tests begins by adjusting the screw up and down to hold the sample between the support plates (**Figure 4**). Then unscrew the oil supply valve, slowly adjust the oil supply handle and gradually increase the flow rate within the specified range. During the test, the amount of oil supplied by the supply handle must be continuously adjusted. The rate of change is checked under the specified conditions. When the pressure value does not increase, or starts to decrease, this means that the specimen has been pushed to the extreme, and the test data will start to be recorded on the machine's digital control unit. The pressure plate completes its stroke, transforming the specimen into a V-shape, and the flexion of the specimen is finally observed (**Figure 5**).

2.6.3. Microscopic Analysis

Device description

The experimental set-up used was an ordinary brand-name optical microscope (Max II 1202.3530M; RATING 220 V 50/60 Hz; FUSE 250 mA; HALOGEN LAMP 6V 20 W; N0 1500189). We used an ordinary brand-name camera (NIKON D 3500), with brightness provided by an iPhone phone lamp.

- How it works

Prior to the metallographic analysis of the specimen microstructure, preparatory sizing work was carried out on the iron bars in 600mm-long pieces, and

Figure 4. Tensile and flexure apparatus showing the device.

Figure 5. Showing the iron bars after V-shaped bending.

Figure 6. The positioning of the iron sample piece in the microscope.

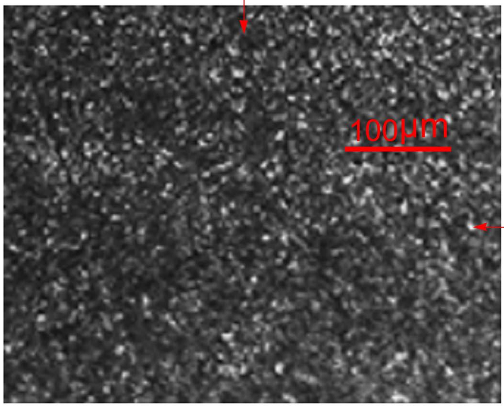

Figure 7. Micrographic appearance showing a structure perlite-globulaire (observation at 100 µm enlargement).

fine-grain file grinding was performed on the specimens, followed by etching of the upper parts (end of iron specimen piece) with a 5 ml solution of concentrated nitric acid, and 50ml of 96˚ ethyl alcohol, in order to reveal the analyze zones in the microscopic view of the specimen (**Figure 6**). Then, the microscopic device set up allowed us to visualize the microstructure of the samples, and the camera (NIKON D 3500) enabled us to take a photo of the sample's microstructure and to know the nature of the structure, shape and size of the grains for the prevention of adequate heat treatment (**Figure 7**).

3. Results and Discussion

This work is focused on the diagnosis and determination of some mechanical parameters of samples of rebar of diameters (20, 25, 28 and 32 mm) produced from recycling of old mechanical parts which litter all the grounds and other dumps, manufactured and sold in the markets in Republics of Guinea, in order to propose to the engineering department of the company ODHAV multi industry, the tracks and possibilities of improvements of the process of production of these rebars which are used by the quasi-totality of the Guinean populations.

The large-diameter 20, 25-, 28- and 32-mm bars were purchased from various sales outlets in Conakry's communes: Matoto, Sonfonia and Kagbelen. The steel rebars purchased were cut into samples of three 500 mm pieces of the same size. The selected sample pieces were cleaned with a wire brush to remove corroded parts, then labelled and packed in polymer bags and sent to the CBITEC laboratory for analysis. Various techniques were used, including tensile and flexural testing using a brand-name machine (CHENXIN, made in China), and microscopic testing. The results of the parameters obtained are shown in (**Tables 1-3** and **Figure 6** and **Figure 7**).

Tensile and bending techniques were used to measure the strength of the steel bars purchased. The yield strength is a parameter that marks the end of the material's elastic behavior and the beginning of its plastic behavior, indicating that when the yield strength is exceeded, the material undergoes irreversible deformation [11]. Tensile testing is one of the most widely used mechanical tests of materials, along with hardness measurement. They are used to characterize strength and deformation behavior under tensile stress [11]. The results are shown in (**Tables 1-3**), The iron samples purchased were all manufactured (scrap recycling system) by the ODHAV multi-industrie company in Conakry, Republic of Guinea) at the following sales outlets: Casse de Sonfonia, Matoto and Kagbelen yielded the following variation in yield strength values: 414.01 - 576.56; 426.34 - 685.40; 438.18 - 591.59 MPa for the four diameters selected (20, 25, 28 and 32 mm) respectively. For purchased samples, the highest values were found for the 32 mm diameter, *i.e.* 660.39; 624.54 and 665.32 MPa

Table 1. Tensile test results for steel bars of four diameters (Sonfonia Casse).

ODHAV steel bar tensile test (Casse Sonfonia)										
Diameter (mm)	Cross-section in (mm²)	Electrical load limit (KN)	Electricity limit (MPa)	Conventional electricity limit (MPa)	Load limit (KN)	Tensile strength (MPa)	Conventional tensile strength (MPa)	Calibration distance (mm)	Calibration distance broken in (mm)	Elongation ratio (%)
	314	130	414.01		17.47	555.63		600	679	13.17
Ø20	314	136	433.12		173.89	553.78		600	675	12.50
	314	138.19	440.09		174.01	554.17		600	681	13.50
	491	268.97	547.80		302.76	616.62		600	675	12.50
Ø25	491	271.02	551.98		298.60	608.15		600	679	13.17
	491	274.37	558.79	500	299.53	610.04	550	600	672	12.00
	615	271.85	420.03		396.13	644.11		600	669	11.50
Ø28	615	273.09	444.05		391.44	636.49		600	667	11.17
	615	275.53	448.02		406.14	660.39		600	664	10.67
	804.2	463.18	575.95		504.13	626.87		600	658	9.67
Ø32	804.2	459.45	571.31		498.64	620.04		600	659	9.83
	804.2	463.67	576.56		499.08	620.59		600	656	9.33

Table 2. Steel bar tensile test results for the four diameters (Matoto).

ODHAV steel bar tensile test (Matoto)										
Diameter (mm)	Cross-section in (mm^2)	Electrical load limit (KN)	Electricity limit (MPa)	Conventional electricity limit (MPa)	Load limit (KN)	Tensile strength (MPa)	Conventional tensile strength (MPa)	Calibration distance (mm)	Calibration distance broken in (mm)	Elongation ratio (%)
Ø20	314	133.87	426.34	500	158.64	505.22	550	600	676	12.67
	314	134.19	427.36		149.26	475.35		600	675	12.50
	314	135.21	430.61		154.99	493.59		600	673	12.166
Ø25	491	255.47	520. 31		265.26	540.02		600	671	121.83
	491	261.80	533.20		269.14	548.15		600	669	11.50
	491	264.05	537.78		269.53	548.94		600	668	11.33
Ø28	615	268.12	435.97		358.06	582.21		600	670	11.66
	615	267.32	434.97		369.03	600.04		600	669	11.50
	615	269.91	438.87		374.62	609.13		600	667	11.17
Ø32	804.2	445.30	553.71		488.36	607.26		600	659	9.83
	804.2	450.30	559.93		500.25	622.04		600	659	9.83
	804.2	451.20	685.40		502.26	624.54		600	657	9.50

Table 3. Tensile test results for steel bars of four diameters (Kagbelen).

ODHAV steel bar tensile test (Kagbelen)										
Diameter (mm)	Cross-section in (mm^2)	Electrical load limit (KN)	Electricity limit (MPa)	Conventional electricity limit (MPa)	Load limit (KN)	Tensile strength (MPa)	Conventional tensile strength (MPa)	Calibration distance (mm)	Calibration distance broken in (mm)	Elongation ratio (%)
Ø20	314	137.59	438.18	500	173.75	553.34	550	600	675	12.50
	314	131.88	420.00		172.99	550.92		600	671	11.83
	314	132.43	421.72		174.42	555.47		600	673	12.17
Ø25	491	273.89	557.82		300.95	612.93		600	668	11.33
	491	263.92	537.52		307.64	625.25		600	669	11.50
	491	270.80	551.53		299.96	610.92		600	665	10.83
Ø28	615	283.24	460.55		399.67	649.87		600	669	11.83
	615	287.06	466.76		400.59	651.36		600	666	11.00
	615	282.66	459.61		409.17	665.32		600	664	10.67
Ø32	804.2	467.34	581.12		498.93	620.40		600	659	9.83
	804.2	472.56	587.61		501.27	623.31		600	657	9.50
	804.2	475.76	591.59		506.49	629.80		600	655	9.17

Table 4. Results of steel bar bending test for four diameters (Sonfonia casse).

ODHAV steel bar bending test (Matoto)										
Diameter (mm)	Cross-section in (mm^2)	Electrical load limit (KN)	Electricity limit (MPa)	Conventional electricity limit (MPa)	Load limit (KN)	Tensile strength (MPa)	Conventional tensile strength (MPa)	Calibration distance (mm)	Calibration distance broken in (mm)	Elongation ratio (%)
Ø20	314	110.12	350.70	500	127.09	404.75	550	250	279.96	11.98
	314	109.73	349.46		128.13	408.06		250	284.05	13.63
	314	108.44	345.41		126.19	401.87		250	282.68	13.07
Ø25	491	237.00	482.26		245.19	499.36		250	284.09	13.64
	491	236.75	482.17		245.03	499.04		250	280.53	12.21
	491	236.42	481.51		243.99	496.92		250	280.07	12.03
Ø28	615	250.01	406.52		363.27	590.68		250	279.07	11.03
	615	250.27	406.94		363.03	590.29		250	276.49	10.59
	615	249.73	406.06		360.00	585.36		250	275.92	10.37
Ø32	804.2	356.27	430.11		475.25	588.47		250	273.53	9.41
	804.2	356.49	443.28		477.66	593.94		250	274.37	9.75
	804.2	357.19	444.15		475.96	591.84		250	273.21	9.28

Table 5. Results of steel bar bending test for four diameters (Matoto).

ODHAV steel bar bending test (Sonfonia casse)										
Diameter (mm)	Cross-section in (mm^2)	Electrical load limit (KN)	Electricity limit (MPa)	Conventional electricity limit (MPa)	Load limit (KN)	Tensile strength (MPa)	Conventional tensile strength (MPa)	Calibration distance (mm)	Calibration distance broken in (mm)	Elongation ratio (%)
Ø20	314	118.79	378.37	500	127.67	406.59	550	250	278.99	11.59
	314	117.94	375.61		128.19	408.24		250	277.51	11.00
	314	119.99	382.13		126.91	404.17		250	275.98	10,39
Ø25	491	236.00	480.65		244.56	498.08		250	281.47	12.69
	491	235.91	480.47		244.04	497.03		250	280.23	12.09
	491	235.67	479.77		243.96	496.86		250	279.96	11.98
Ø28	615	249.17	405.15		359.47	584.50		250	280.12	12.05
	615	248.93	404.76		359.08	583.87		250	279.01	11.60
	615	248.64	404.29		358.73	583.30		250	278.93	11.57
Ø32	804.2	357.97	445.13		476.26	592.25		250	276.68	10.67
	804.2	357.11	444.06		475.32	591.05		250	273.98	9.59
	804.2	356.89	443.78		476.02	591.92		250	275.11	10.04

Table 6. Results of steel bar bending test for four diameters (Kagbelen).

ODHAV steel bar bending test (Kagbelen)										
Diameter (mm)	Cross-section in (mm^2)	Electrical load limit (KN)	Electricity limit (MPa)	Conventional electricity limit (MPa)	Load limit (KN)	Tensile strength (MPa)	Conventional tensile strength (MPa)	Calibration distance (mm)	Calibration distance broken in (mm)	Elongation ratio (%)
Ø20	314	118.42	377.13	500	125.99	401.24	550	250	284.36	13.74
	314	116.99	372.57		130.29	414.93		250	282.79	13.12
	314	121.03	385.44		129.47	412.32		250	280.47	12.18
Ø25	491	235.09	478.79		244.32	497.67		250	282.08	12.83
	491	234.99	478.59		242.91	494.72		250	281.93	12.77
	491	234.75	478.11		242.75	494.40		250	280.69	12.28
Ø28	615	248.21	403.59		357.69	581.61		250	281.13	12.45
	615	247.95	403.17		357.11	580.67		250	279.98	11.99
	615	247.67	402.06		356.97	580.44		250	280.52	12.21
Ø32	804.2	364.91	453.76		477.16	593.33		250	274.79	9.92
	804.2	369.47	459.43		475.21	590.91		250	275.08	10.03
	804.2	368.09	457.62		474.49	590.01		250	274.39	9.76

(for samples taken from Casse de Sonfonia, Matoto and Kagbelen). However, all the values for Casse Sonfonia, Kagbélén and only the 28- and 30-mm diameter values for Matoto are above the 550 MPa standard, while the three 20- and 25-mm diameter tensile values (**Table 2**) and all the diameter values for Kagbelen (**Table 4**) are below the 550 MPa standard. According to [10] [12], the variation in yield strength from one sample to another depends on the structure and composition of the steels. The Electricity Limit values calculated for traction are: the three 20 and 28 mm diameter values, one value (**Table 1**), the 20, 25 and 28 mm diameter values (**Table 2**); three 20 and 28 mm diameter value (**Table 3**). For bending: all values (**Tables 4-6**) are below the normal 500 MPa. The tensile strength of a material is its ability to withstand or contain a load during stretching without being irreversibly transformed. Ferrous metals or scrap contain 90% pure iron in most cases, or they are weakly alloyed with other metals. They are resistant, shiny, ductile and good conductors of heat and electricity. They are composed of positive ions bathed in a sea of mobile electrons and tightly combined in a crystalline structure. These properties mean that when they are subjected to an external force such as traction, they don't break, but are deformed. This deformation, which expresses their response to this force without being broken, would be due to the sea of mobile electrons that protects the cations from violent repulsion and enables the metal to just change of form [12]. The anomalies found in the samples may probably be due to factors influencing the characteristics of an alloy, such as: chemical (corrosion) due to the poor preservation of iron bars which are spread out under high humidity (with the risk of oxidation) sold in these outlets, physical (lack of heat treatment) and mechanical (forging, bending, rolling) [13]. Elongation, as the name suggests, refers to the extension of a material's length through tensile stress until the specimen breaks. These values, together with the calibration and broken distances, are given in the (**Tables 1-3**) [13] [14] [15]. For all samples, very high values were observed in the 32 mm diameter range, *i.e.* 660.39, 624.54 and 665.32 MPa (for samples taken from Sonfonia Casse, Matoto and Kagbelen). Bending tests on the various samples gave the best results in the 28- and 32-mm diameters for the three sampling areas (Sonfonia Casse, Matoto and Kagbelen), ranging from 581.61 - 593.94 MPa. Microscopic analysis of a material is a technique for assessing the internal structure of a steel, which is made up of crystalline zones in the form of micro-grains that are oriented in the crystalline structure according to the alloy composition or steel manufacturing method the results of microscopic analysis showed us a perlite-globular structure at 100 µm observation, composed of the ferrite and cementite. That is recognizable on (**Figure 7**) in the form of grains.

4. Conclusion

For this reason, the aim of this work is to determine certain mechanical parameters of large-diameter iron bars (20, 25, 28 and 32 mm) obtained from scrap recycling by the multi-industry company ODHAV in the Republic of Guinea. To do this, we studied the mechanical behavior of these recycled reinforcing iron bars, sold in Guinean markets by non-professionals in various sales outlets in Conakry, such as Casse Sonfonia, Matoto and Kagbélén (Republic of Guinea), by means of mechanical tests (traction and flexion). The following methods were used: tensile strength test, bending test and microscopic observation of the steel structure. It was shown that, for all the samples, the highest values were observed at the 32 mm diameter level, values are: 660.39, 624.54 and 665.32 MPa (for the samples taken (Casse de Sonfonia, Matoto and Kagbelen). Bending test results were best at 28- and 32-mm diameters for all three outlets (Sonfonia Casse, Matoto and Kagbelen), ranging from 581.61 to 593.94 MPa. The bads results, tensile and bending results were obtained in Matoto, Sonfonia Casse and Kangbélen for diameters 2 and 25 mm respectively. This deterioration is said to be due to the high humidity in the Conakry area, which is one of the factors that degrades the quality of metals, as they are susceptible to corrosion caused by a chemical reaction when the metal is in contact with oxygen and humidity. Microscopic analysis of a material is a technique appreciation of the internal structure of a steel. So, the results of microscopic analysis showed us a perlite-globular structure at 100 µm observation, composed of the ferrite and cementite. That is recognizable on **Figure 7** in the form of grains.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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