Tensile Strength Determination of heat Treated Austenitic Stainless Steel AISI 316L Using (ABI) Method

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Abstract

In this study, austenitic stainless steel AISI 316L has been selected to investigate the effect of aging time and temperature on tensile strength using (ABI) technique. Heat treatment consisted of aging at temperature of 400 ^{o}C, 600 ^{o}C and 800 ^{o}C and socking time for 0.5, 1.5, 10, 24 and 72 hrs.For microstructure examination, an optical microscope were used. The results showed that with increasing the aging time at 400 ^{o}C and 600 ^{o}C the tensile strength will increase but this approach inverted at 800 ^{o}C. These results could be attributed to some metallurgical transformation that occurs during heat treatment like changing in grain size, carbide and nitride precipitation along the grain boundaries, and secondary austenite.

KEY WORDS: Tensile strength, 316L, austenitic stainless steel, ABI, heat treatment

ايجاد مقاومة الشد القصوي للصلب المقاوم للصدأ اللاوستنايتي AISI 316L المعامل حراريا وذلك باستخدام تقنية (ABI)

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الخلاصة

في هذه الدراسة استخدمت سبيكة الصلب المقاوم للصدا الآستنايتى AISI 316L لتحديد تاثير التغيرات الميتالورجية التى تحصل نتيجة المعاملات الحرارية علي مقاومة الشد القصوي وذلك باستخدام تقنية (ABI) (Automated Ball Indentation). المعاملة الحرارية تتكون من التعتيق في ثلاث درجات الحرارية المختلفة (400 ^{o}C,600 ^{o}C,800 ^{o}C)و لخمسة فترات زمنية مختلفة (0.5,1.5,10,24,72)ساعة لكل درجة.اضهرت النتائج بان زيادة زمن التعتيق من 400 ^{o}C و 600 ^{o}C ان مقاومة القصوي تزداد و لكن المادة تتصرف عكس ذلك في درجة الحرارة 800 ^{o}C وان اسباب هدة النتائج تعود بشكل اساسي الي التغيرات الميتالورجية في الصلب اللاوستنايتي ومن بين هدة التغيرات التحولات الطورية,تغير حجم البلورات ،ترسيب كاربيدات ونتريدات علي حدود البلورات،......الخ

الكلمات الدالة:مقاومة الشد،الصلب الاوستنايتيكى،ABI،المعاملة الحرارية

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Introduction

AISI 316L austenitic stainless steel is nowadays a widely used engineering material due to its good ductility and toughness over a wide range of temperature,exelent corrosion and oxidation resistance and good formability .AISI 316L stainless steel used in many industries including the bioprocess or pharmaceutical industries ,super heaters and heater components in fluid system application. [1, 3]

Large systems of AISI 316L tubing are welded in place and during welding in which heat effected zone produced on either side of the weld line will bring about a major micro structural alteration in weld metal and heat effected zone with respect to the base metal will occurs involving precipitation of sigma phase, delta ferrite, various carbides and chromium nitrides .These transformation seriously effect the mechanical and corrosion properties of material [4,5,6]

Compared with ferritic –martensitic stainless steel,AISI 316L has superior high temperature strength and reliable compatibility with a media[7,8].The most common intermetalic phase found during heating austenitic stainless steel is sigma phase which is tetragonal crystalline structure and it is responsible for reduction in toughness at room temperature. [4]

Automated ball-indentation:-

(ABI) is relatively simple, rapid and non-destructive technique, requires small amount of material with very little specimen preparation, and can be adopted for in-situ testing on real structures. One of the advantages of (ABI) technique is that it is non-destructive, since no material is removed by the specimen, a smooth shallow special indentation less than 0.3 mm deep is left at the end of the test. This spherical impression is harmless to the tested structure because it has no sharp edges, and so it does not introduce any stress concentration sites [9] The Jin Weon Kim[10] compared the tensile properties of stainless steel type AISI 316L obtained from ABI test and that of tensile test he found that the degree of ABI test data is reasonably acceptable.

Haggag et al [11] reported that excellent agreement was obtained between tensile strength of austenitic stainless steel AISI 316L thermally aged at 343 ^{o}C measured by ABI test and that from conventional tensile test.

In this research variation of tensile strength and microstructure of austenitic stainless steel AISI 316L as functions of aging time and temperature have been investigated.

Experimental Procedure

The chemical composition of austenitic stainless steel AISI 316L is given in Table (1). Spectro Spark Analyzer machine (CE, Gmb and KG Co, Germany 2008) is used for chemical analysis of austenitic stainless steel AISI 316L in Erbil Technical Institute, Erbil, Iraq.

Table (1) Chemical composition of austenitic Stainless Steel AISI 316L

Chemical Composition	***C***	***Cr***	***Ni***	***Mo***	***Mn***	***Si***	***N***	***Ti***	***Cu***	***Fe***
AISI 316L	0.025	16	11.8	2.56	1.2	0.06	0.1	0.03	0.55	Bal.

Tensile test were performed using ABI device. (ABI-Ernst Model Twin R/SR, SN0053, date 2000) as shown in Fig. (1).

The stainless steel specimens for tensile strength and metallographic studies were prepared by cutting (shearing process) from a sheet to required dimension 1Cm * 2Cm *2mm. flat shape according to ABI device requirement.

Fig. (1) ABI –Ernst device

To investigate the effect of heat treatment on tensile strength of austenitic stainless steel AISI 316L heat treatment at three temperature 400 ^oC,600 ^oC and 800 ^oC were carried out and for each of these temperature five different times 0.5 hr ,1.5hr ,10hr ,24hr and 72 hr were selected

Three test cycles were selected for each heat treated specimen; average value and standard deviation have been calculated as follow:

$$S^2 = \frac{\sum_{i=1}^{3}(x_i - \bar{x}\ )^2}{n-1}$$

$$\bar{X} = \frac{\sum xi}{n}$$

$$S = \sqrt{\frac{\sum_{i=1}^{3}(x_i - x^{-})^2}{n-1}}$$

$$n = 3$$

The Versamet union 6264 ITEM No. 23-55, Marui-co.LTD, Japan used for metallographic examination. The specimens etched chemically according to ASTM standards by ferric chloride and nitric acid reagent in which consist of saturated solution of $Fecl_3$ in HCl to which a little HNO_3 is added and etching time of 2 minutes [12].

Results and discussion

Figure (2) showed the microstructure of austenitic stainless steel as received condition.

Table (2) showed the tensile strength of average values of three tests for austenitic stainless steel AISI 316L. The table (2) and Fig. (3) showed that with increasing the aging time at 400 ^oC the tensile will increase and AISI 316L exhibit maximum tensile strength when heat treated at 600 ^oC for 72 hours among all of the aging temperature and times selected in this study which reaches to 542

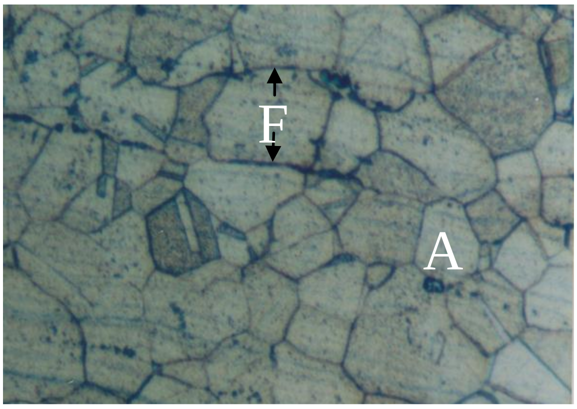

Fig. (2) Microstructure of AISI 316L austenitic stainless steel as received (X600).

MPa compared to 475 MPa for as received condition. These results attributed to some metallurgical transformation that occurs during heat treatment. Figure (4) showed the metallographic studies for AISI 316L specimen aged for 72 hrs. The figure demonstrates that a large amount of chromium carbide precipitated along to grain boundaries compared with an as received condition Fig. (2).

Table (2): Tensile strength of heat treated stainless steel AISI type 316L

Temperature °C	**Time (hr)**	**Average tensile strength (MPa)**	**Standard Deviation ±**
As received		466	4.5
400	0.5	475	3
400	1.5	477	3.46
400	10	532	3.6
400	24	536	3
400	72	542	3.46
600	0.5	462	3.6
600	1.5	475	2.64
600	10	476	4.35
600	24	489	3.6
600	72	533	2
800	0.5	513	3.46
800	1.5	504	5.5
800	10	503	3
800	24	478	3.46
800	72	466	3.6

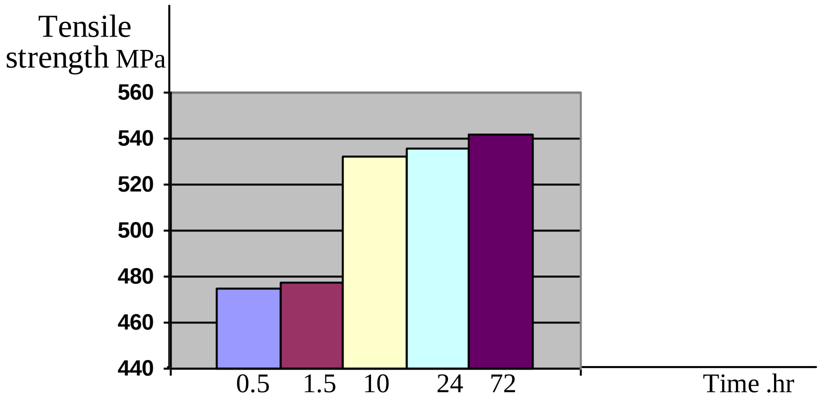

Fig. (3) Effect of aging time on Tensile strength of austenitic Stainless steel AISI 316L heat treated at 400 °C

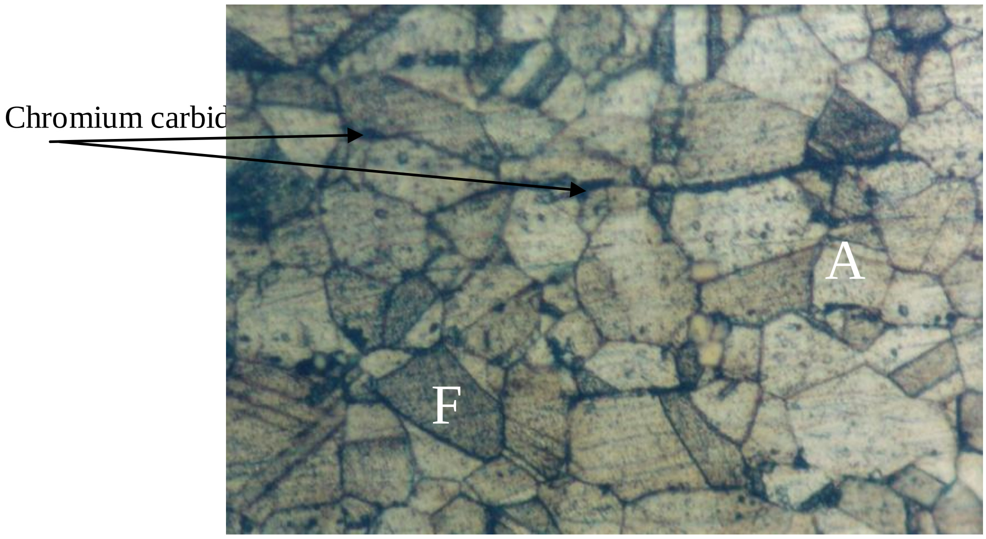

Fig. (4) Microstructure of heat treated AISI 316L austenitic stainless steel at (400 ^{o}C) for (72) hrs (X600).

Table (2) and Fig. (5) showed that the tensile strength of aged AISI 316L specimens increased with increasing the aging time and reached to 533 MPa at 72 hours.

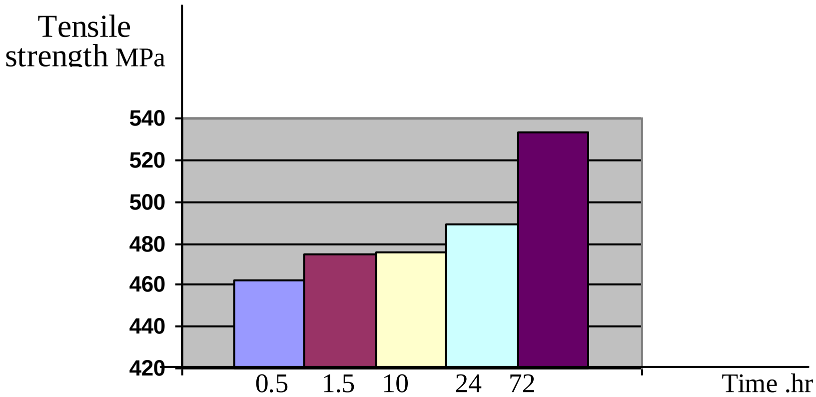

Fig. (5) Effect of aging time on Tensile strength of austenitic Stainless steel AISI 316L heat treated at 600 ^{o}C

Increasing the tensile strength of AISL 316L can be explained in terms that besides of precipitation of chromium carbides a dense formation of sigma phase can be evident and other phases like chi(x) phase may form all of these phase strongly affects the tensile properties of austenitic stainless steel. Figure (6) showed the metallographic studies of specimens aged 600^{o}C for 72 hours which showed a great amount of continuous and discontinuous precipitation along the boundaries.

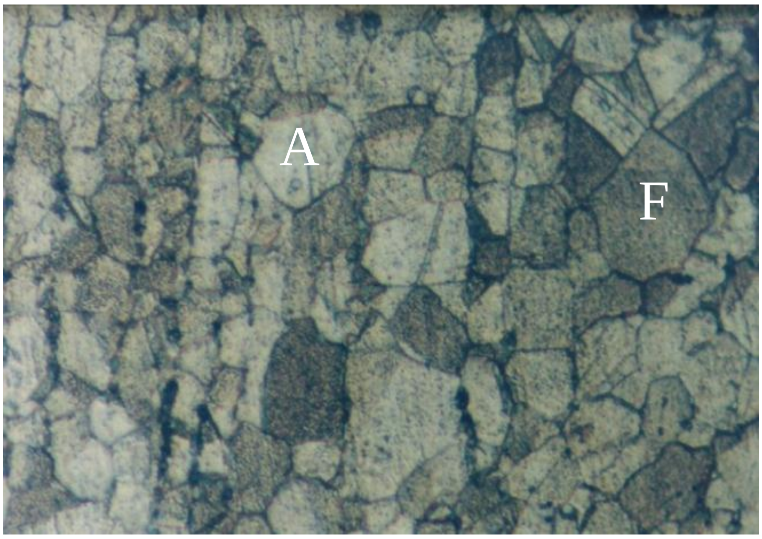

Fig.(6) microstructure of heat treated AISI 316L austenitic stainless steel at (600 °C) for (72) hrs (X600).

Table (2) and Fig. (7) showed that the tensile strength of AISI 316L specimens aged at 800°C decreased with increasing the aging time from 0.5hour to 72 hours. These results attributed to increasing the grain size with increasing the aging time and temperature, and increasing grain size delays the being sensitization and frequently decreasing the precipitation along the grain boundaries. Figure (8 and 9) showed these metallurgical aspects in austenitic stainless steel AISI316L specimens aged for 10 hrs. and 72 hrs. respectively.

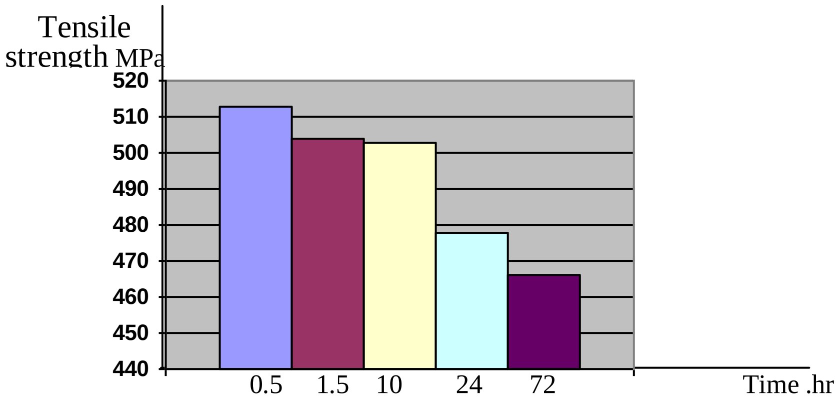

Fig. (7) Effect of aging time on Tensile strength of austenitic Stainless steel AISI 316L heat treated at 800 °C

Long time and high temperature lead to more diffusion of Cr occurs towards the surface. The delta ferrite content decreased with increasing annealing temperature and time.

Tensile strength of specimens aged at 800 °C for 0.5 hrs and 10 hrs are higher than that of the specimen aged at 600 °C for the same times the reason of this attributed to precipitation of high brittle and denies sigma phase particles as it appears in specimen aged at 800 °C for 10 hrs in Fig.(8).

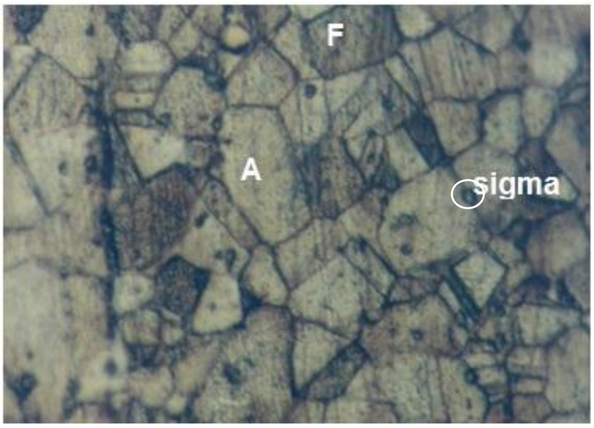

Fig. (8) microstructure of heat treated AISI 316L austenitic stainless steel at (800 ^{o}C) for (10) hrs. (X600).

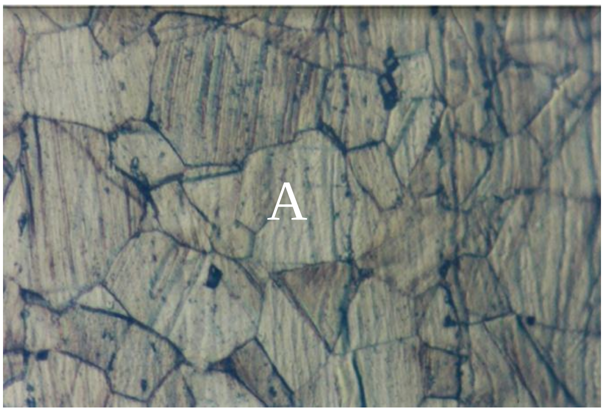

Fig.(9) microstructure of heat treated AISI 316L austenitic stainless steel at (800 ^{o}C) for (72) hrs (X600).

Asadollah Karimiyan et al [13]also found that at the aging temperature of 850^{o}C the delta ferrite is rapidly replaced by a network of brittle sigma phase particles which causes increase in tensile strength of AISI 316L austenitic stainless steel. Omyma.H.Ibrahim et al[14]also found that increasing aging time of austenitic stainless steel AISI316L at 800 ^{o}C reduces the impact toughness due to transformation of ferrite phase to high brittle sigma phase at this temperature.

Conclusions:

1. Tensile strength of AISI 316L increased with increasing the aging time from 400 ^{o}C and 600 ^{o}C.
2. Austenitic stainless steel AISI 316L exhibit maximum tensile strength when aged at 400 ^{o}C for 72 hrs.
3. Tensile strength of AISI 316L decreases with increasing the aging time at 800 ^{o}C.
4. The tensile strength of AISI 316L specimens aged at 800^{o}C for (0.5, 1.5 and 10 hrs) is higher than that at 400 ^{o}C and 600 ^{o}C for the same aging times but this approach inverted for long times 24hrs and 72 hrs.

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