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TEL ÇEKME İŞLEMİNDE KALIP KALİBRASYON BÖLGESİ UZUNLUĞUNUN 1045 ÇELİK TEL MUKAVEMETİ ÜZERİNE OLAN ETKİSİNİN İNCELENMESİ

INVESTIGATING EFFECT OF BEARING LENGTH ON TENSILE STRENGTH OF 1045 STEEL IN WIRE DRAWING OPERATION

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ÖZET

Bu çalışmada, tel çekme işleminde kalibrasyon uzunluğunun çekme mukavemeti üzerine olan etkisi incelenmiştir. Kalibrasyon bölgesinin etkisini iki farklı redüksiyon oranı ve filmaşın çapı kullanılarak gösterilmiştir. Elde edilen sonuçlara göre, kalibrasyon bölge uzunluğu arttıkça mukavemet artışı gözlemlenmiştir. Ancak, kalibrasyon boyunun uzun olması üretim esnasında çeşitli imalat problemlerine sebebiyet vermiştir. Çapsal mikrosertlik dağılımları ise kalibrasyon boyu arttıkça aralarındaki farklarda da artış gözlemlenmiştir. Mikrosertliğin artmasının esas sebebinin kalibrasyon boyunun artmasıyla elde edilen yüksek sürtünme kuvvetinin oluşturduğu deformasyon sertleşmesidir.

Anahtar Kelimeler: Tel çekme, kalibrasyon uzunluğu, deformasyon sertleşmesi, tel çekme kalıbı.

ABSTRACT

In this work, effect of bearing length on tensile strength was investigated. The influence of the bearing length is illustrated using two different reduction ratios and wire diameters. According to the results, the increase in strength was observed as the length of the bearing zone increased. However, the long bearing length caused various manufacturing problems during production. Microhardness distributions in wire cross section, on the other hand, increased as the length of bearing increased. The main reason for the increase of microhardness is the deformation hardening caused by the high friction force obtained by increasing the bearing length.

Keywords: Wire drawing, bearing length, deformation hardening, wire drawing die.

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INTRODUCTION

Wire drawing is the most common method used to manufacture wire. It is a cold forming process. It is an indispensable technique for the industry because the wire diameters are obtained with high tolerance and low surface roughness, low forming cost and being a serial process (Nilsson & Olsson, 2011). Wire drawing is done by processing semi-finished product called as alloy wire rod sets.

It has usage areas in numerous applications such as welding wires, brake wire, bridge ropes. Defects occurring during production significantly affect the strength of the wire. At the same time, the design of the die has a great influence on wire strength. The strength obtained in pearlitic steels can be increased up to 7 GPa (Wei et al., 2020).

Wire rod is a product obtained after hot processing. After the hot process, a oxide layer forms on the wire rod surface. The presence of oxide layer causes mold wear during wire drawing. For this reason, various deoxidation processes are carried out. Also, Wire circumference is covered with various lubricants to minimize mold wear during wire drawing operation (Gillström & Jarl, 2007). High wear during wire drawing causes friction force that rises unevenly and induces wire breaks.

Plastic deformation and friction forces must be controlled during wire drawing operation. The bearing length in the wire drawing die is of high importance in controlling of the friction forces. If bearing length is long, friction forces increases that causes undesired cases such as breakage and stripping of the outer covering layer. On the other hand, If the bearing length is short, wire rod wire that spring backs cannot provides desired tolerance size (Korchunov et al., 2014) Also, the bearing length plays an important role in the strength of the drawn wire, significantly controlling the amount of deformation hardening. In this study, the effect of the bearing length on the strength and hardness of the drawn wire was investigated. The optimum bearing length were determined.

MATERIAL AND METHOD

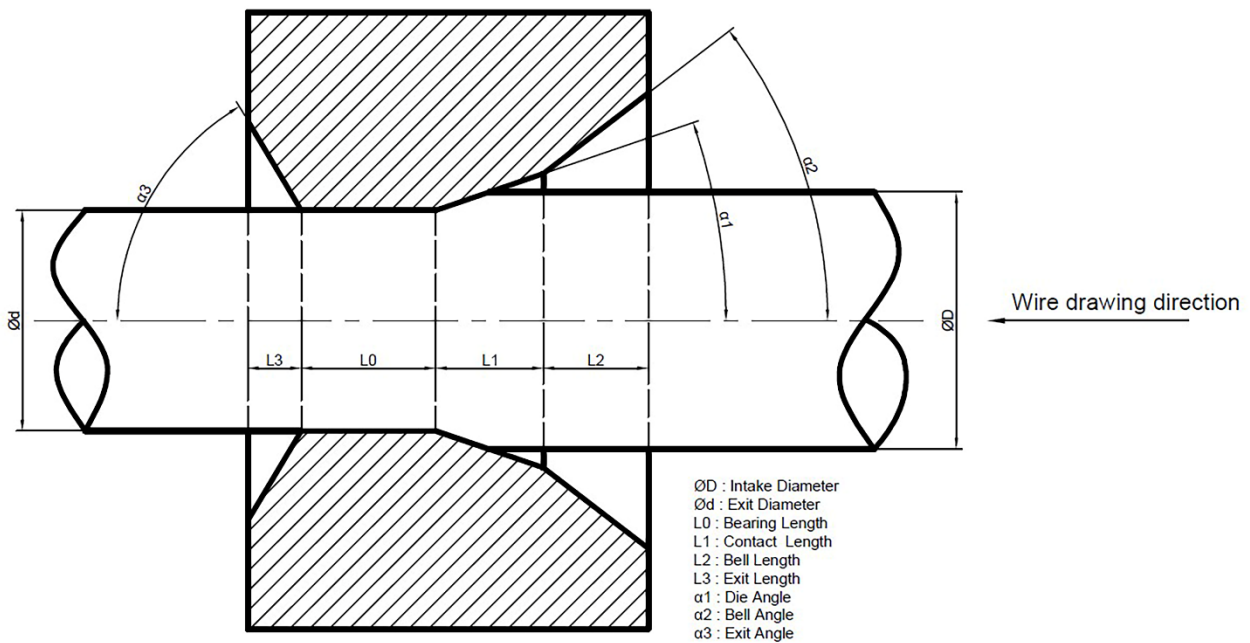


Figure 1. The Geometry of Wire Drawing Die

The technical details of wire drawing die manufactured and used experiments is shown in Figure 1. In experiments, the effects of the reduction ratios were also investigated. In the first set of experiments, a wire drawing process was applied from 1.8 mm diameter to 1.6 mm diameter by providing 11.11% rolling ratio. In the second set of experiments, wire drawing was applied from 1.2 mm diameter to 1.1 mm diameter by applying 8.3% rolling ratio. The geometric dimensions of the used dies are presented in Table 1 and 2.

Table 1. The Dimensions of Dies for The First Experiments

| Die No | ØD | Ød | L0 (%d) | L0 (mm) | L1 (mm) | L2 (mm) | L3 (mm) | α1 (°) | α2 (°) | α3 (°) |
|--------|-----|-----|---------|---------|---------|---------|---------|--------|--------|--------|
| 1.1 | | | %30.Ød | 0.48 | | | | | | |
| 1.2 | 1.8 | 1.6 | %40.Ød | 0.64 | 12 | 3 | 3 | 6 | 15 | 30 |
| 1.3 | | | %50.Ød | 0.8 | | | | | | |
| 1.4 | | | %60.Ød | 0.96 | | | | | | |

Table 2. The Dimensions of Dies for The Second Experiments

| Die No | ØD | Ød | L0 (%d) | L0 (mm) | L1 (mm) | L2 (mm) | L3 (mm) | α1 (°) | α2 (°) | α3 (°) |
|--------|-----|-----|---------|---------|---------|---------|---------|--------|--------|--------|
| 2.1 | | | %30.Ød | 0.33 | | | | | | |
| 2.2 | 1.2 | 1.1 | %40.Ød | 0.44 | 12 | 3 | 3 | 6 | 15 | 30 |
| 2.3 | | | %50.Ød | 0.55 | | | | | | |
| 2.4 | | | %60.Ød | 0.66 | | | | | | |

It is essential to minimize the friction force in the wire drawing process. Therefore, various modifications are made on the die and wire. While manufacturing of molds, wire drawing contact surfaces were polished to minimize friction force. Figure 2 shows a wire drawing die with polished surfaces. In order to reduce the friction force between the mold and the wire, zinc phosphate was coated on the wire surface by dipping method. Furthermore, calcium-based solid soap lubricant was used during wire drawing. Figure 3a and 3b show the wire drawing machine and wire drawing test setup. Experiments were carried out on Mekosan wire drawing machine. In both experimental sets, the wire drawing speed was kept constant at 7 m/s.

**Figure 2.** Wire Drawing Die

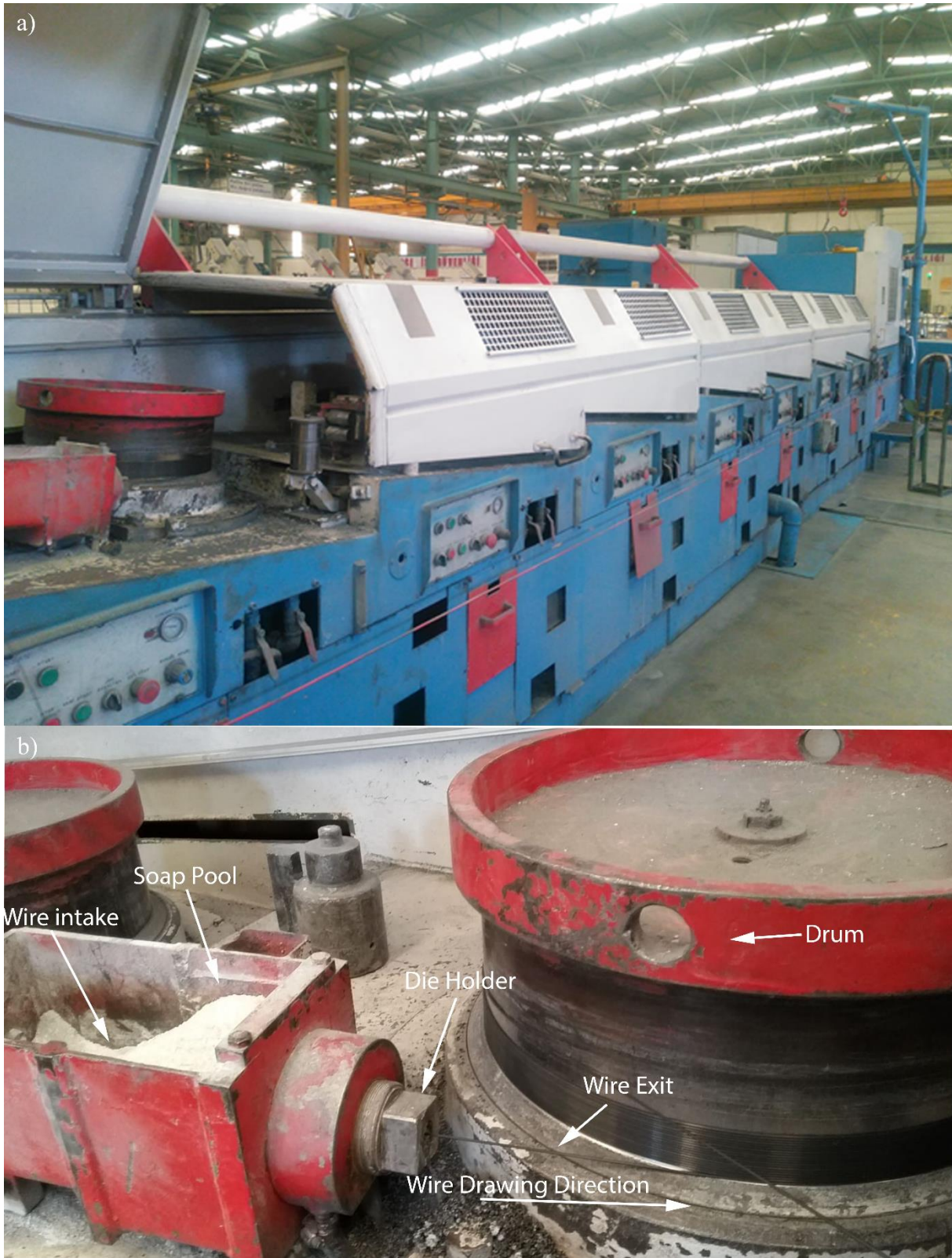


Figure 3. a) Wire Drawing Machine and b) Wire Drawing Setup

The length of the wire drawing process for each experiment is 250 000 m. Wire rod material is 1045. Chemical composition of 1045 steel wire is presented in Table 3. Wire rods are reduced to 1.8 and 1.2 mm diameters before the experiment and their strength values are shown in Table 4.

Table 3. Chemical Composition of 1045 Steel Wire.

| C | Mn | Si | Mo | Cr | Ni | P | S |
|------|------|------|------|------|------|-------|------|
| 0.47 | 0.72 | 0.39 | 0.11 | 0.41 | 0.48 | 0.037 | 0.03 |

Table 4. Wire Strengths Measured Before Experiment.

| Wire Material | Wire Diameter (mm) | Tensile Strength (MPa) | Elongation (%) |
|---------------|--------------------|------------------------|----------------|
| 1045 | 1.8 | 1102 | 18.1 |
| 1045 | 1.2 | 2141 | 10.2 |

Tensile strength measurements were executed Alşa brand tensile device that has 2 ton tensile capacity. Tensile tests were carried out at a speed of 5 m/min. For each experiment, 5 different samples were taken and subjected to tensile testing and then, average values were taken. Microhardness tests were performed with the vickers indentation tip on Wilson Hardness device. Vickers hardness measurement was carried out on the Hv0.2 scale and the force application time was 10 seconds. Metallographic examinations were performed with Nikon Eclipse L150 optical microscope. Samples were etched with 3% Nital solution before metallographic examination.

RESULTS AND DISCUSSION

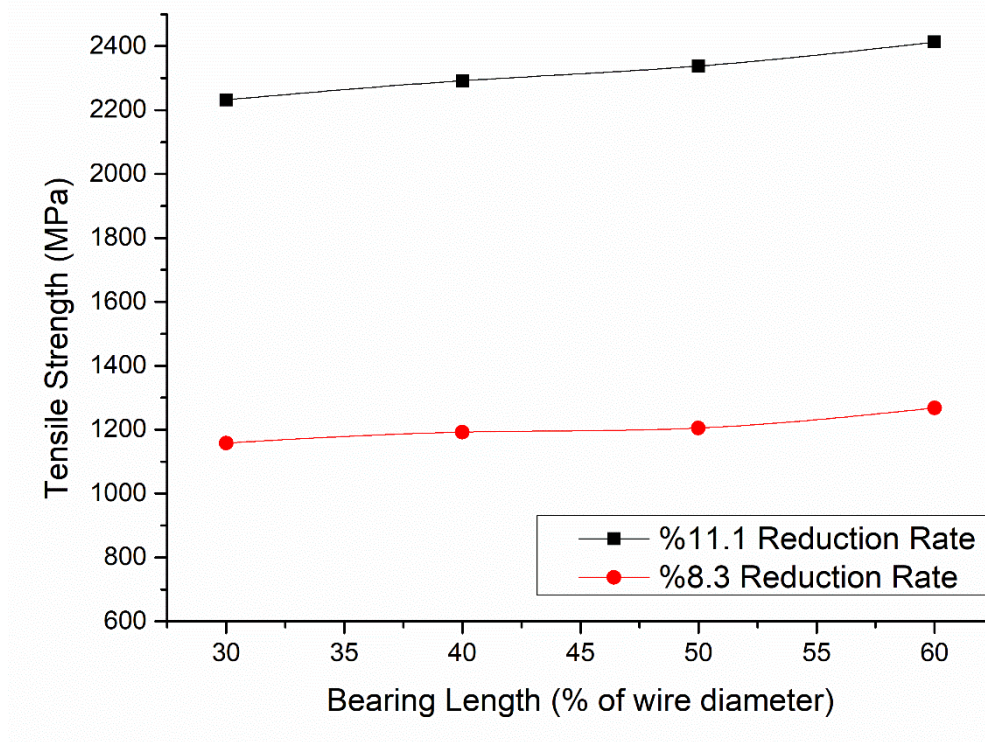


Figure 4. Effect of Bearing Length on Tensile Strength under Different Reduction Ranges

The effect of the bearing length on tensile strength under different reduction rates is shown in Figure 4. As the reduction rate increases and the wire thickness decreases, tensile strength of the wire increases due to the deformation hardening phenomenon. As the bearing length increases, an increase in wire strength were taken place.

The 1.2 mm diameter wire, whose cross section has been narrowed by 11.1%, has a tensile strength of 2141 MPa before it is subjected to wire drawing. By increasing the bearing length from 30% of the wire diameter to 60%, the tensile strength increased approximately 200 MPa. This increase amount is approximately 110 MPa for 1.8 mm

diameter wire, whose cross section has been narrowed by 8.3% that had a tensile strength of 1102 Mpa before wire drawing.

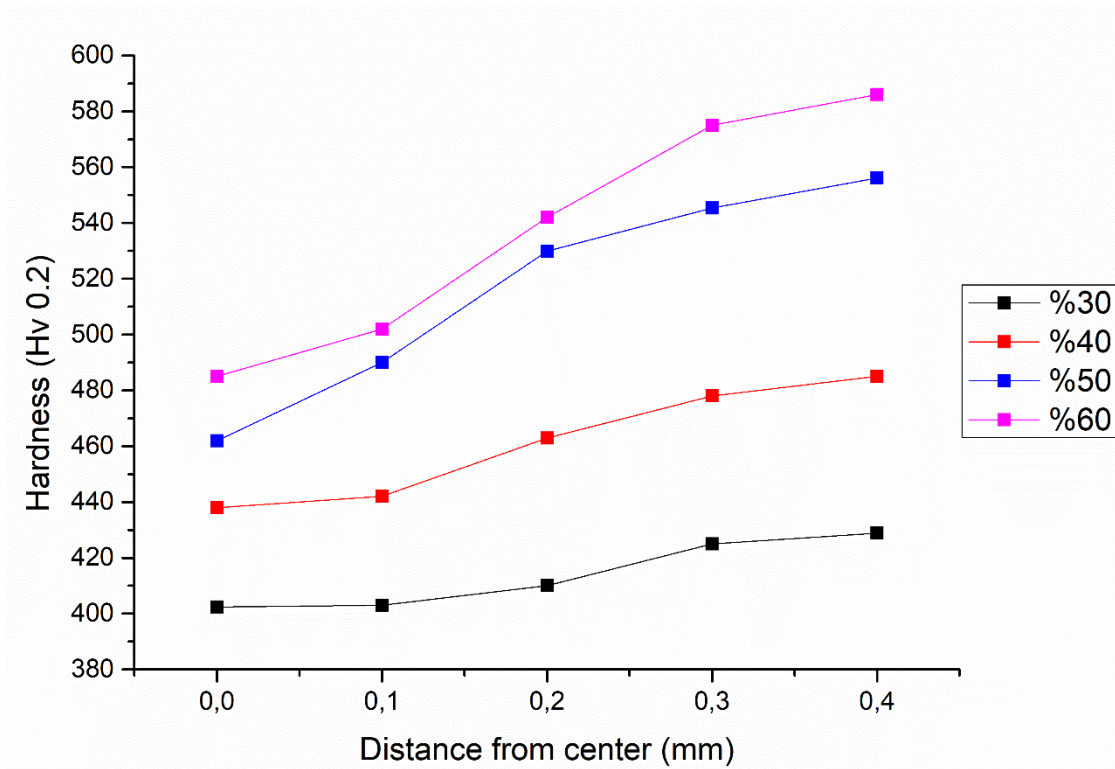


Figure 5. Effect of Bearing Length on Hardness Distribution from Wire Cross Section

Figure 5 shows the effect of different bearing length on hardness distribution of cross section in 1.1 mm diameter wire. The hardness increased significantly as progress from the center of the wire to outer diameters. Increases in the bearing length causes elevation in hardness values. As the bearing length increases, the hardness difference between the outer and the center of the wire cross section increases. Hardness elevation is a result of deformation hardening. The amount of hardness is also an indicator of which areas under how much deformed during wire drawing (Sas-Boca et al., 2017). The highest strength on the outer diameter of wire is the main indicative of highest local stress. The amount of hardness is also an indicator of which areas under how much deformation during wire drawing.

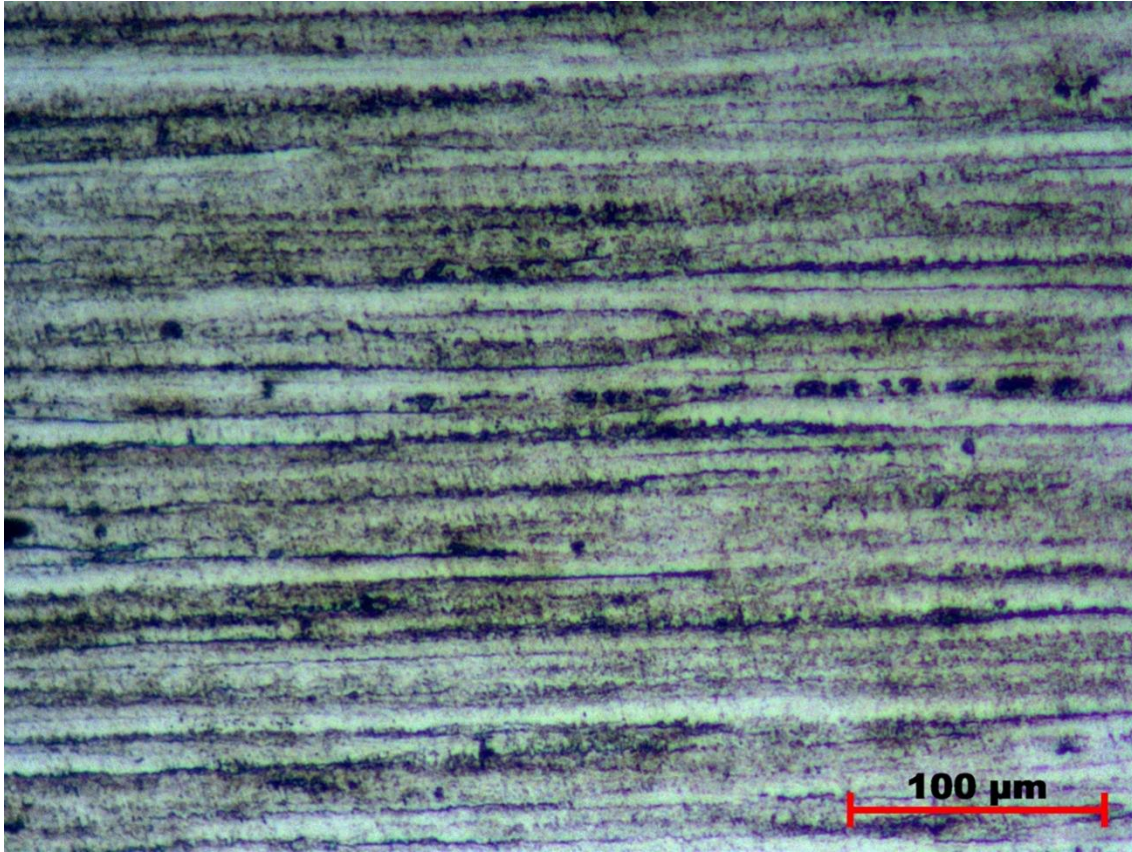


Figure 6. Microstructure of the 1.6 mm Diameter Wire

Figure 6 shows the microstructure of the wire with a diameter of 1.6 mm applied an area reduction of 8.3%. Accordingly, the grains are oriented towards the wire drawing direction. Due to the nature of the wire drawing process, rolling lines can easily be seen through cross section. 0.45% C in 1045 wire material did not form a pearlitic structure in the microstructure. Since the ratio of 0.45% C is far from the eutectoid transformation point, the perlite rate is very low. Low perlite ratio limits the amount of deformation hardening to reach high levels (Xu et al., 2019).

Although the brittleness that achieved with deformation hardening is high, deformation accumulation in small sections causes various tension irregularities during wire surface. Was observed that as the bearing length increases, breaks due to irregular stress deposits and coating stripping were occurred. Figure 7.a shows the zinc stripping that takes place at a bearing length of 50%. Zinc coating is stripped due to the high bearing length surface that caused high friction force. In addition to zinc coating zinc-phosphate layer was also stripped (Fig. 7.b).

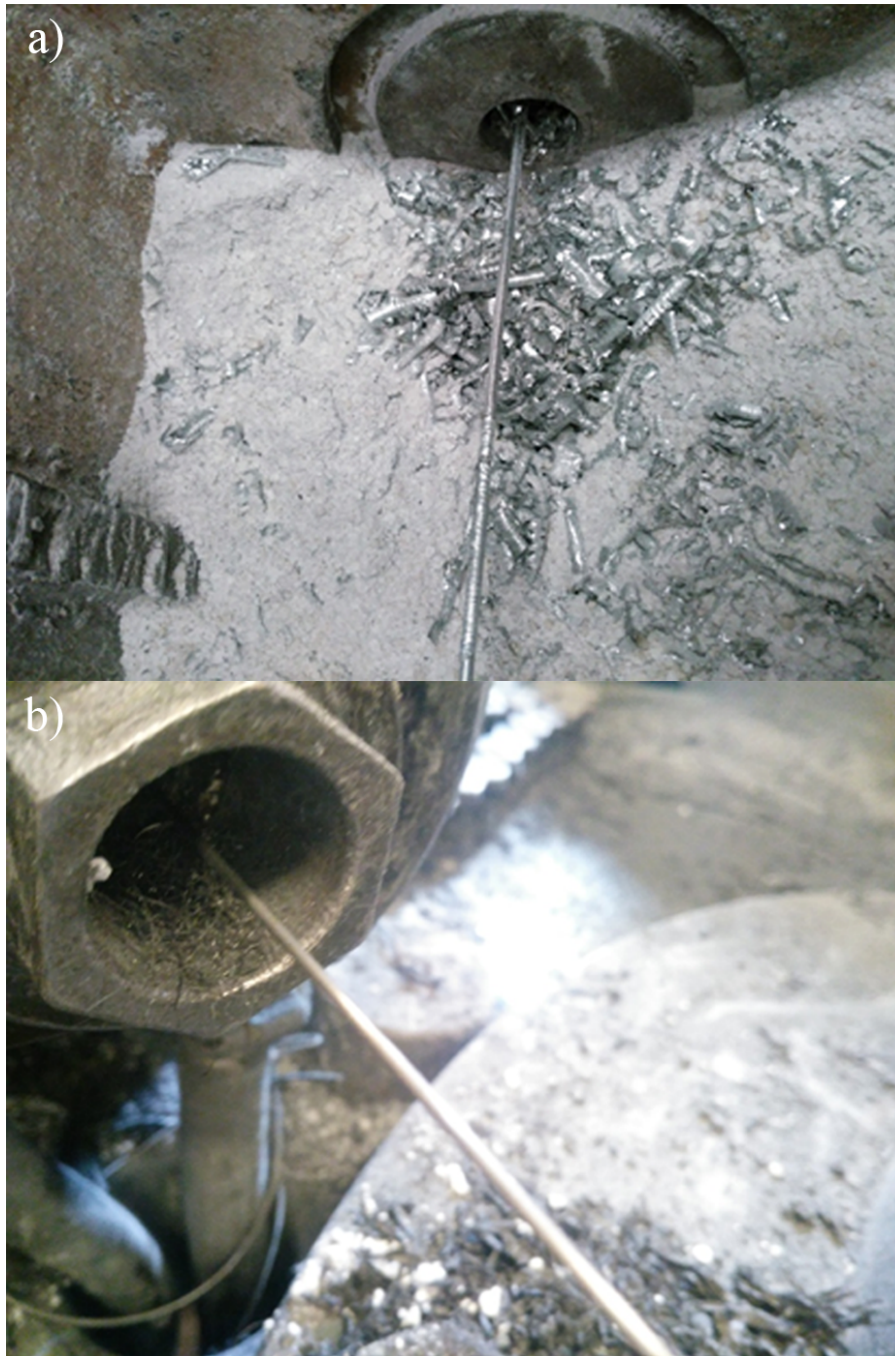


Figure 6. a) Zinc and b) Zinc-Phosphate Coating Peel-off with a 50% d Bearing Length (1.8 mm Wire Diameter)

Other problems encountered in high bearing lengths are breakage and scratching during wire drawing. Figure 8 a) and b) shows the surface scratches and rupture surface image formed in 50% and 60% bearing length, respectively. The formation of surface scratches is caused by the ineffectiveness of lubrication as a result of the increased friction force caused by the increased bearing length.

The fracture surface (Figure 8.b) is examined, it can be seen that the tip of the breaking surface is parallel to the drawing direction. In this case, the effect of arranging the grains in the direction of drawing is great. The failure formed due to crack initiations as a result of tension irregularity between the grains. These crack initiations continue in the grain boundary direction, causing the cross section to weaken and then, sudden rupture is developed (Schade, 2006).

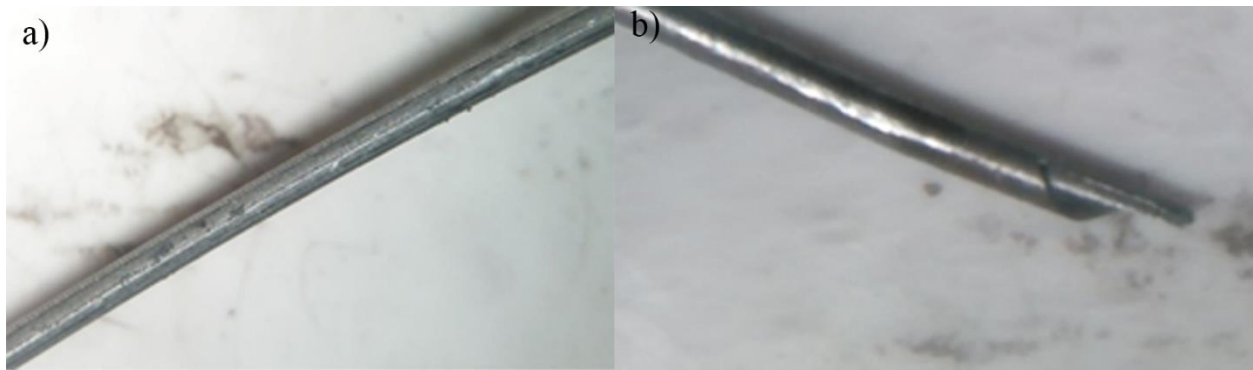


Figure 8. a) Scratch and b) Breaking Surface Formation on 1.8 mm Diameter Wire with 50% and 60% Bearing Lengths

CONCLUSIONS

In the experiments, the effect of different bearing lengths of 1045 steel wires with a diameter of 1.8 and 1.2 mm on strength was investigated in wire drawing operation. The effect of the area reduction rate was also investigated using different reduction rates in both diameters. In the light of the data obtained, the following results can be drawn;

1-As the bearing length increases in all experiments, wire tensile strengths increases. However, this increase causes coating scrapes and irregular wire breaks at 50% bearing length and above. Therefore, it is not recommended to use 50% of wire diameter and higher bearing length in designs.

2-If the bearing length is maintained about 30% and 40% of wire diameter values, wire drawing is done in a healthy way.

3-During the wire drawing process, the increase in the bearing length caused the deformation hardening. Deformation hardening was observed highest at the outermost points of the wire.

4-As bearing length increases, the differences between hardness distribution in the wire cross section were increased. This phenomenon give rise to formation of crack initiations.

5-It is essential to control the friction force during wire drawing. Otherwise, scratches on the outer surface and sudden breaks were formed.

6-Since the amount of carbon in the wire material will affect the perlite ratio, a different bearing length study must be performed for each type of wire materials. Otherwise, it is inevitable to encounter wire breakage and much higher deformation hardening more than expected.

KAYNAKLAR

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