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The Effect of The Heat Treatment Conditions on the Relation Between Bending And Deformation in 16Mo3 Sheet Material

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ABSTRACT: In the conducted study; the material micro structure-deformation interaction of 16Mo3 (1.5415) steel sheet material and its impact on the hardness value were examined depending on the ambient conditions of the heat treatment. Experimental studies were planned upon three different samples as without heat treatment, normalization and tempering heat treatments. For this purpose, the sheet materials were subjected to the process of deformation before and after the heat treatment with the bending angles of 60º and with R4.5 stapler tip diameter. The material micro structural characterization and hardness measurements of the deformation studies before and after the heat treatment were respectively conducted with the use of scanning electron microscope (SEM) and micro hardness device. The existence of the deformation tapes and grain orientations of 16Mo3 steel sheet material was detected micro-structurally thanks to the test samples taken especially from the middle zone of deformation. The highest hardness value in the middle zone of the sheet material to which deformation was applied was attained with tempering heat treatment.

Keywords: Spring-back, Spring-go, Heat treatment, Sheet metal forming, Bending

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I. INTRODUCTION

Today, sheet metal forming process has a great importance within the direction of meeting the increasing needs of the modern society. Notably the energy and automotive sectors, it is encountered in many areas such as land, sea, air and space vehicles, various household goods and machines, industrial tools, industrial structures and machine production, defense industry and medicine [1-3]. Sheet metal moulding having an important place among the production methods provides a great time gain due to the fact that production is conducted serially when there is a mass production. One of the most significant implementation areas of sheet metal forming processes is the process of bending [4-16]. Bending process is one of the most important implementation areas conducted without machining among the sheet metal forming techniques. Bending is the process of rotating the work piece round an axis for the purpose of giving the desired shape and profile via a mould convenient for the process.

As a result of the bending processes, elastic and plastic deformations occur when force is applied on the sheet material. Depending on the applied force; elastic deformation (temporary transfiguration) occurs on the material in the event that yield stress cannot be exceeded and permanent transfiguration plastic deformation occurs on the material in the event that yield stress is exceeded. Bending method is a production method preferred due to the fact that it improves mechanical properties by increasing the toughness of the sample and providing an oriented material flow [17].

It is known that permanent transfiguration occurs due to the elastic and plastic tensions on the sheet material depending on the force applied during the bending process. Crumplings, wrinkles or laceration may occur in the sheet material during the shaping (bending) of the sheet materials or plated via plastic deformation [18-28]. In this situation, the mechanical properties of the sheet materials are negatively affected. Ideal mould design and production also decrease the time and labor force costs spent with trial-error method.

It is beneficial to conduct the design of the mould by taking the properties of the sheet material into consideration. It is necessary to determine the important parameters of the used sheet materials such as elasticity module, yield stress, breaking stress and tensile stress [15]. The mechanical properties of the materials are mainly dependent on the chemical composition and internal structure. The mechanical properties of the materials are a function of these processes due to the fact that the internal structure of the materials is dependent on the applied mechanical and heat treatments. Therefore; the microstructure and mechanical properties of the materials could be improved depending on the applied heat treatment conditions (stress relieving, normalization, tempering etc.) in the processes of sheet material forming [7-10].

In the conducted experimental study, deformation implementations were carried out with the use of 16Mo3 (1.5415) sheet materials depending on the bending works. The micro structural transformations and mechanical properties of the materials were examined under the applied heat treatment conditions. The deformation works especially before the heat treatment was compared in terms of the characterization and mechanical properties of the materials in terms of the applied heat treatment conditions.

II. EXPERIMENTAL

Cr-Mo alloy 16Mo3 (1.5415) steel sheet materials were used in the realized experimental study. The chemical composition and mechanical properties of the sheet materials used in the studies are respectively shown in Table 1 and Table 2.

Table1. The chemical composition of 16Mo3 sheet material (wt. %)

C	Si	Mn	P	S	Cr	Co	Ni	Mo	Cu
0.149	0.230	0.737	0.011	0.007	0.042	0.014	0.039	0.286	0.006

Table 2. The mechanical properties of 16Mo3 sheet material

Tensile Strength (MPa)	Yield Strength (MPa)	Hardness (Vickers)	Elongation (%)
480	220	220	22

V bending mould was designed and produced for the sheet material forming applications. The production of the male stapler and female mould of the used bending mould (Figure 2) was made of Ç1390 scissor steel in CNC vertical processing center. The process of tempering was applied for the purpose of terminating the tensions in the internal structure of the material against the probability of the occurrence of any fracture and breakage due to the impact in the bending mould material.

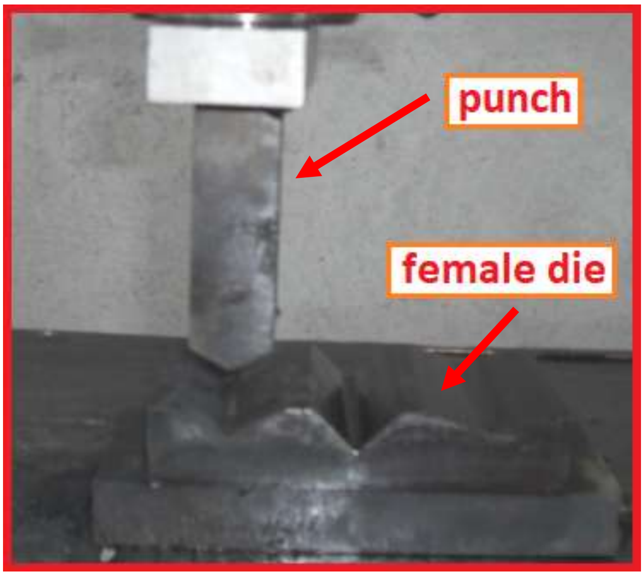


Figure 2. V bending die

The sheet material forming processes conducted with 60º bending angle and with the use of stapler tip diameter (Figure 2) were conducted under the conditions of normalization (NH), tempering (TH) and without heat treatment. Wire erosion device was used and small experiment samples were prepared for the assessment of the material deformation, material microstructure and mechanical properties depending on the bending process applied before and after the heat treatment (Figure 3).

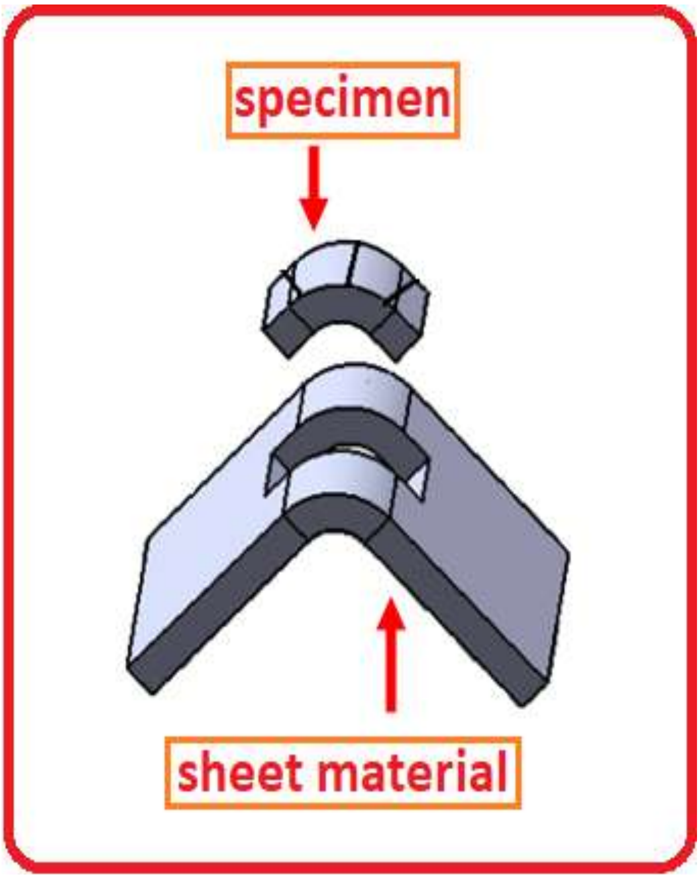


Figure 3. Test specimens; Cut area in wire erosion

Experiment samples were prepared right in the middle zone of the sheet material depending on the bending process. Sheet material micro structure examinations were conducted with the use of Leica branded optic microscope depending on the heat treatment conditions and deformation works. For this process; general metallography works which are respectively as sanding (600, 800 and 1200 grid), polishing (3µm diamond solution) and searing (2% Nital) were conducted to the sheet materials. At the same time; JOEL JSM–6060LV model scanning electron microscope and energy distribution spectrometer (EDS) connection were used for the determination of the micro structural differences occurring in terms of the deformation depending on the conditions of the sheet material before and after the heat treatment. SHIMADZU branded micro hardness (HV 0.1) device was used and measurements were conducted for the hardness changes in the general sheet material and deformation zone following the sheet material micro structural examinations (depending on before and after the heat treatment).

III. RESULTS AND DISCUSSION

Pieces were cut from the middle deformation zones by using the wire erosion bench from the sheet materials for the purpose of being able to reveal the interaction of deformation-microstructure after II, NI and MI as a result of the forming works applied to 16Mo3 sheet materials depending on 60º bending process and the attained micro structural images of the sheet materials were given (Figure 4).

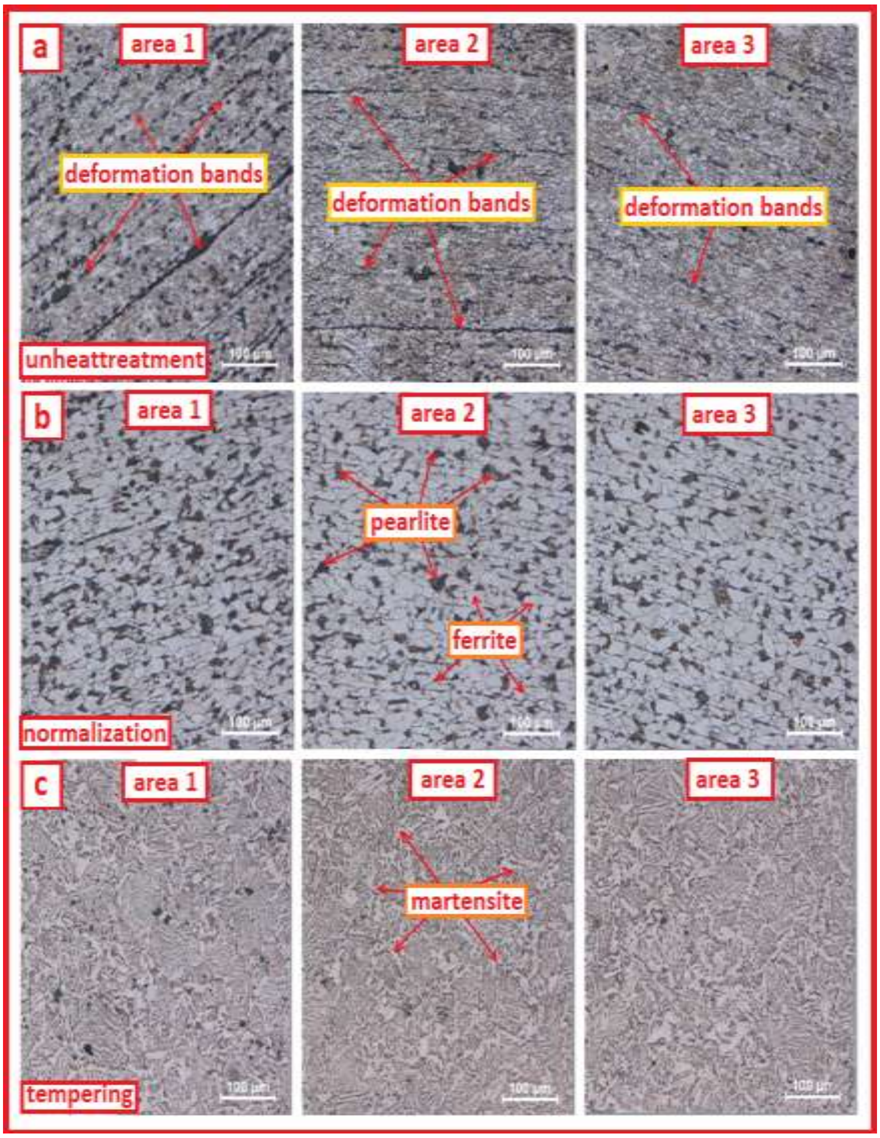


Figure 4. The microstructural images of sheet materials after deformation; a) UH, b) NH, c) TH

In Figure 4a; when the post-deformation micro structure images of the un-heat treated sheet materials were examined, it was detected that the deformation tapes and grain orientation were clearly seen in the grain structure of the sheet material due to the deformation mechanism efficient depending on the forming process. After the applied heat treatments; deformation tapes and grain orientations catch the attention due to the fact that the micro structure of the sheet materials to which especially the normalization heat treatment was applied gained a homogeneous structure (Figure 4b).

It was observed that the martensitic structure attained as a result of the tempering heat treatment is not efficient on the attained micro structure images of the deformation tapes and grain orientations due to the resistance it shows to deformation because it is arbitrary and needle-like (Figure 4c).

SEM image attained as a result of the micro structure examinations of the middle deformation zone of the un-heat treated sheet material is shown in Figure 5. When SEM image given in Figure 5 was examined, general EDS analysis was conducted as the fifth analysis as well as the point and zone analyses taken from 4 different zones from the middle deformation zone of the sheet material (Figure 6). The micro structure of 16Mo3 sheet material consists of ferrite phase and perlite structure. It is seen that point 1 and the zones no. 2 and 4 shown in Figure 5 show perlitic structure. Perlite structure forms gain orientation due to plastic deformation.

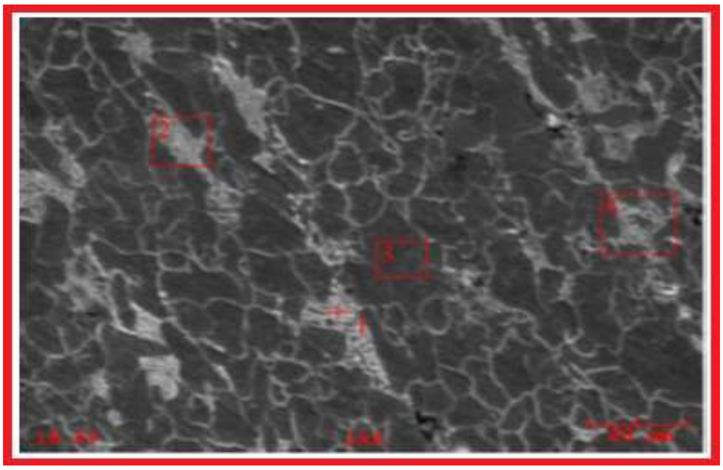
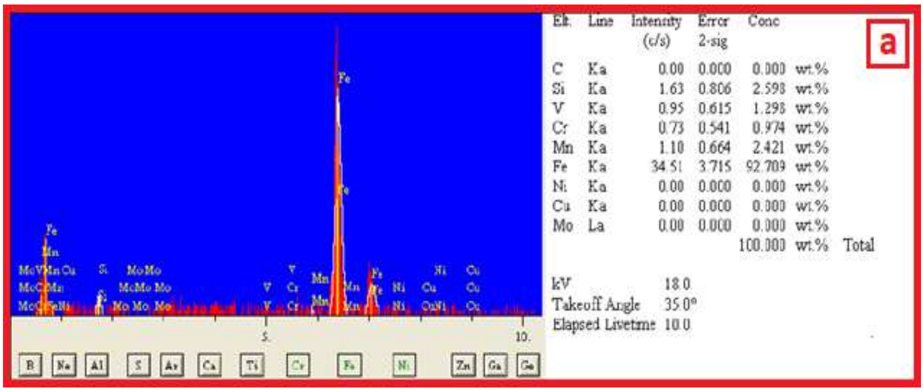
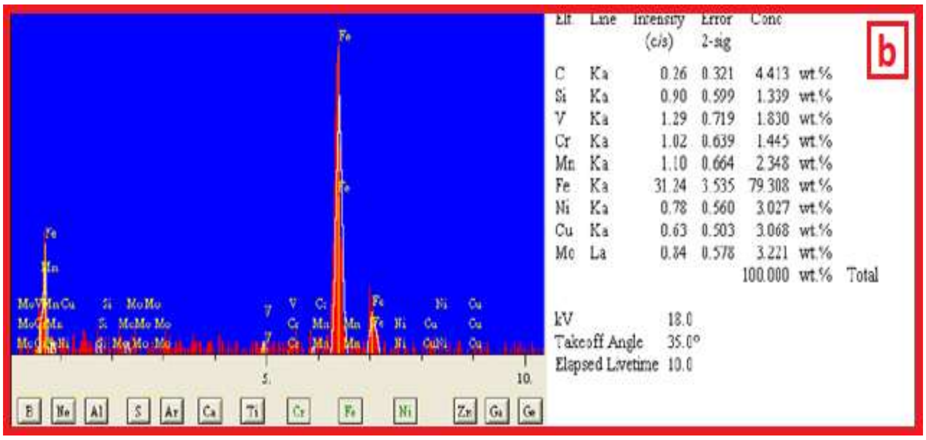
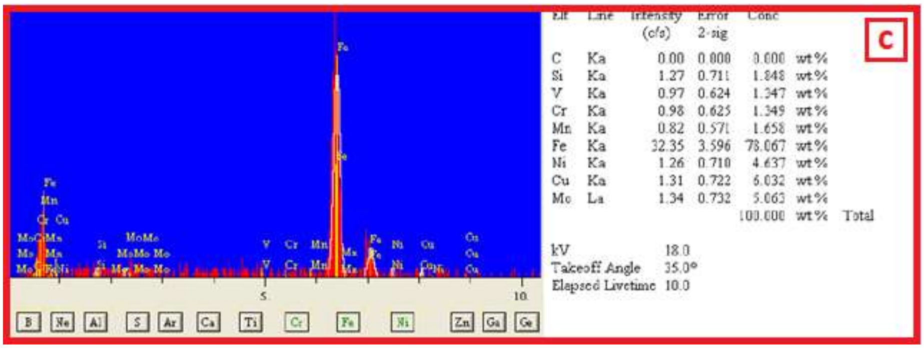


Figure 5. SEM image of UH specimen







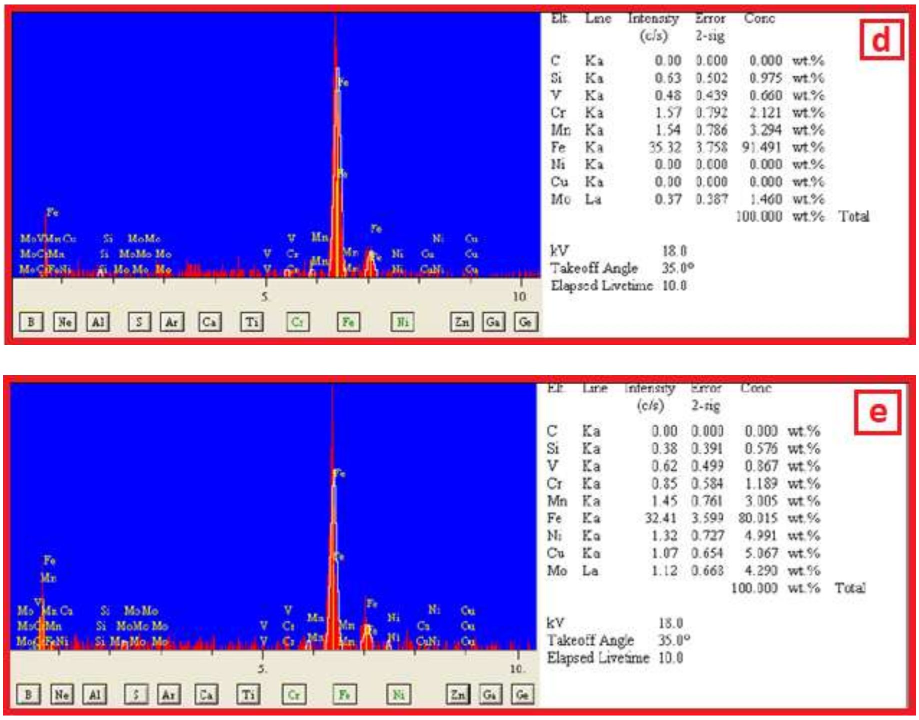


Figure 6. EDS analysis of UH specimen;
(a) 1. point, (b) 2. area, (c) 3. area, (d) 4. area, (e) general

The alloy element ratios of the perlite structure by % weight are respectively given in Figure 6a-b-d. 3rd zone forms ferrite (Figure 6c). When the micro structure of the sheet material in Figure 6 was examined, alloy elements taking place in the ferrite and cementite phases (C, Si, V, Cr, Mn, Fe, Ni, Cu and Mo) were shown with EDS general analysis results (Figure 6e).

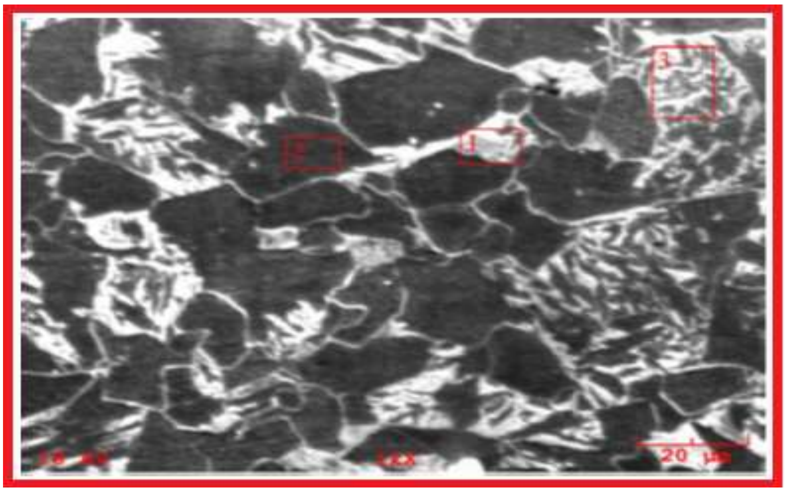


Figure 7. SEM image of NH specimen

SEM image of the sheet material to which normalization heat treatment was applied and which was attained as a result of the micro structure examinations of the middle deformation zone is shown in Figure 7. When SEM image in Figure 7 was examined, it was observed that the perlite (white color) structure covers mostly the ferrite (black color) zones. At the same time; EDS analysis and sheet material general EDS analysis of three different zones were conducted on SEM image (Figure 8a-b-c-d). The analysis result of the 1st and 3rd zones shows the formation of perlite structure in micro structure in the EDS analysis conducted on the SEM image of the sheet material to which normalization heat treatment was applied (Figure 8a-c). The conducted analysis of the 2nd zone gives information regarding the chemical composition of the ferrite phase (Figure 8b). SEM image and EDS analysis of 16Mo3 sheet material to which tempering heat treatment was applied and which were attained as a result of the micro structure examinations of the middle deformation zone are respectively shown in Figure 9 and 10. The martensitic structure occurring during the watering process is too hard and crispy for many applications and its impact resistance and formability are low. At the same time; it causes to the occurrence of high tensions in the piece as a result of rapid cooling [29]. For this reason; tempering heat treatment was applied both for the purpose of giving a satiated structure to the piece by terminating its crispiness and decreasing its tensions. It was determined that the micro structure attained as a result of tempering clearly defined the martensitic structure defined as arbitrary and needle-like.

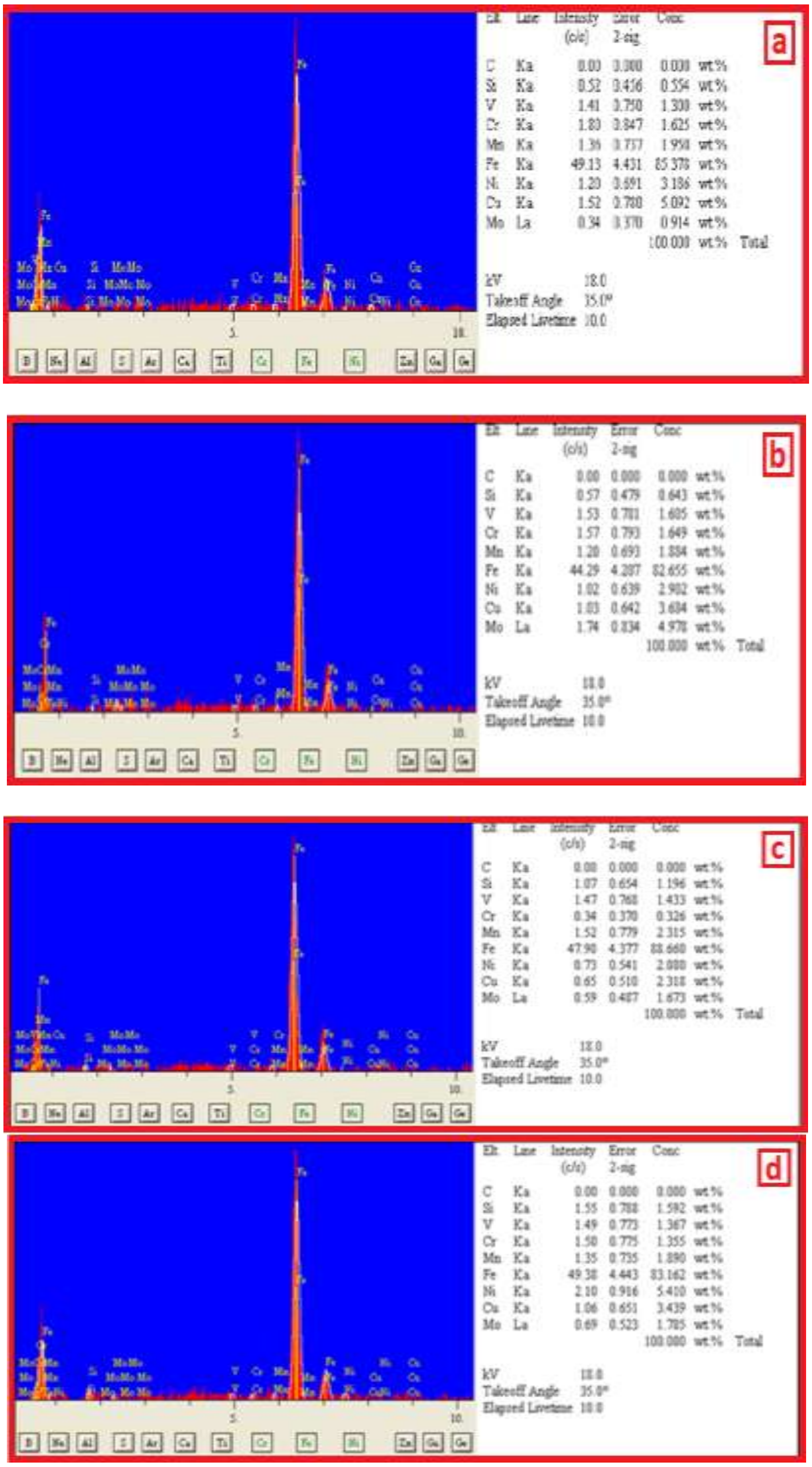


Figure 8. EDS analysis of NH specimen; (a) 1. area, (c) 2. area, (c) 3. area, (d) general

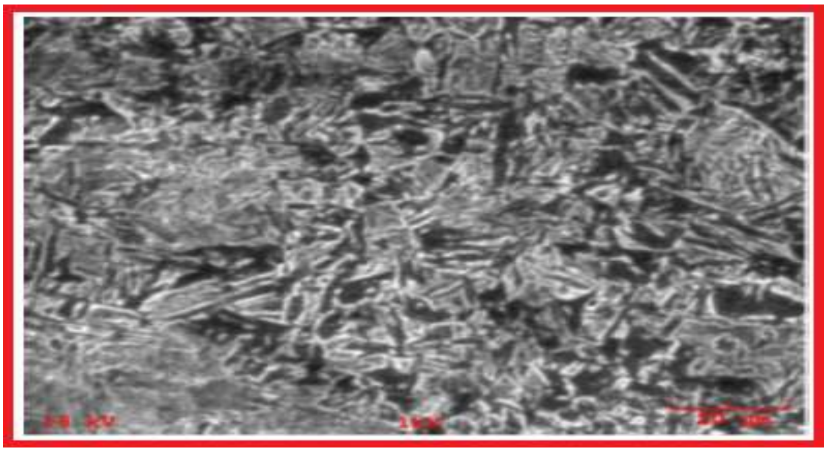


Figure 9. SEM image of TH specimen

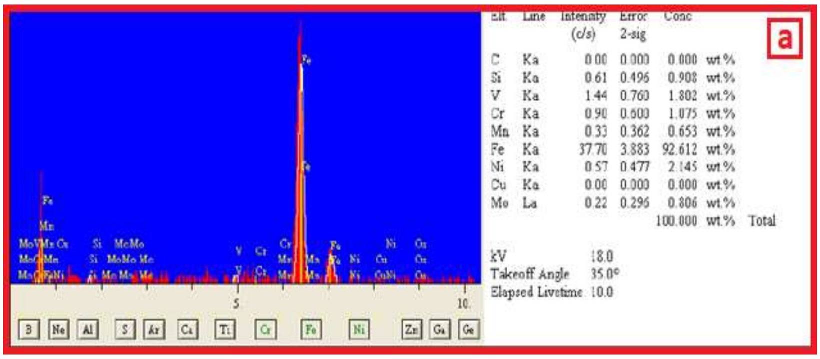


Figure 10. EDS analysis of TH specimen; (a) general

Micro hardness results of 16Mo3 sheet materials before and after deformation are shown in Figure 11 under the applied heat treatment conditions. The hardness of the un-heat treated sheet material was measured the lowest as 218 and 235 HV before and after the deformation. However; it was determined that the highest hardness (389 and 465 HV) is given by the tempering heat treated sheet materials in both conditions before and after the deformation. As the deformation ratio increases, the ratio of distortion and intensity of dislocation occurring in the cage and grain structures of the material increase. The increase both in the distortion ratio and dislocation intensity hardens the movement of dislocation. Hardening of the dislocation movement causes to the increase in the hardness and strength of the materials. The increase in the hardness and strength of the materials as a result of the plastic deformation causes to the deformation strain hardening [30-32]. For this reason, hardness values have also shown an increase in DFB.

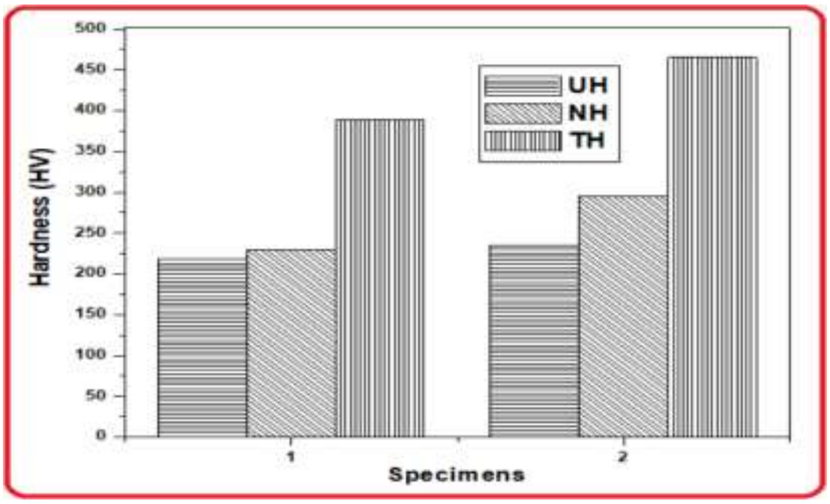


Figure 11. Change of specimen hardness; (1) before deformation, (2) after deformation

IV. CONCLUSIONS

The impact of the normalization and tempering heat treatment conditions applied to 16Mo3 steel sheet materials on the hardness of the material was examined together with the interaction of steel sheet material deformation-micro structure. The results attained in this situation are summarized as follows;

Following the micro structure examinations of 16Mo3 steel sheet material; martensitic structure with its arbitrarily oriented and needle-like grain structure was clearly observed in the ferrite-perlite structure of the non-heat treated material, in the thin ferrite-perlite structure of the material to which normalized heat treatment was applied and in the material to which tempering heat treatment was applied. Hardness values have increased after deformation in all the sheet materials when compared to pre-deformation. The highest hardness value was measured as 465 HV after tempering heat treatment in the middle deformation zone of the sheet material. Material hardness increased by approximately 16% after the deformation when compared to the same sheet material. Depending on the amount of the applied deformation; the amount and grain orientation of the micro-structurally observed taping could not be clearly seen in the sheet material to which tempering heat treatment was applied when compared to the sheet materials to which no heat treatment or normalization heat treatment were applied.

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