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Effect of Isothermal Annealing Temperatures and Roller Burnishing on the Microhardness and Surface Quality of H13 Alloy Steel

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ABSTRACT

AISI H13 tool steel is applied widely to produce many kinds of hot work dies, such as forging dies, extrusion dies, die-casting dies and so on. The successful employment of metal in engineering application relies on the ability of the metal to meet design and services requirements and to be fabricated to the proper dimensions. The capability of metal to meet these requirements is determined by mechanical and physical properties of the metal. Burnishing processes is considered as a surface plastic deformation method, which used to improve surface texture (micro hardness, average surface roughness, and maximum surface roughness). This work present the effect of isothermal annealing temperature and roller burnishing process on the surface properties of H13 alloy steel .This steel was annealed at a different temperatures to get different types of pearlite with different grains and grain size. After that, the steel was burnished with different forces, feeds, and burnishing speeds. The effect of annealing temperatures and roller burnishing on the hardness, micro hardness, average surface roughness and microstructure and metallographic analysis have been investigated. The results showed that roller burnishing could increase the surface hardness under the selected specified conditions depending on the isothermal annealing temperatures by 104%, 45% and 90% for the work parts with 300^{0}C, 500 ^{0}C and 6200C annealing temperatures respectively. In addition, roller burnishing significantly improves the smoothness of the steel surfaces. The average roughness obtained was ranged from 0.11µm to 0.17µm. In this paper, the microstructure analysis, micrograph of the isothermal annealed H13 alloy steel have been given. It has been shown that depending on the isothermal annealing temperature there are different types of grains and grain size of treated steel in pearlite phase.

1. Introduction

The benefits for the manufacture of components from hardened steel substantial in terms of reduced machining costs and lead times compared to the more traditional machining route presented by Callister [5]. AISI H13 tool steel is applied widely to produce many kinds of hot work dies, such as forging dies,

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extrusion dies, die-casting dies and so on. The hardness of AISI H13 tool steel varies with its application for the different type of dies. AISI H13 hardness recommended is at 43–52HRC for extrusion dies, at 44–50HRC for die-casting dies, at 40–55 for forging dies [10]. Heat treatment is the process of heating and cooling a metal in its solid state in order to obtain the desired changes in its physical properties, which commonly used for steels. Modifies microstructure of the material by raising temperature of material, holding the temperature for a period, followed by specified controlled cooling schedule. Important manufacturing process that makes it possible to obtain better products with less expensive materials need to understand effects of carbon contents, of alloy additions, and temperature control alloying elements and heat treatments greatly affect a material strength, hardness, ductility, toughness, fatigues resistance and wear resistance [10]. The properties measured during mechanical testing can be rationalized by considering the effect of microstructure features, such as grain size and particle content. The heat treatment temperature is the main factor in determining the grain size and it is possible to get different grain sizes for the same material using different heat treatment temperatures at relative variation. Heat treatment is the process of heating and cooling a metal in its solid state in order to obtain the desired changes in its physical properties, changes in structure and mechanical properties.

Some metal working processes such as conventional machining methods (e.g. turning and milling) cannot provide the optimal quality of the surface. The resulted surfaces have inherent irregularities and defects like tool marks and scratches that cause energy dissipation (friction) and surface damage (wear). However, surfaces and their properties are as important as the bulk properties. Therefore, the surface should be free of defects and undesirable residual stresses. Surface treatment is used to improve some mechanical properties such as appearance, hardness, wear, and fatigue resistance. There are many finishing processes used to produce surfaces with high quality. These processes could be classified into chip removal processes, such as grinding, and chipless processes, such as burnishing.

Burnishing is an important cold-forming process; the principle of the burnishing process is based on an indenting tool (ball or roller) rolling against the workpiece's surface. Plastic flow of the original asperities occurs when the yield point of the workpiece's material is exceeded. In this way, asperities are flattened. Compressive stresses are also induced in the surface layer, giving several improvements to mechanical properties. Besides producing a good surface finish, the burnishing process has additional advantages over other machining processes, such as increasing hardness, improving corrosion resistance and increasing fatigue resistance as a result of producing compressive residual stress [1].

A literature survey shows that many works has been conducted on the burnishing processes. The studies showed that the burnishing processes improve the surface properties of the machined parts. Hassan and AL-Bsharat [2] studied the influence of burnishing process on surface roughness, hardness, and microstructure of some non-ferrous metals. Hassan et al. [3] optimized the effect of the burnishing force and number of tool passes, on surface roughness using response surface method. Hassan and Al-Dhifi [4] used ball-burnishing tool to improve the wear resistance of brass components. They found that the burnishing process can be used to improve the wear resistance of the brass components. Luca et al. [7] investigated the influences of certain burnishing parameters on roughness of hardened steel specimens. El-Axir and Ibrahim [8] introduced a new burnishing tool. They used the center rest of a lathe as ball burnishing tool. The result of their investigation showed that the surface characteristics were improved with this burnishing tool. El-Tayeb et al. [9] studied the effects of roller burnishing contact width and burnishing orientation on the surface quality and tribological behavior of aluminum 6061. El-Axir et al. [10] constructed a new ball burnishing tool design to improve the out-of-roundness and microhardness of inner surfaces by internal ball burnishing process. El-Tayeb et al. [11] studied the influence of roller burnishing process on hardness and roughness of cylindrical thermoset and thermoplastic polymers surfaces. They found that there is a good possibility of using the roller burnishing process as finishing process on the surfaces of polymers components, and the effect of this process is more pronounced on thermoplastic than on thermoset. Al-qawabah [12] studied the effect of roller burnishing on the surface roughness and hardness of Zn - 5% Al alloyed by copper at varied percentages. He found that there is an inverse relation between the depth of hardening and the copper content. The optimum surfaces occurs in Zamac5Z10% Cu alloy.

In present work, the effects of different isothermal annealing temperatures, on some mechanical properties and structures of commercial H13 alloy steel have been studied. After that, the annealed specimens burnished under different burnishing conditions. In particular, the effect of the burnishing force, feed, and burnishing speed on the surface hardness and roughness have been studied

2. Materials and Experemintal Procedure

2.1. Materials

In this paper, alloy steel H13 was studied, according to (AISI), it has characteristics like inability, dimensional stability during hardening , good combination of hardness and toughness .Table 1 shows the chemical composition of H13 alloy steel.

Table 1. Chemical composition of H13 alloy steel.

Type: (AISI)	C Wt%	Si Wt%	Mn Wt%	Cr Wt%	Mo Wt%	V Wt%	W Wt%	Ni Wt%
H13	0.40	1.0	–	5.30	1.40	1.0	–	–

2.2. Preparation of the Specimens

Cylindrical H13 alloy steel bar was cut into small pieces, using a band saw to produce the 170mm length specimens. The specimens were turned using single point carbide cutting tool by a conventional lathe machine with the standard cutting conditions to obtain the diameter of 25mm, after that the specimens were heat treated then the specimens were ground using a cylindrical grinding machine to attain the dimensions shown in Fig 1.

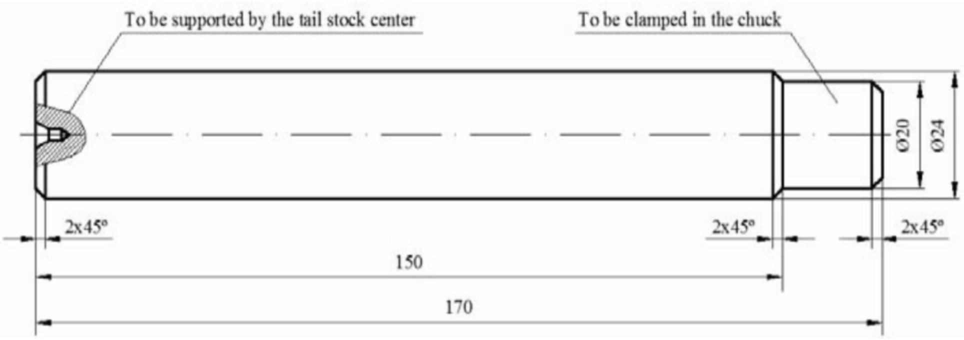


Fig 1. Workpiece geometry.

2.3. Heat Treatment

The heat treatment is the controlled heating and cooling of metals to alter their physical and mechanical properties without changing the product shape. Heat treatment is sometimes done inadvertently due to manufacturing processes that either heat or cool the metal such as welding or forming. Heat Treatment is often associated with increasing the strength of material, but it can also be used to alter certain manufacturability objectives, such as improve machining, improve formability, and restore ductility after a cold working operation. Thus, it is a very enabling manufacturing process that can not only help other manufacturing process, but can also improve product performance by increasing strength or other desirable characteristics. In this paper, the specimens annealed by isothermal process using different isothermal annealing temperatures (300^{0}C, 500^{0}C and 6200C). The isothermal annealing process shows in Fig 2.

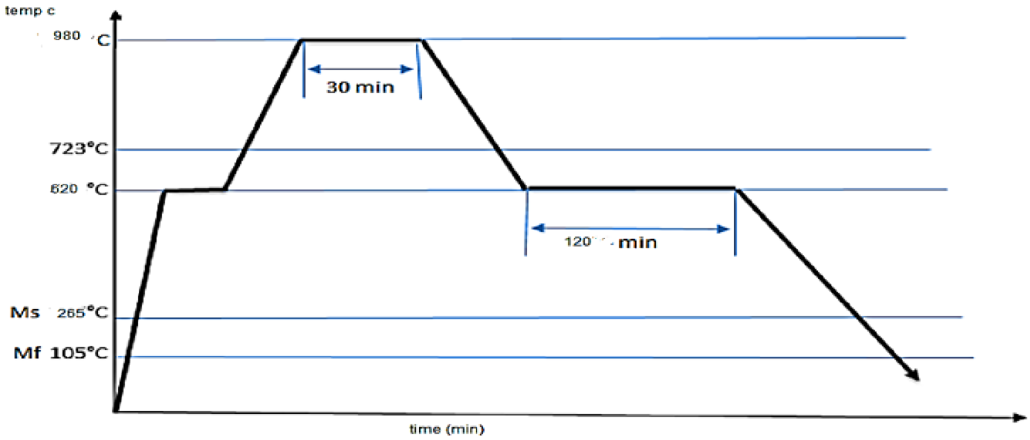


Fig 2. Isothermal annealing diagram at 620 ^{0}C.

Using the roller burnishing tool with a special holder as shown in Fig 3. The outside cylindrical surfaces of the specimens were pressed with the given parameters in Fig 4.

Fig 3. Roller burnishing tool.

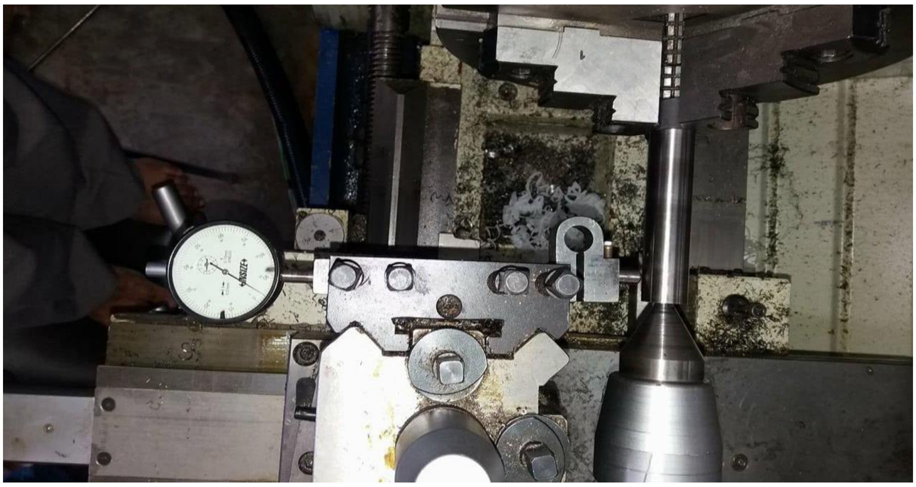


Fig 4. Setup of roller burnishing process on lathe machine.

2. Micro Hardness Test Result

The micro hardness of varies roller burnishing forces and feeding for each annealed H13 alloy steel specimen at different annealing temperatures are present in Figures 5 to 7.

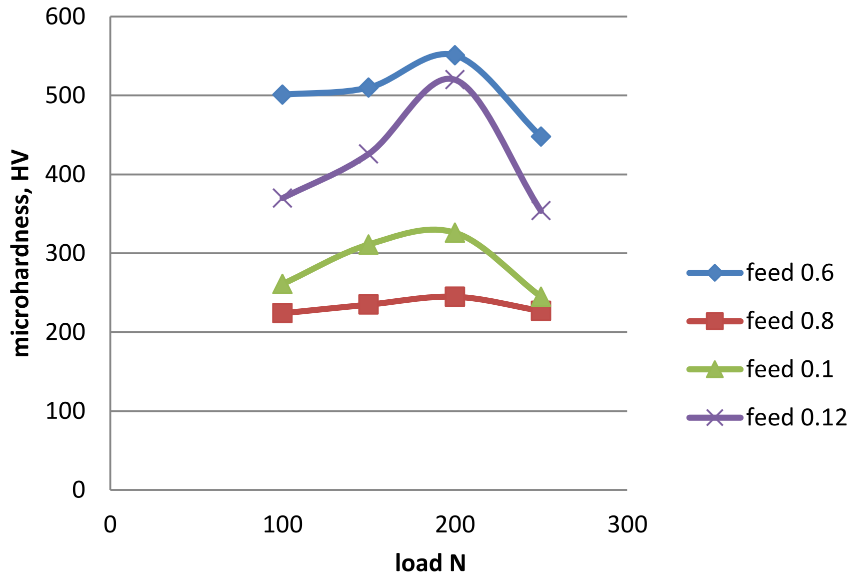


Fig 5. The effect of roller burnishing force and feed on the microhardness (isothermal temperature 300 ^{0}C, initial microhardness 270 HV) 104%.

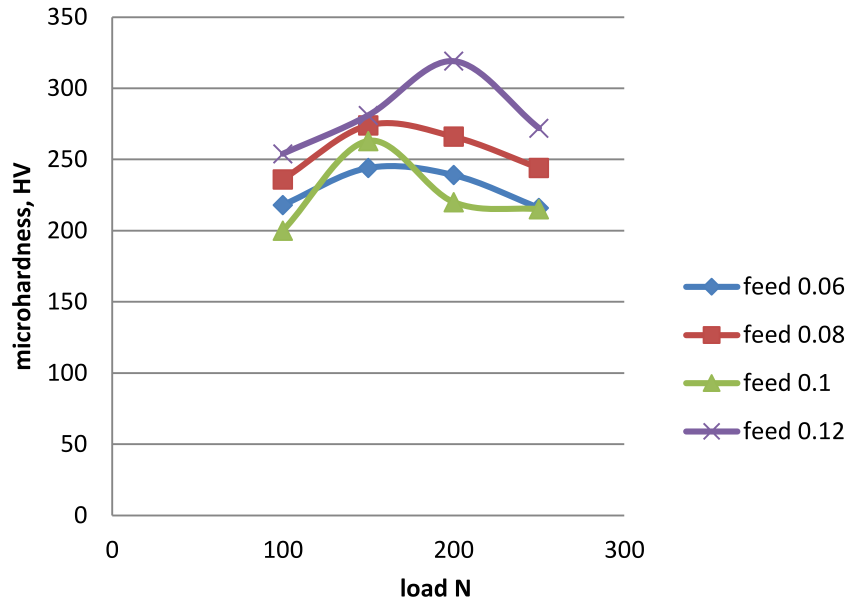


Fig 6. The effect of roller burnishing force and feed on the microhardness (isothermal temperature 500 ^{0}C, initial microhardness 220 HV) 45%.

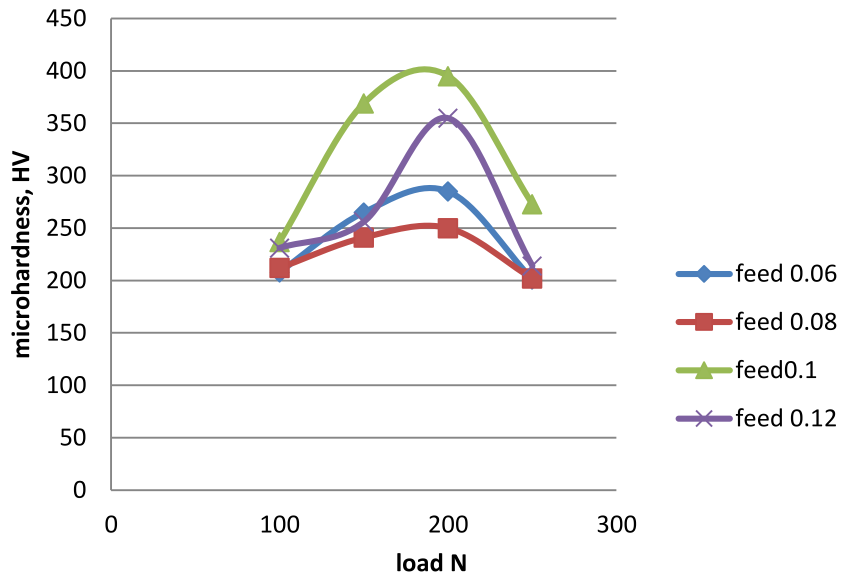


Fig 7. The effect of roller burnishing force and feed on the microhardness (isothermal temperature 620 ^{0}C, initial microhardness 207 HV) 90%.

Depending on the grain size and the type of pearlite, we got the different hardness of different groups of work parts, so the maximum hardness is the hardness of bainite (annealing temperature is 300^{o}C) and the hardness of the fain pearlite is the minimum. The results showed that roller burnishing could increase the surface hardness under the selected specified conditions depending on the isothermal annealing temperatures because of the different ability for plastic deformation, by 104%, 45% and 90% for the work parts with 300^{0}C, 500^{0}C and 620^{0}C annealing temperatures respectively.

3. Surface Roughness Test

The surface roughness of varies roller burnishing forces and feeding for each annealed H13 alloy steel specimen at different annealing temperatures are present in Figures (8-10).

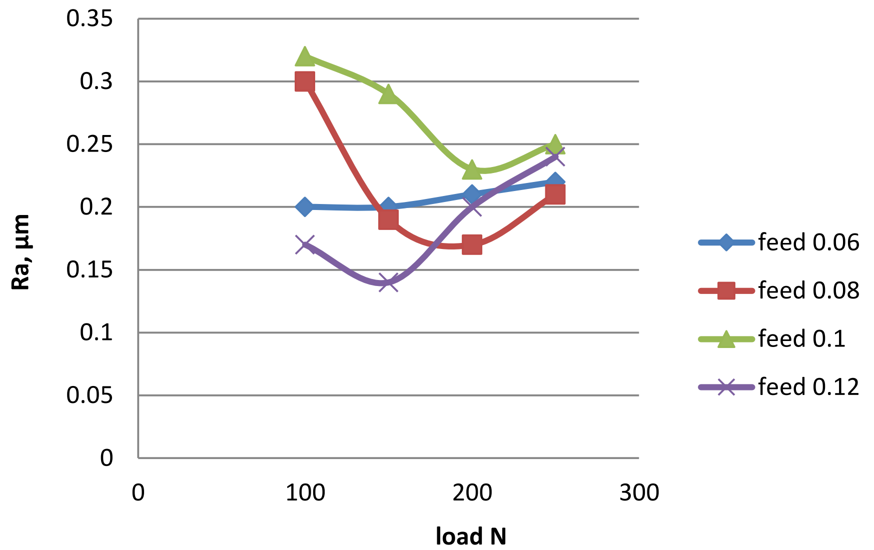


Fig 8. The effect of roller burnishing force and feed on the surface roughness Ra (isothermal temperature 300 ^{0}C, initial…

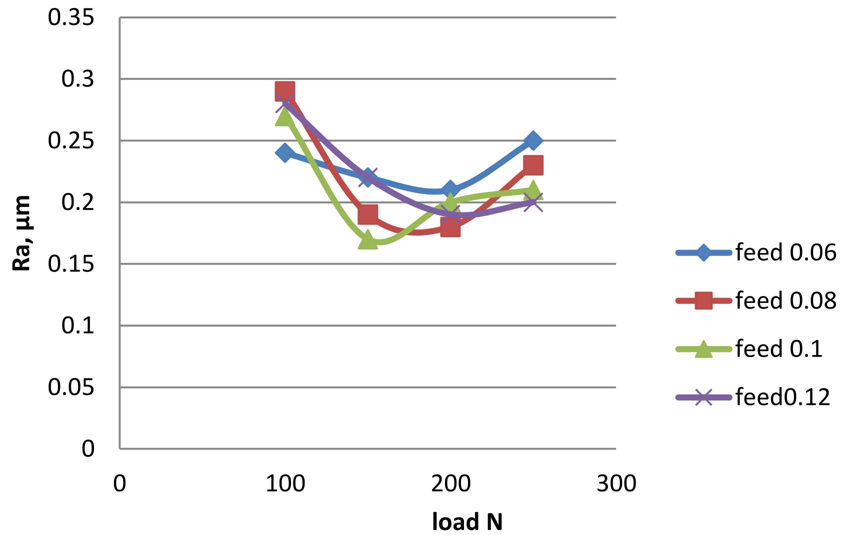


Fig 9. The effect of roller burnishing force and feed on the surface roughness Ra (isothermal temperature 500 ^{0}C, initial Ra 0.25µm) 32%.

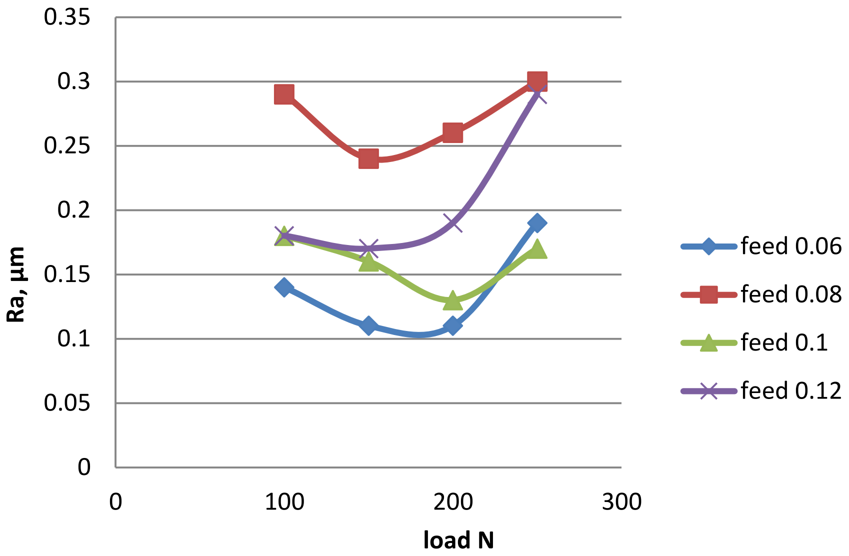
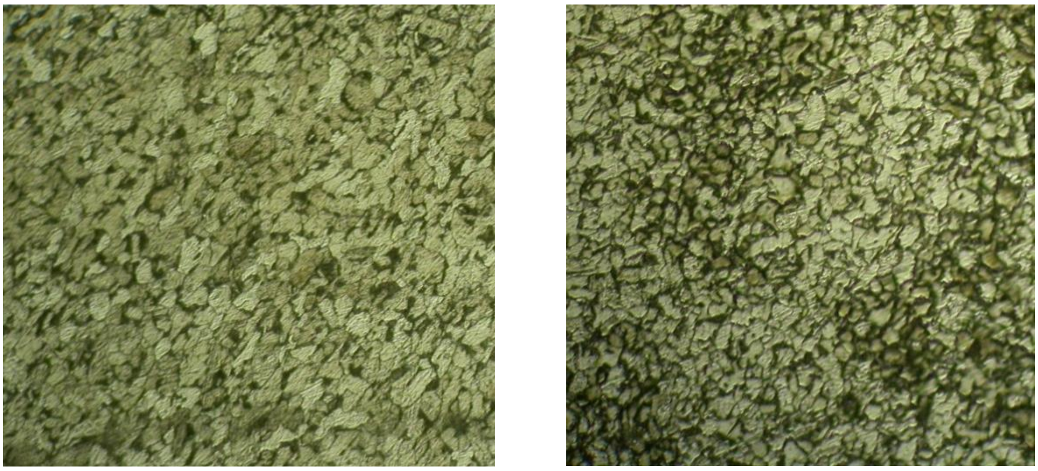


Fig 10. The effect of roller burnishing force and feed on the surface roughness Ra (isothermal temperature 620 ^{0}C, initial…

The surface roughness test shows the effect of roller burnishing force and feed on the surface roughness Ra. roller burnishing significantly improves the smoothness of the steel surfaces. The average roughness obtained was ranged from 0.11µm to 0.17µm, while the surface roughness Ra before burnishing was ranged from 0.19µm to 0.25µm, depending on the grain size and the type of pearlite by different isothermal annealing temperatures.

4. Surface Microstructure Test

The properties of metals highly depend on their structures. The internal and surface structures determine how materials perform under a given application. The effects of most industrial processes applied to metals to control their properties can be explained by studying their rnicrostructures. Therefore, microscopic inspection was carried out in this study to show the effect of isothermal annealing temperature on the type of producer pearlite. At temperatures just below the eutectoid, relatively thick layers of both the ferrite and Fe3C phases are produced. This microstructure is called coarse pearlite. The thin-layered structure produced in the vicinity of 500^{0}C is termed fine pearlite. In addition to pearlite, other micro constituents that are products of the austenitic transformation exist that one of these is called bainite at a very low temperatures. Fig 11 shows different two types of pearlite with different grains at different isothermal temperatures (coarse pearlite at isothermal temperature 620 ^{0}C and fine pearlite at 500^{0}C).



A B

Fig 11. The microstructure of isothermal annealed H13 alloy steel (A-at 620^{0}C and B- at 500^{0}C) with magnification of X.400.

5. Conclusions

The effect of annealing and roller burnishing processes in some surface properties of AISI H13 alloy steels was studied. The following points can concluded from the experiment results:

I. Depending on the isothermal annealing temperature, there are different types of grains and grain size of treated steel in pearlite phase.
II. Different types of grains in pearlite phase are different by their ability for plastic deformation.
III. Roller burnishing as a surface plastic deformation process could increase the surface hardness under the selected specified conditions depending on the isothermal annealing temperatures by 104%, 45% and 90% for the work parts with 300^{0}C, 500^{0}C and 620^{0}C annealing temperatures respectively.
IV. Roller burnishing significantly improves the smoothness of the steel surfaces. The average roughness obtained was ranged from 0.11μm to 0.17μm, while the initial roughness before burnishing was ranged from 0.19μm to 0.25μm.

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