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Topographic Profile and Roughness Analysis of Cold Drawn Pearlitic Steel

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Abstract: The high carbon steel properties combination allow it application in different areas, such as: bridge cables, piano wire, tire wire, and others. The high resistance associated with acceptable levels of ductility showed by theses steels has been, for many years, the topic of considerable scientific research [1]. The material studied in this work was SAE 1070 steel wires that compose the tire metallic structure. The wire drawing process was carried up to 12 passes resulting in a reduction average between 15 to 21 %. The material roughness was measured with the help of Confocal Microscope and Atomic Force Microscope. It was observed a discrepancy between the topographic profiles of the as-received and wire drawn samples. The roughness surface of deformed material can cause friction areas and hamper lubricant adhesion during further processing. The topographic profile of deformed microstructure is characterized by lamellae aligned with the drawing direction.

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I. INTRODUCTION

In the last few decades, progressively cold drawing Fe-C materials, especially cold-drawn pearlitic steel wires, have attracted considerable attention due the wires mechanical properties in sample chemical compositions [2]. The pearlite lamellar structure of high carbon steels is a composite structure comprising ferrite and cementite phase. Although some amount of cementite, which is considered to be undeformed, in fact, the wire of pearlite lamellar structure can be drawn to extremely small diameters [3]. This occurs because the lamellar structure intercalates the high strength constituent - the cementite, with the ferrite, which is more ductile. For this reason, the pearlitic steels present the combination of high tensile strength with acceptable levels of ductility and toughness which provides an elevated degree of drawing strain.

The mechanical properties make the pearlitic steel wires an important industrial material used for a wide variety of applications such as steel cords for automobile tires, galvanized wires for suspension bridges, pianos strings and railroad rails [4]. The properties combination and the extensive application make the pearlitic wires object of great interest from manufactures and researchers with the aim to understand microstructural characteristics that affect properties and determinate conformation process parameters. Within the process parameters one of the most important in the wire drawing of steel wire is the lubrication. Several problems are caused by a deficient lubrication system such as wire rupture, heterogeneous deformation and excessive wear of the die.

The material surface roughness is responsible for lubricant adhesion on contact surface. However, others relevant parameters of the drawing process, such as friction and wear, also are directly associated to roughness. The knowledge of roughness formation and how it interacts with other elements during deformation process is extremely important. In addition to the external surface analysis, the microstructure topographic profile helps the material characterization and understanding of pearlite deformation mechanisms. In this context, the objective of this work is analyze topographic profile of SAE 1070 steel, before and after the drawing process, evaluating their consequences for deformation process.

II. MATERIAL AND METHODS

The material used in this study consisted in SAE 1070 steel wires with chemical composition of 0.712C, 0.01S, 0.489Mn, 0.007P, 0.225Si, 0.003Al, 0.016Cr, 0.009Cu, 0.006Ni, 0.005Mo, 0.01N, expressed in wt%. The as received material with 5.50 mm diameter was forming by hot rolling with continuous cooling. They were not afterfinish machined or cold formed. The steel wire was cold drawn in 12 passes with reduction rate of 15 to 20% reaching a diameter of 1.55 mm. The machine used was a commercial OZ CAMS model with 12 drawing steps without sliding. In the process tungsten carbide dies were used. For the lubrication of the material Vicafil Sumac 2 (Sodium Stearate) dry soap was used in a passing box. The topographic profile was analyzed with help of Atomic Force Microscope and Confocal Microscope.

III. RESULT

External Surface Topographic Profile

Figure no1 and no 2 shows SAE 1070 steel surface topographic profile of as-received samples and after wire drawing process.

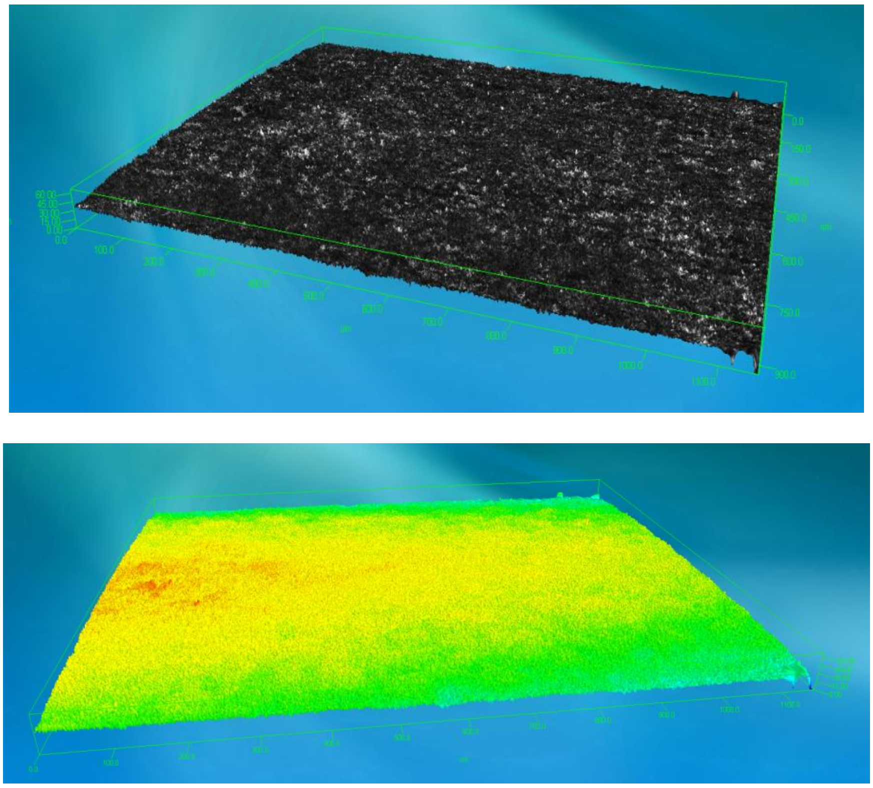

Figure no 1: Confocal Miscroscope. Surface Topographical Profile of SAE 1070 steel on initial condition.

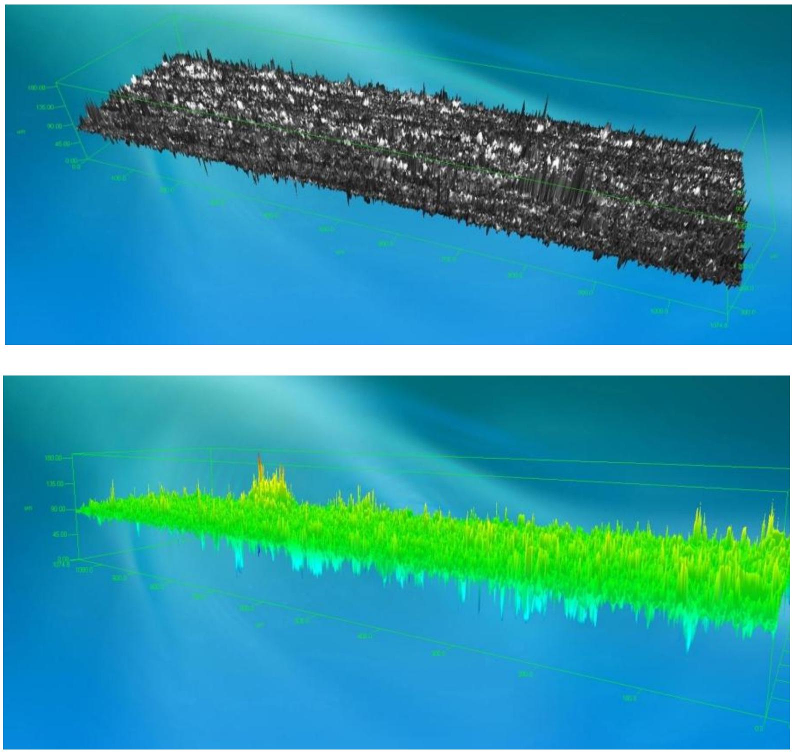

Figure no 2: Confocal Miscroscope. Surface Topographical Profile of SAE 1070 steel after wire drawing process.

Table no 1: Roughness parameter of SAE1070 steel in initial condition and after wire drawing process.

Roughness Parameter	As received material	Deformed material
Ra	1,899	3,985
Rp	7,668	26,696
Rv	7,924	48,893
Rz	15,218	48,893
Rt	18,233	101,890
Rq	2,439	5,821
Rsk	-0,081	0,166
Rku	3,480	15,603

Microstructure Topographic Profile

The Figure no 3 shows the microstructure topographic profile of as- received material and drawn material.

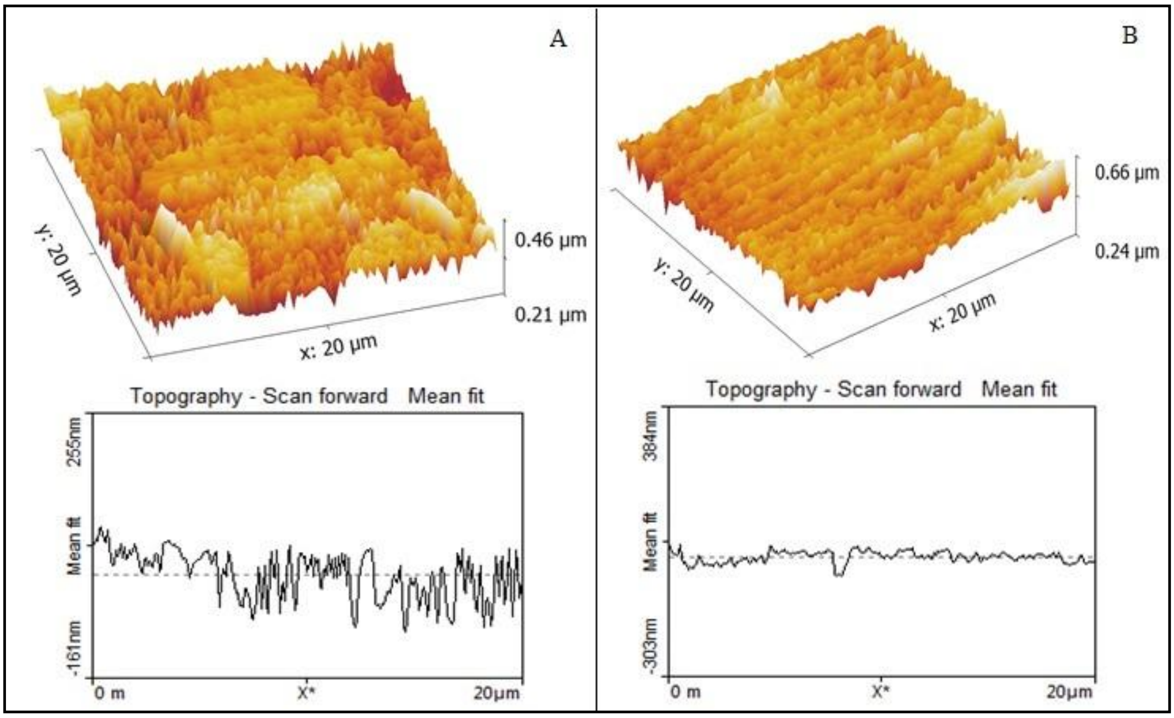

Figure no 3: Atomic Force Microscope. Microstructure Topographic Profile of SAE 1070 steel (A) as-received material and (B) after wire drawing process.

IV. DISCUSSION

The surface topographical characteristics of the deformed material are formed by many factors such as: thermomechanical processing type, lubrication, friction, deformation degree, wear, and others.In the drawing process, during the reduction of wire thickness by deformation passes, the wire surface roughness increases as the degree of deformation increases, a behavior called by Thomson and Nayak[5] free surface roughening. Comparing the topographic profile of Figures no 1 and no2 it is possible to observe a considerable change after wire drawing. The density and height of the peaks increased gradually along the deformation passes.

Comparing roughness parameter in Tableno 1, its observed that, despite the Roughness Average (Ra) between the two materials are close, the topographic profile between them are very different. This fact can be confirmed by other roughness parameters. The Mean Roughness Depth (Rz) which represents the distance between the highest peak and the deepest valley is quite different between the two materials, such as the Total Roughness (Rt). It is evident that drawn material has peaks and valleys considerably higher than as-received material. The Asymmetry Factor (Rsk) also confirms the difference between materials topography, as-received material has negative value indicating the roughness profile has fewer peaks. This roughness parameter indicates the nature of the surface produced by the forming process. The negative Rsk is characterized by the presence of more valleys than peaks thus favoring retention of the lubricating film. In this way, it is possible to infer that the topographic characteristics of the starting material favor more the lubrication process than the drawn material [6].

The high difference between Ra and Rt parameters in drawn material can result in negative consequences for lubrication system. According to [7], this factor may lead wear area formation due to the lubricant film reduce during drawing process. In this context, Thwaite [6] affirm the necessity to avoid high roughness in order to maintain lubricant film thickness.

The SAE 1070 steel is anhypoeutectoid steel with pearlite structure composed of ferrite and cementite in a staggered microstructure of lamella colonies [8]. This microstructure is composed by an extremely resistant phase, the cementite, and the ferrite phase which has good ductility. The difference of mechanical properties between two constituents of pearlite structure allows observing topography on microstructure.The Figure no 3 allows to observe the topographic profile discrepancy of as-received material and after drawing process. As-received material topography is quite irregular because the lamellas. The deformed microstructure topography appears more homogeneous as illustrated in image and graph in Figure no 3B.This occurs because the lamellae were aligned with the drawing direction. However, although more homogeneous, the deformed microstructure has higher amplitude peaks than as-received material microstructure.

V. CONCLUSION

Its possible concludes that comparing topographic profile, the drawing process significantly changes the roughness of external surface and the material microstructure. In both cases, the drawn material showed higher amplitude peaks. The roughness surface of deformed material can cause friction areas and hamper lubricant adhesion during further processing. The parameters Rt and Rsk presented by the material before and after the drawing process prove this tendency. The topographic profile of deformed microstructure is characterized by lamellae aligned with the drawing direction.

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