Microstructure and Mechanical Properties of Cold Rolled AISI 1018 Low Carbon Steel

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Abstract. In this investigation, mechanical properties and microstructure of AISI 1018 low carbon steel in the form of strips with the dimensions about 50×25×4 mm subjected to cold rolling gradually by 20, 30, 40, and 50% were studied. The effect of the percentage of cold rolling on the mechanical properties of AISI 1018 low carbon steel was estimated by using tensile test, Brinell hardness test. The tensile test was done by using Universal Tensile Machine (UTM) to define yield strength and tensile strength as the percentage of increasing in the deformation, while the Brinell hardness number was obtained for each percentage of rolled deformation. Also, the microstructure of the specimens was analyzed by optical microscope. The results of this investigation show that the yield strength decreased with increasing the percentage of cold rolled as 300, 233, 200, and 171 MPa, while the tensile strength decreased as 368, 297, 274 and 238 MPa respectively. While Brinell hardness number increased with increasing the percentage of rolling deformation as 145, 192.1, 221 and 240.3 (HB) respectively. This is, in turn, show that increasing brittleness as a result of increasing rolling deformation. The photomicrographs of the specimens show that increasing in percentage of cold rolling leads to stretch the grains, which consist of fine ferrite grains with the pearlite grains.

1. Introduction

Since low carbon steel possess low mechanical properties such as hardness, tensile strength, and ability to cold working and don’t respond to the heat treatment in which the properties may be increased by cold working. The main applications of low carbon steel are automotive components, structural sections and sheets using in bridges, pipe lines, and buildings. Cold working is an important process in steel production as well as to improve the mechanical properties or to obtain a desirable shape [1-3]. Cold rolling directly influences on the structure and properties material because of it is considered as no recrystallization can be occurred. The grains gradually extend in the direction at which the deformation occurs and then arrangement the crystallographic lattice can be happened in directional character. Due to the effect of deformation, bonding character for the other phases can be developed, such as pearlite structure or another inclusion. Hence, due to the deformation, crystallographic texture and structural arises which in turn causes the directional effect of the mechanical properties [4]. An important part for the strips and hot rolled is subjected to cold rolling; in cold rolling, the recrystallization cannot be occurred because of low working temperature [5]. The aim of cold rolling process is to produce strips or sheets with high surface finishing and the cold rolling products were then softened by annealing heat treatment before manufacturing [6]. A specific characteristic of the deformation for the structure is...
anisotropy of the mechanical properties and at the same time, the direction of grains arrangement is extremely dependent on the deformation due to the cold rolling of strips and sheets [7]. There are many researches were published in this field, Nurudeen A. Raji and Olucke O. Oluwole [8] studied the effect of cold drawing on mechanical properties of 0.12 wt.% C steel using to manufacture the nails. Different degrees of cold drawing were used gradually by 20%, 25%, 40%, and 50%. The results of this work show that increasing the degree of cold working leads to increase Brinell hardness number and decreasing the yield strength, tensile strength, ductility, and toughness. Frederike et al. [9] were studied the effect of additional shear strain induced during the symmetrical rolling (SR) and asymmetrical rolling (ASR) on the mechanical properties and microstructure. ASR was carried out by using a rolling diameter ratio about 2:1. The results of this work show that a simple addition of shear strain induced by ASR affected extremely the microstructure and improving the mechanical properties. Whilst Y. Liu et al. [10] investigated the effect of cold-rolled on the mechanical properties and microstructure of SAE 1078 pearlitic steel. The cold rolling used in this study up to 90%, the percentage of cold rolling of the mechanical properties of AISI 1018 low carbon steel.

2. Methodology

2.1. Experimental Material

Material used in this work is AISI 1018 low carbon steel in the form of strips with 50×25×4 dimensions. Table.1 shows the chemical composition of AISI 1018 low carbon steel. Table.2 shows the mechanical properties of AISI 1018 low carbon steel.

| Table 1. Show chemical composition of low carbon steel AISI 1018 wt% |
|-------------------------------|-------------------------------|
| C | Si | Mn | P | S |
| 0.12 | Less than 0.0005 | 0.442 | Less than 0.0005 | 0.0269 |
| Cr | Mo | Ni | Al | Co |
| 0.0097 | Less than 0.001 | 0.0119 | 0.0052 | Less than 0.001 |
| Cu | Nb | Ti | V | W |
| 0.0135 | Less than 0.001 | Less than 0.0005 | 0.0009 | 0.0056 |
| Ta | Sn | Zr | Zn | B |
| 0.0082 | Less than 0.001 | 0.0054 | 0.0036 | Less than 0.0015 |
| As | Pb | Se | Sb | Fe |
| 0.0155 | Less than 0.001 | Less than 0.001 | 0.0071 | Remain |

| Table 2. Mechanical properties of low carbon steel AISI 1018 |
|-------------------------------|-------------------------------|
| Tensile Strength, MPa | Yield Strength, MPa | Vickers Hardness | Modulus of Elasticity, Gpa | Poisson’s Ratio | Elongation, % |
| 440 | 370 | 131 | 205 | 0.29 | 15 |

2.2. Cold Rolling Process

The specimens used in this work in strips form, the specimens were cold rolled by using rolling machine with many stages at different cold rolling percentages about 20, 30, 40 and 50%. Cold rolling was calculated by using the following equation [11].

\[ C.W = \frac{(A_0 - A_f)}{A_0} \times 100\% \]

(1)
2.3. Mechanical Properties

Mechanical properties of AISI 1018 low carbon steel used in this work under cold rolling were defined by tensile test using Universal Tensile Machine (UTM) to evaluate yield strength, tensile strength, and ductility depending on the percentages of cold rolling. While the hardness number was obtained by using Brinell hardness test for each percentage of cold rolling using 750 Kg for 15 sec. Table 3 show the mechanical properties of the specimens before and after cold rolling with different percentages.

| C.W, % | BHN  | $\sigma_y$ (MPa) | $\sigma_{U.T.S}$ (MPa) |
|--------|------|-----------------|------------------------|
| 0      | 126  | 325             | 448                    |
| 20     | 145  | 300             | 368                    |
| 30     | 192.1| 233             | 297                    |
| 40     | 221  | 200             | 274                    |
| 50     | 240.3| 171             | 238                    |

3. Microstructural Examination

The microstructure reflected the mechanical properties of the material. The microstructure of the specimens was evaluated by optical microscope (OM) and scanning electron microscopy for each percentage of cold rolling. Microstructure examination was done for the specimens before and after cold working. After the cold rolling, the microstructure of the specimens was evaluated in the perpendicular section and in the parallel direction of cold rolling.

4. Results and Discussions

The mechanical properties essentially affected by the percentage of cold rolling as applicable for strip manufacturing.

4.1. Effect of cold rolling on tensile properties

Figure 1 show stress-strain curves for the different percentages of cold rolling. Different percentages of the cold rolling causes different deformation, from the Figure 1, it is noted that the increasing in stress leads to increase the strain, especially after proportional limit. After limit proportionality, the strain hardening will occurred as a result of increasing in stress due to the increasing the percentage of cold rolling. The yield strength is defined as the point at which the elastic deformation transforms to plastic deformation. The yield strength of the present alloy reduces with the increasing of percentage of cold rolling, which in turn reduces the ductility of material and causes the brittleness of material because of the strain hardening as a result of cold rolling.

![Figure 1. Stress-strain curves for the specimens with different C.W, %](image-url)
Also, the increasing of percentage cold rolling reduces the tensile strength due to strain hardening and makes the material brittle as well as for the same reasons deal with yield strength. Figure 2 show the increasing in percentage of cold rolling leads to decrease tensile strength and yield strength.

![Figure 2. Ultimate tensile strength yield strength for different C.W, %](image)

4.2. **Effect of cold rolling on the hardness**

Figure 3 shows that the increasing in percentage of cold rolling increases the hardness of low carbon steel due to the increasing of deformation. This is in turn corresponded to the strain hardening as a result of cold rolling which lead to reduce the thickness of steel strip.

![Figure 3. Brinell hardness number vs. C.W, %](image)

4.3. **Microstructure Analysis**

During cold rolling, initially, elastic deformation occurred as a gradually elongation of the grains in the parallel direction of cold rolling. Increasing in percentage of cold rolling leads to the transition of the deformation from elastic deformation to the plastic deformation as a yield point is separated between
them. The specimens to evaluate the structure by optical microscope after cold rolling were consisted of the fine grains of the ferrite with minor grains of pearlite. Increasing the percentage of cold rolling leads to increase the elongation of ferrite and pearlite grains as shown in Fig. 4, which in turn extremely affected the mechanical properties; this is agreed with [12].

![Photomicrographs of the specimen before and cold rolling.](image)

**Figure 4.** Photomicrographs of the specimen before and cold rolling.

5. **Conclusions**

From the research, we can conclude several conclusions which are:

i. Increasing the percentage of cold rolling leads to decrease yield strength, tensile strength, and ductility.

ii. Increasing the percentage of cold rolling leads to increase the hardness.

iii. Increasing the percentage of cold rolling leads to increase the elongation of the grains.

iv. After cold rolling the microstructure of the specimens consist of ferrite and pearlite.

References

[1] Ohashi T et al 2008 Arch. Mater. Sci. Eng. 30 51.
[2] Schindler I et al 2006 J. Achiev. Mater. Manuf. Eng. 18 231
[3] Kamwal T et al 2009 Journal of Pakistan Institute of Chemical Engineering 37 51.
[4] Grachev S V et al 2005 Metallovedenic i Temiczeskaja Obrabotka Mtalow 1 19.
[5] Schindler I et al 2004 Arch. Civ. Mech. Eng. 4 104.
[6] Pawlak S and Krzton H J 2006 J. Achiev. Mater. Manuf. Eng. 36 18.
[7] Zhang X et al 2016 Act. Mater. 114 176.
[8] Raji N A et al 2011 Mater. Sci. App. 2 1556.
[9] Berrenberg F et al 2018 Mater. Sci. Eng. A 709 1722.
[10] Liu Y et al 2018 Mater. Sci. Eng. A 709 115.
[11] Huda Z 2009 Eur. J. Sci. Res. 26 549.
[12] Janosec M et al 2007 Arch. Civ. Mech. Eng. 8 29.