Influence of Ausforming Treatment of 0.4wt%C Steel Modified With Nb On The Microstructure And Hardness Properties

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Abstract

In the present work the relationship between the microstructure and the hardness of the Steel both with and without an addition of niobium was studied. Investigation by direct observation using optical microscopy was carried out.

The purpose of this work was to analyze the effects of the low thermomechanical treatment of ausforming on the final microstructure and hardness of steel and of the same steel modified with niobium.

It was found that the deformation during low thermomechanical treatment of ausforming introduces changes in the microstructure, such as carbide precipitation, which affect the hardness of the steel.

The results show that the mechanical properties of the ausformed Steel depend on the deformation temperature, amount of deformation. The addition of niobium lead to change in the hardness of the Steels investigated.

Key Words: Ausforming, Microstructure, Hardness

تأثير المعاملة (Ausforming) على التركيب ألمجهري والصلادة لصلب 0.4%wtC مضافاً إليه عنصر النيوبيوم

الخلاصة

في هذا البحث تم دراسة التركيب ألمجهري والصلادة لصلب 0.4%wtC في حالته الاعتيادية وبين نفس الصلب بعد إن أضيف إليه عنصر النيوبيوم. حيث تم التعرف على التغيرات في التركيب ألمجهري من خلال الفحص الميكروسكوبي الذي اجري على العينات باستخدام المجهر الضوئي.

إن الغرض من هذا البحث هو تحليل تأثيرات المعاملة الميكانيكية الحرارية عند درجات حرارة منخفضة والتي تعرف بـ(Ausforming) على التركيب ألمجهري النهائي والصلادة للصلب في حالته الاعتيادية وكذلك بعد إدخال تعديل على تركيبة الكيمياوي من خلال إضافة عنصر النيوبيوم. فقد وجد بان التشويه عند المعاملة الميكانيكية الحرارية في درجات الحرارة المنخفضة يسبب في حدوث عدة تغيرات في التركيب ألمجهري و يسبب في وجود ترسبات كاربيديه والتي بدورها تؤثر على صلادة الصلب.

وقد أظهرت النتائج بان الخواص الميكانيكية للصلب والذي أجريت له هذه المعاملة تعتمد على درجة حرارة التشوه ،ومقدار التشوه .كما إن إضافة عنصر النيوبيوم أدى إلى تغير في صلادة الصلب الذي هو بصدد البحث فيه.

الكلمات الدالة: المعاملة الميكانيكية الحرارية، التركيب المجهري، الصلادة

Introduction

Ausforming is actually a particular case of a more general processing and heat treatment sequence known as thermomechanical treatment, and the microstructural features of an ausformend Steel determine its properties[1].

Ausforming is an important process in producing high strength Steels of good toughness. Deformation of the metastable austenite causes the formation of a uniform high dislocation density and the simultaneous precipitation of a fine dispersion of alloy Carbides.

On cooling the material to room temperature, martensite with a very small plate size is produced, and the resulting Steel comprising very fine martensite of high dislocation density, has an outstanding combination of properties, these varying with alloy composition and processing variables[2].

Carbide forming elements are essential to ensure that fine dispersions of alloy Carbides are formed during treatment. The use of elements such as titanium, vanadium, niobium and molybdenum is advantageous to be air hardening, because the Carbides of these metals resist coarsening and show secondary hardening during tempering, and thus help to raise the strength of steel[3].

In particular, it was show that the addition of about 0.05%Nb caused a marked retardation in refining the size of precipitation-strengthening particles[4]

Experimental Procedure

Commercial steel was applied as the starting material for thermomechanical working experiments in the form of rectangular plates having dimensions of (55*42*10)mm.

The chemical composition of the materials is listed in table – 1.
The initial thickness (t) of the specimens varied according to the desired reduction. Various a mounts of reduction in thickness were used (50,60and 70%).

0ne step forging was done using air hammer with 3 ton capacity. The final thickness ranged from 5 to 7 mm.

The materials were divided into three groups and subjected to one of the following treatments:-

1- Austenitisation at 1150°C for 30min and cooling in air to 550°C,followed by Forging with reduction (Deformation) of 50%, Quenching in air and Tempering at temperature 600°C for 2h.
2- Austenitisation at 1150°C for 30°C min and cooling in air to 550°C, followed by Forging with reduction of 60%, Quenching in air ,and Tempering at a temperature 600°C for 2h.
3- Austenitisation at 1150°C for 30 min and cooling in air to 550°C, followed by Forging with reduction of 70%, Quenching in air, and Tempering at temperature 600°C for 2h .

A specimen having a laterally embedded thermocouple [DT-96 Temperature controller, Thermocouple k type (NiCr), Measure Range 20-1200°C] was prepared and calibrated.

Results

Microstructure Properties

Microstructural observation was carried out on ausformed Steel by using optical microscopy. The microstructure was revealed by chemical etching in 2%Nital.

Significant and complex changes in the microstructure were observed after ausforming, such as changes in the form of austenite grains, precipitation, growth and coalescence of the Carbides, changes in the particle com-positions, twin and deformation band formation .

The process is influenced by the following variables:
initial microstructure, chemical composition of the steel, heating rate, soaking temperature, deformation temperature and amount of reduction.

It was observed in this work that the austenite grain shape was markedly affected by the deformation process.

The grains were elongated, exhibiting deformation bands and twins (figure 1). The deformation bands were randomly distributed, showing the nature of the plastic deformation.

The carbide precipitation was greatly affected by the austenite plastic deformation. This induced a finer precipitation inside the grains, as shown in (figure 2a).

In undeformed specimens the precipitates were larger and more widely spaced, as shown in (figure 2b).

This suggests that the defects, mainly dislocations, act as nucleation sites[5]. The segregation of carbon is therefore high in the deformed material. Thus, highly dispersed precipitates may be formed in the matrix. The more random the distribution of carbon in the matrix, the more random will be the precipitation[6].

It has been observed[7] that in hot austenite deformation the preferential nucleation occurred, at grain boundaries and twins. Roland and Quillard[8] observed that the nucleation rate of new phase increased with deformation but the growth rate was not affected.

In the present work, despite the large number of favorable sites for recrystallisation and nucleation of new phases, few were actually active. In some specimens it was possible to identify ferrite mainly on high angle grain boundaries, this microstructural defect occurred in some ausformed specimens.

Typical grain boundaries are due to austenitic grain boundary migration before the start of recrystallisation, in which a grain having high dislocation density is consumed by its neigh-bourse[9]. In present work the deformation temperature was low, and the migration of grain boundaries is difficult. Migration is, however, made possible by the austenite deformation process, in which grain accommodation is accompanied by displacement of the grain boundaries. In some of the present specimens the high deform-ation may have been accomplished by grain boundary sliding[7]

Mechanical Properties

Rockwell cone hardness 120°C was measured on the transverse section of the specimens after ausforming. In all specimens an average of three measurements was taken.

There is no doubt that there is a strong correlation between the microstructure and the mechanical properties of metallic materials. Consequently, the changes in hardness after various thermomechanical treatments can be related to the distinct micro-structures induced by ausforming. As can be seen from curves 1 to 6 in (figure.3), the hardness of the steel modified with niobium and deformed depends on the amount of deformation.

In the present work, specimens having the same composition deformed at the same temperature show the same work hardening behavior. Therefore, the differences in hardness can be attributed to unequal size and distribution of the precipitates present, and this agree the present results and those of Zackary and Justusson[10].

Deformation can change the mechanical properties of an ausformed material by changing the work hardening capacity.

From a comparison of curve 1 with curve 3 and curve 2 with curve 4 in [Fig3],it can be seen that the deformation temperature produced different work hardening behavior. These results are in agreement with those of Gerberich[11] who showed that the mechanical properties of 0.4wt%C [H-11] ausformed steels are independent of deformation temperature.

It can be seen from (figure 3) that the martensite hardness increased proportionally to the deformation under-gone during thermomechanical treatment. Some authors have attributed the strengthening produced by ausforming to fine carbide dispersion [12], others have considered that the presence of carbides is irrelevant, the strengthening being a consequence of the high dislocation density produced by ausforming[13].

It can be seen from (figures 1 to 2) that several mechanisms may influence the mechanical properties after ausforming, such as deformation bands, increase in grain boundary area, and carbide precipitation. During ausforming carbon is removed from the austenite by carbide precipitation. This produces a martensite less rich in carbon and, consequently, less hard and more ductile. Also, during the deformation, the carbides prevent dislocation motion in the austenite, increasing the dislocation density and leading to a highly dislocated martensite after transformation. This martensite has higher mechanical properties than un deformed martensite.

Conclusions

The results of the present work show that :

1- The enhancement of mechanical properties as a result of ausforming is proportional to the amount of deformation.
2- The hardness increases with increasing deformation, and the steel shows a hardness comparable to that of the steel modified with niobium.
3- An important change which occurs with the deformation is the introduction of a high dislocation density and dispersed fine precipitates.
4- The occurrence of secondary hardening shows that after ausforming there is still some alloy in solution that can precipitate during tempering.
5- The amount of secondary hardening is greater afterausforming compared with the behaviour of nonausformed materials.

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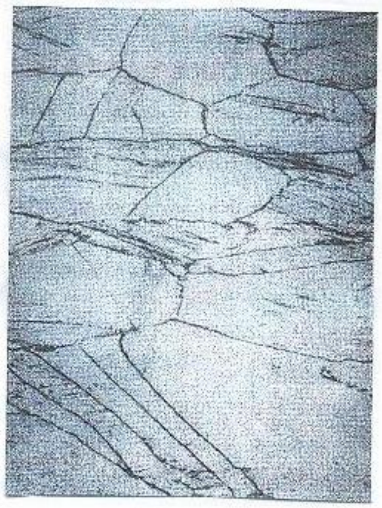
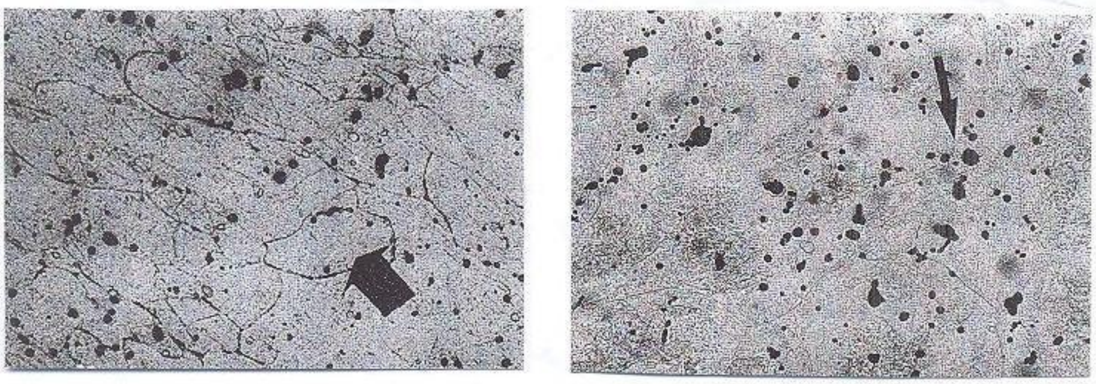
Table (1): Chemical analyses of Steels investigated wt%.

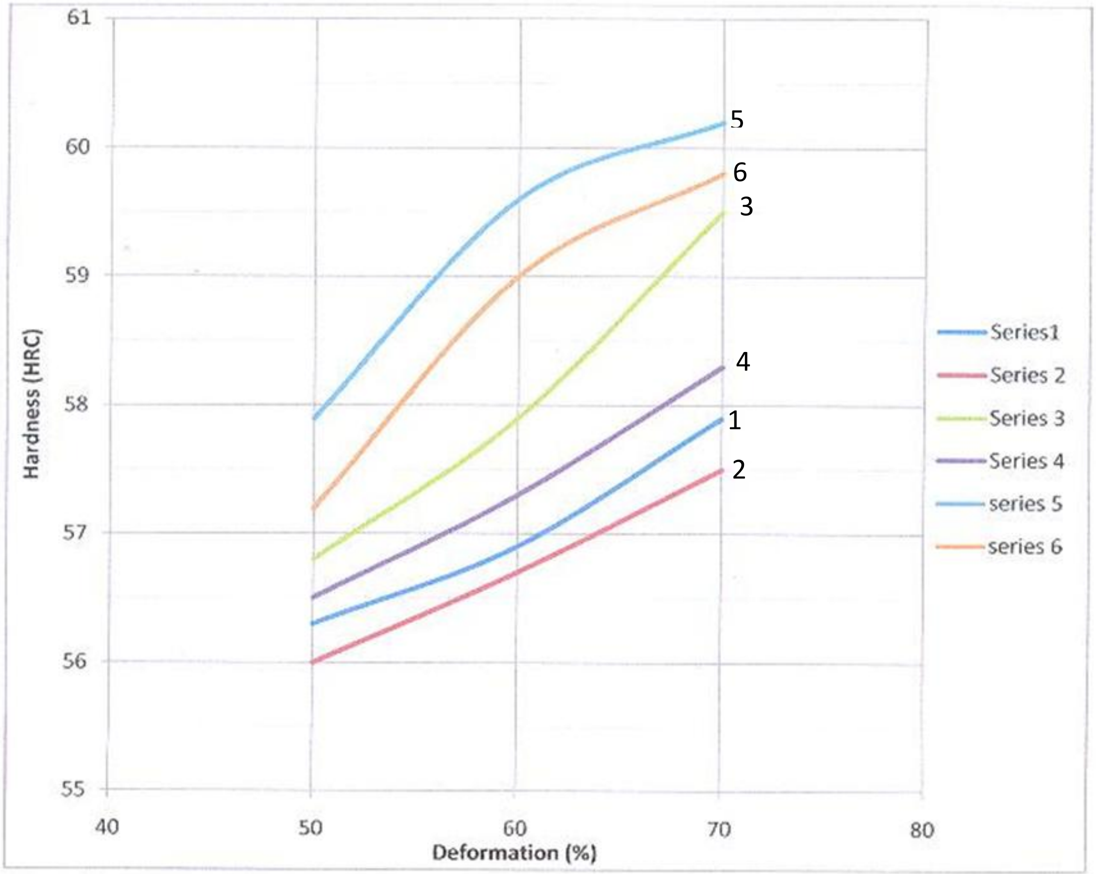
	C	Si	Mn	Cr	Mo	Nb	V	Fe
Steel	0.41	0.95	0.37	5.0	1.22	_	1.03	Ball
Steel+Nb	0.37	0.96	0.42	5.36	1.26	0.07	0.36	Ball



Figure(1): Austenite grain elongated during ausforming showing ausformation bands X540 .



Figure(2):- Fine Carbide precipitation in martensite matrix . X540



Figure(3):- Effect the amount of deformation on hardness .

1- steel +Nb→Austenised at 1150ºC Deformed by 50% at 550ºC .
2- steel →Austenised at 1150ºC Deformed by 50% at 550ºC .
3- steel +Nb→Austenised at 1150ºC Deformed by 60% at 550ºC .
4- steel →Austenised at 1150ºC Deformed by 60% at 550ºC .
5- steel +Nb→Austenised at 1150ºC Deformed by 70% at 550ºC .
6- steel→Austenised at 1150ºC Deformed by 70% at 550ºC .