Similar and Dissimilar Nd:YAGlaser Welding of NiTi Shape Memory Alloy to AISI 420Stainless Steel

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Abstract

Similar NiTi shape memory alloy(SMA) plates, 420 Martensitic stainless steelplates and dissimilar NiTi shape memory alloy with Martensiticstainless steel were welded by a pulsed Nd:YAGlaser welding method.The nature microstructure of the base metal (BM), weld zone (WZ), interface and the heat affected zones(HAZ) were showedby in a scanning electron microscope (SEM) and optical microscope.Vickers hardness tests wasconducted to specifythe properties of the weld. The outcomes showed that the hardness of dissimilar NiTi-Stainless steel (St.St.) weld is higher than that in similar NiTi-NiTi and St.St.-St.St. weld.TheMicrostructural examination in both NiTi-St.St. and NiTi-NiTi welds illustrates that the solidification process in the fusion zone changed the kind of plan to the cell type as well as the changes that occur in the cell to dentritic kind of intra- region of the weld through the weld center in the welded sample sides but in the St.St.-St.St. weld showed dendrite microstructure. In this study it is found that the increase of the welding speed leads to a decrease in hardness in all jointsNiTi-NiTi, NiTi-St.St. and St.St.-St.St.

Keywords: Nd:YAG laser, NiTi, Shape memory alloy, Stainless steel

الخلاصة

صفائح متشابهة للسبيكة الذاكرة الشكل (نيكل تيتانيوم)، صفائح الفولاذ المقاوم للصدأ المارتنسايتي(420) والصفائح المختلفة من السبيكة الذاكرة الشكل (نيكل تيتانيوم) والفولاذ المقاوم للصدأ المارتنسايتي قد تم لحامها بطريقة اللحام الليزر النبضي. تم استخدام المجهر الالكتروني الماسح والمجهر الضوئي لاظهار البنية المجهرية لمعدنالاساس ومنطقة اللحام والمنطقة المتاثره بالحرارة والمنطقة البينيه. جرىاختبار صلادة فيكرز لتحديد خواص اللحام.اشارتالنتائج الى ان صلادة اللحام للنيكل تيتانيوم–الفولاذ المقاوم للصدأ هو اعلى من صلاده اللحام المتشابة نيكل تيتانيوم– نيكل تيتانيوم او الفولاذ المقاوم للصدأ– الفولاذ المقاوم للصدأ. البنية المجهرية لكلا النوعين من اللحام نيكل تيتانيوم – الفولاذ المقاوم للصدأ، نيكل تيتانيوم– نيكل تيتانيومظهرت نوع التجمد على طول منطقة الانصهارو تتغير من مستوي الخلوي الى شجيري ظمن الحد الفاصل لمنطقة اللحام الى الخط الوسطي للمنطقة نفسها وفي كلا الجانبين من نيكل تيتانيوم وكذلك الفولاذ المقاوم للصدأ، لكن البنية المجهرية تظهر على شكل شجيري في اللحام الفولاذ المقاوم للصدأ–الفولاذ المقاوم للصدأ.

في هذه الدراسة وجد أيضا ان زيادة سرعة اللحام تؤدي الى تقليل الصلاده في الأنواع الثلاثة من الربط.

الكلمات الافتتاحية: الليزر النبضي، نيكل تيتانيوم، السبائك الذاكرة الشكل، الفولاذ المقاوم للصدأ

1.Introduction

In the recent years, its possible to the improve performance and reduce the costs.The most utilized manufacture has Mergeddifferentmaterials,This leads to in an increase in request for weld materials at different joints and to be utilized in widely manufacturing output. There are many types of techniques for welding like diffusion bonding [LiHM *et.al.,*2011], friction welding[Fukumoto S *et.al.*,2010], brazing[Vannod J *et.al.,*2011], plasma-arc welding and laser welding [Li HM *et.al.,*2012, Li HM *et.al* 2010,Shojaei A,A *et.al* .,2015andCeyhun KÖSE (2016)],but laser welding is the more important [Khana MMA et al 2010].The most important reason for this case is fastevolution in modern technology for last years.Someof the benefits and disadvantage of welding bylaser incompared to new other welding, ries inthe effect ofbeam on properties. The greatallowed welding is based on the keyhole method, and in the decreaseheattransfer to the materialsoutput a quitenarrowof heat affected zone (HAZ) andvery low residual stress and minimum distortions besidesthat areutilized in several medical applications [Ventrellaa VA *et.al*.,2010, Padmanaban G *et.al.,* 2010andR.K. Gupta 2015]. The dissimilar joints explain afall properties because the creation of brittle compounds like $TiFe_2$, $TiCr_2$, whenshape memory was welded to stainless steel.Thus, addendum appropriate elements may be an obtainable way to alter the weld composition and ameliorate the joint properties . At this time,addendum Niis active formendingtheTiNi/steeljointproperties.Asupplemental trouble appearswhen it involves thewelding jointly of materials with various some metallurgical and similar physical aspects, like thelaserabsorptionof lengthwave, conductivity and fusion point. The creation of the metallurgical phasesin many certinmaterials leads to fall in mechanical properties in the joint area. Reducingthe solubility because elements of alloying lead to cracking. The distribution of this alloying element along the area of the weld and the properties of the area, can determine from hardness and tensile tests that were likewisemeasured.Shape memory andMartensite stainless steel are popularly utilized for process of manufacturing with perfect mechanical propertiesand good resistance to corrosion, Martensite stainless steel can be utilized beneath high and low temperature. Many types of stainless steels can't be utilized under high temperature due to the change by heat treatment; martensite stainless steel habitis utilized for a large number of applications like generation of steam, blades mixer, tools of cutting and many other applications in this field [NaseryIsfahany *et.al.,* 2011].

The studiedof laser were executed in research welding by Nd:YAG of shape memory andmartensite stainless steel, much research was done on welding of laser. Khana et al 2010.studiesthe effect of laser , speed and diameter of the laser beam on the engineering side and on the properties of martensite stainless steel. The sampls were welded circularyand joints , and the parameters of welding approach their rates between 800-1100 W and 4.5-7.5 m/min. Also it noted that the power and speed of welding are affect to the form of geometric of bead welding. Great hardness value in heat affected zone is found about 700 Hv.S.H. Baghjari et al 2013deals with pulsed laser welding of 420 martensitic of stainless steel welded and placed in a certain order so that the distance or spacing between samples up to a value of zero Sometimes.The samples are welded at the shape of butt. The influence of parameters such as voltage, diameter of beam, frequency, duration, and welding speed on the dimensions of weldhas been verified and the perfect ones obtained values up to the 450 V, 0.6 mm diameter, 6 Hz, 5 msand 1.5 mm/s. The results showed the presence of some of the remains of delta ferrite in the composition and roughness carbides in HAZ. The hardness in the HAZ increasesclearly. The Objective of this researchis to study the effect of various welding speedwhen other parameters (Peak power, Pulse duration, Frequency) on hardness and microstructure for all jointsNiTi-NiTi, NiTi-St.St. and St.St.-St.St.are fixed.

2. Experimental work

2.1 Materials and samples preparation

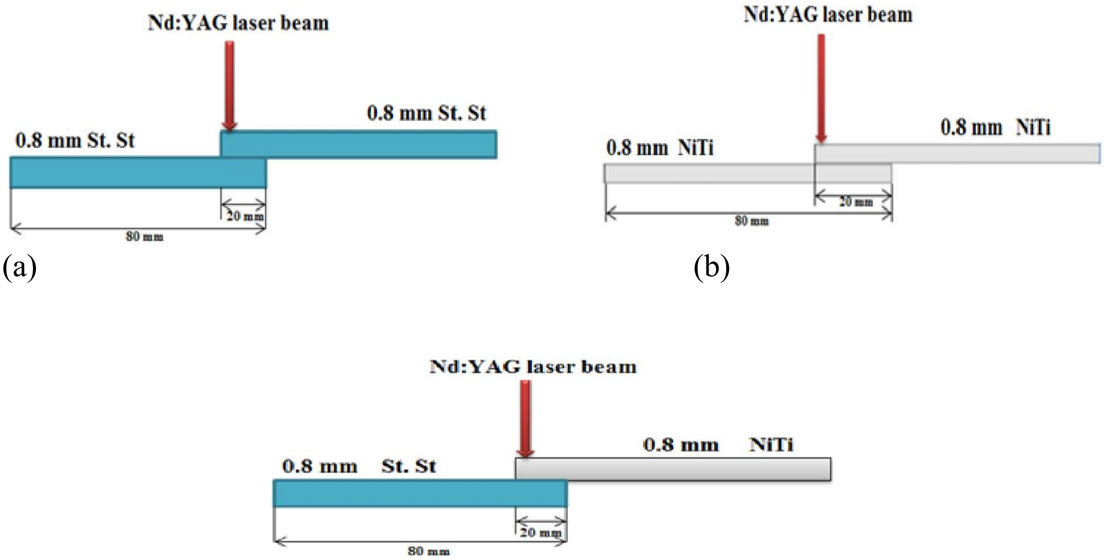
NiTi shape memory alloy plate and AISI420 stainless steel plate (manufactured in china) were utilized in the tests and the chemical composition of the two base alloys wasmentioned in Table(1) . The dimensions of the plateswere (80) mm length, (20) mm width and(0.8) mm thickness.The plates were put inadilutehydrofluoric and nitric acidssolutionfor15 sec.toeleminatethe layers of the oxide before welding operation .The sample safter that cleaned in acetone bath and then in distilled water.

Table 1: Chemical composition of base alloys (wt%)

Materials	Ni	Ti	Cr	Mn	Si	C	P	Fe
NiTi	53	47						
AISI 420Martensite Stainless Steel	0.15	-	13.63	0.17	0.40	0.18	0.04	Rem.

2.2 Laserwelding

The NiTi–St.St.,NiTi–NiTi and St.St.-St.St. association were kept in contact and overlapped with each other. Fig. (1) shows the diagram of weldn NiTi-NiTi, St.-St. and NiTi-St. Welding process used a Nd :YAG laser welding system.Variables for welding parameters that joined the two dissimilar and similar materials successfully in the tests ,(J) were the laser input energy, (ms)the laser pulse duration , (Hz) frequency and(W) peak power.



(a) (b) (c)

Fig. (1): Schematic laser weld (a) St.St.-St.St. (b) NiTi-NiTi (c) St. St.- NiTi

2.3. Microstructural characterization

Mounting is initially utilized byepoxy to prepare the samples.The samples were polished by metallographics and papers of 600, 1000 ,1500 ,2000 SiC grades , and etched with 5ml HF +20 ml HNO_3 + 25 mlH_2O solution. Before welding the oxide layer was eliminated from the plate surface by grinding, and then the plate was cleaned in an acetone bath and dried in air.Microstructuresofthejointswereshown by utilizing scanning and optical microscope respectively.

2.4. Hardness test

Mechanical property test was done at room temperature .The Vickers microhardness profiles over theweldzone ,heat- affected zone and base metal in all similar and dissimilar joints are measured by utilizing microhardness device. The microhardness was executed on the joints , with a Vickers hardness tester utilized a load of (4.9 N) and a dwelltimeof(10)s.The average hardness value was determined by average of thre etest spoints.

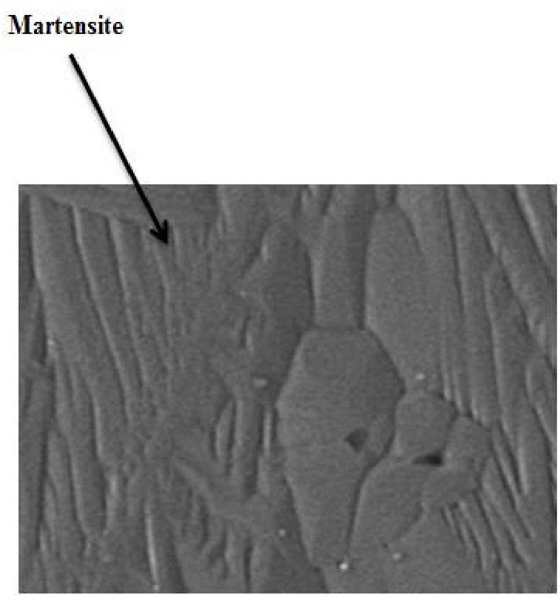
2.5 Parametersof the Laser welding

The effected of welding speed on both microstructure and microhardness to three main regions weld zone, heat affected zone and base metal. The samples welded by changingthe welding speed five time (6, 7, 8, 9, 10) mm/sec while other parameters like peak power, pulse duration, frequencyall are fixed. Threejoint NiTi-NiTi, NiTi-St.St. and St. St.arewelded by laser with various welding speed.

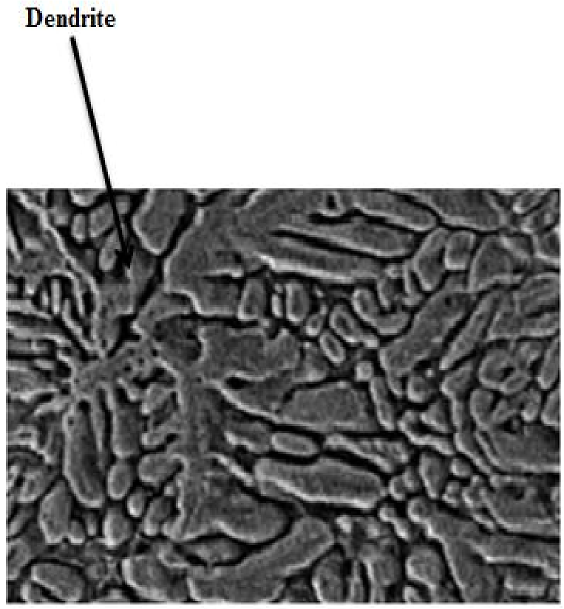
3. The results and discussion

3.1 The Microstructure of the weld joint

Optical and scanning electron microscopewere utilized to illustrate microstructure of the welded zone of the three joints. Fig. (2) shows the SEMin the weld area, interface and the area near B.Mof the dissimilar NiTi–St.St. joint and NiTi-NiTi. As it is shown, solidification process will vary from region to region across the weld area and other regions of the semi- area cellular level to the last region to dendritic type.This was caused by an increase in the cooling speed through the welded area into three zones toward the weld center .It can be observed that dendritic microstructure resulted from the fast cooling rate in the weld area during St. St.[G. R. Mirshekariet al 2013 andHongmei Li et al 2013]. Fig. (3) shows the optical microstructureof the base metal,interface and of the thewelded zone of NiTi and St. St.joints.



(a)



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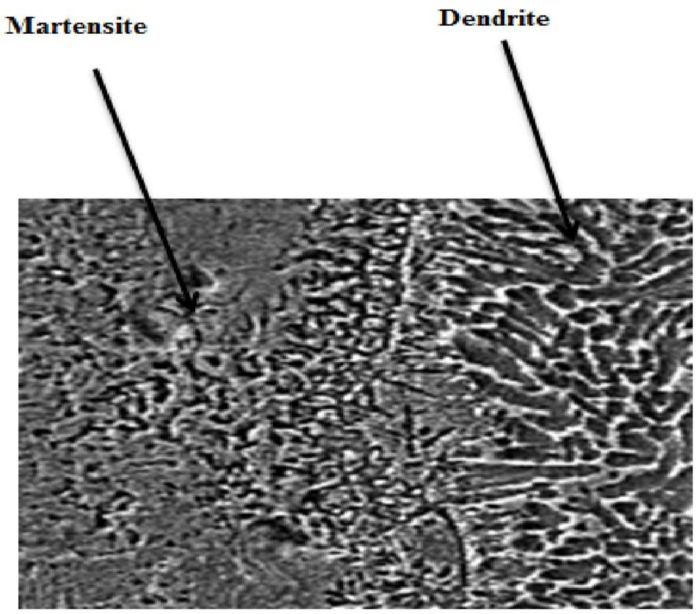
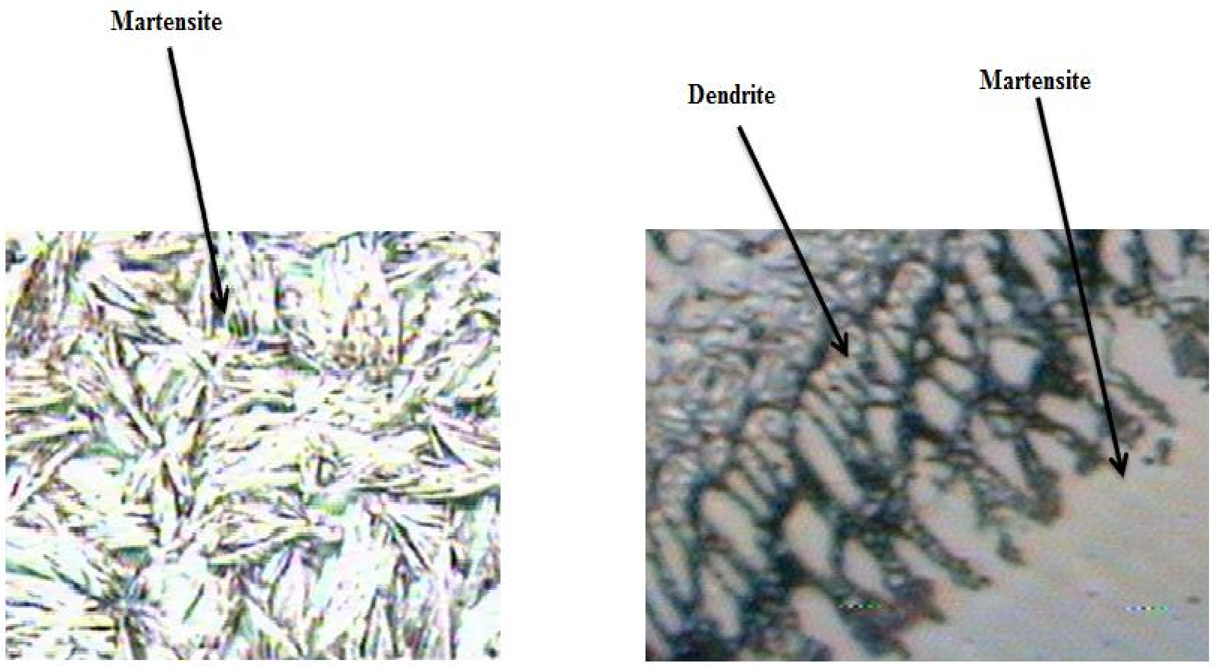
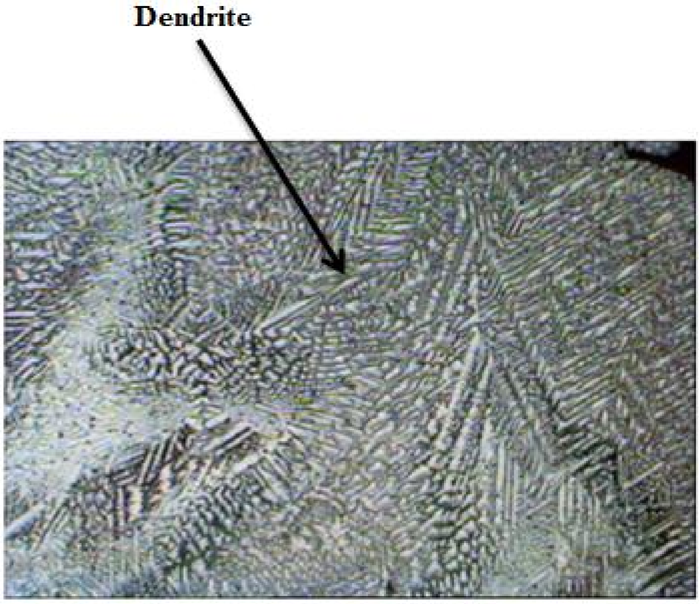


(c)

Fig. (2):SEM (a) NiTi (BM) (b) NiTi-St.St. (WZ) (c) NiTi-St.St. (Interface)



(a) (b)



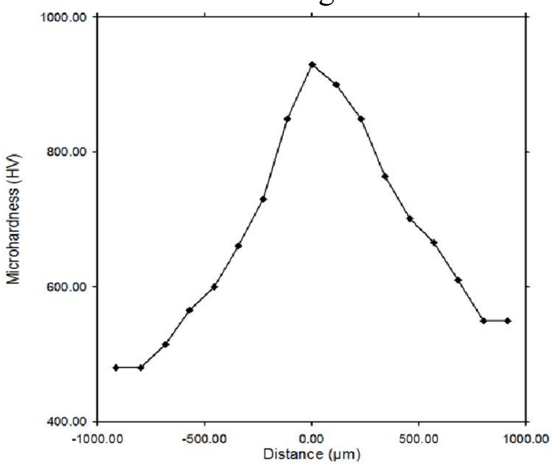
(c)

Fig. (3):Optical microscope (a)NiTi (BM) (b) NiTi-St. St. (Interface) (c) NiTi-St.St. (WZ)

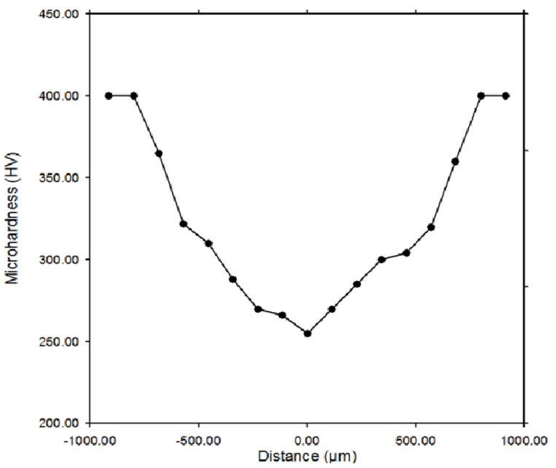
3.2 Hardness measurements

Figure (4) show the vickers hardness for NiTi-NiTi, NiTi-St.St. and St.-St. It can be observed hardness of NiTi-NiTi is increased from weld zone to base metal.This change in hardness value was because the grain growth increased in heat in the affected area and small particle composition , while the large size of the granules in the same area , andalso due to the grains are of small size on the near side of the metal base and rough in the molten region [Ceyhun KÖSE (2016) and Keskitalo *et.al*.,2013].

This means that the hardness of the weld zoneis less than both base metal and heat effected zone which reaches 255 HV.It is observed that hardness of NiTi-St.-St. decrease from weld zone to base metal because of the intermetallic compound formation in the weld zone[Chan et al 2012].Brittle intermetallic compound make the weld zone of high hardnessthat reaches about 930 HV.In St.-St. hardness decrease at the region of fussion to the metal of base because fine grain at the weld zone. Great hardness value in welding zone reaches about 400 HV.



(a)



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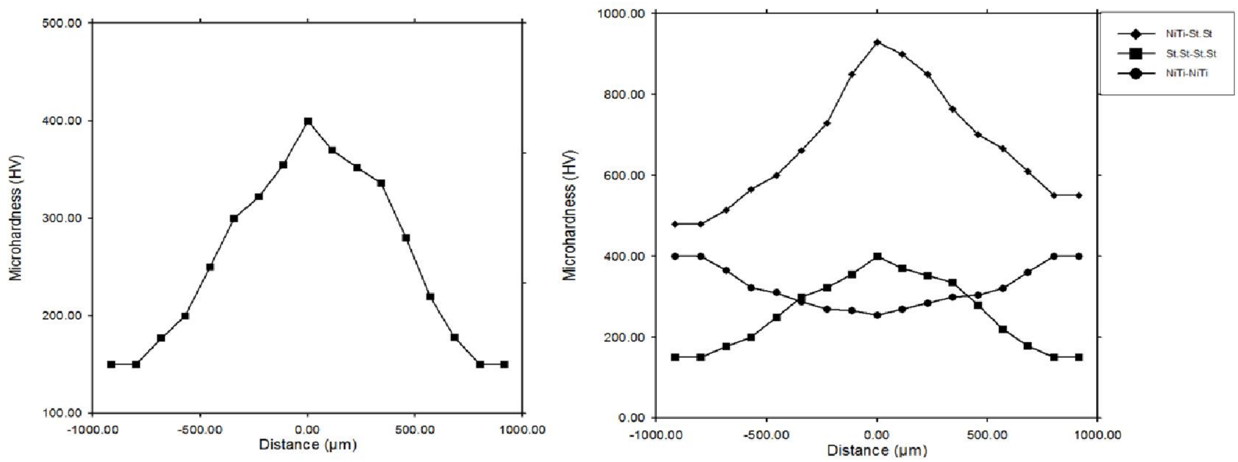


(c) (d)

Fig. (4):Varationmicrohardness with distance from weld center (a) NiTi-St.St.(b) NiTi-NiTi (c) St.St.-St.St. (d) NiTi-NiTi, St.St.-St.St. and NiTi-St.St.

3.3 Parametersof laser welding

Both the peak power and welding speed have the highest effecton the weld zone for all joints NiTi-NiTi, NiTi-St.St. and St.St.-St.St. Effect welding speed on welding zone come from due to the fact the increase welding speed will not getting enough heat to result the full fusion that which makes weak weld zone .while the increase of the peak power result enough heat lead to to obtain deep penetration make the weld zone of good properties[Khana MMA et al 2010]. Through the results obtained it is found the best parametersare Peak power (2 KW), Pulse duration (5 ms), Frequency (35 Hz), welding speed (6 mm/Sec). Table (2) shows change able of the welding speed with fixed other parameters. Figure (5) illustratesthat the bead of the best sample gives the best value of microhardness and the best microstructure, the figure also shows that the bead of weld zone is regular and does not contain any defect. Therefore; this sample has the best properties.

Table (2): Change the welding speed with fixed other parameters

Sample number	Peak power (KW)	Pulse duration (ms)	Frequency (Hz)	Welding speed (mm/sec)
1	2	5	35	6
2	2	5	35	7
3	2	5	35	8
4	2	5	35	9
5	2	5	35	10

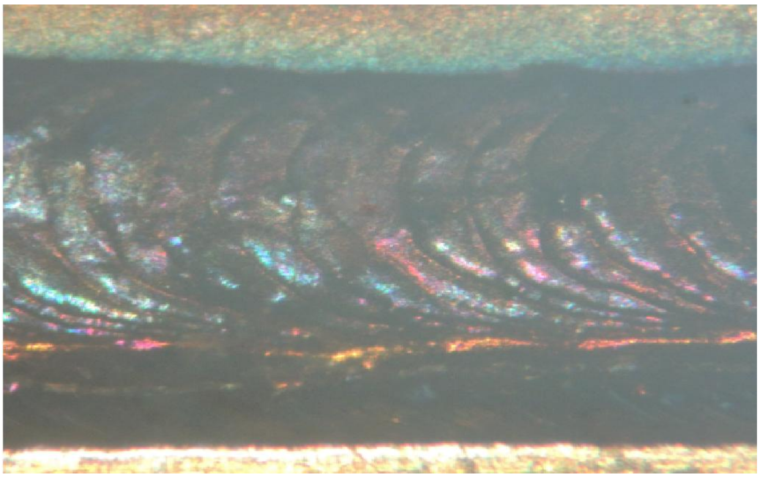
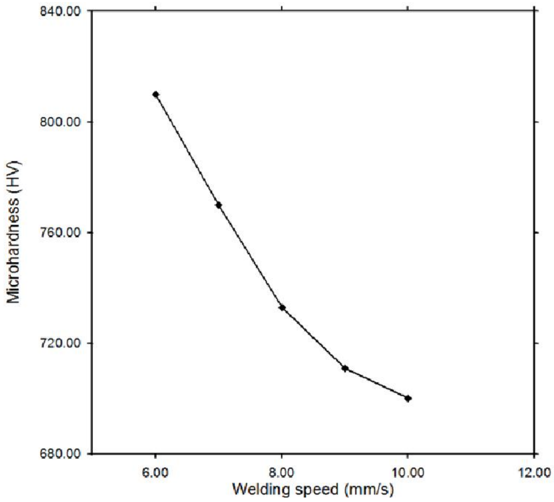
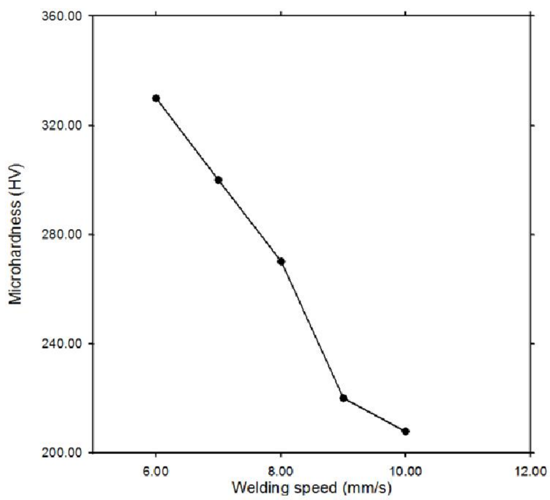


Fig. (5): Bead of weld zone for best sample

Fig. (6) shown the relation between welding speed and microhardness, in all joints NiTi-NiTi, NiTi-St.St. and St.St.-St.St.microhardness decreases with the increase welding speed because more time interaction between the laser beam and the sample that lead to weak weld zone. When increase the welding speedincreses. The interaction time of the laser beam with the sample is becomesvery little. It means that the heat input to the sample is very little[Keskitalo et al 2013].



(a)



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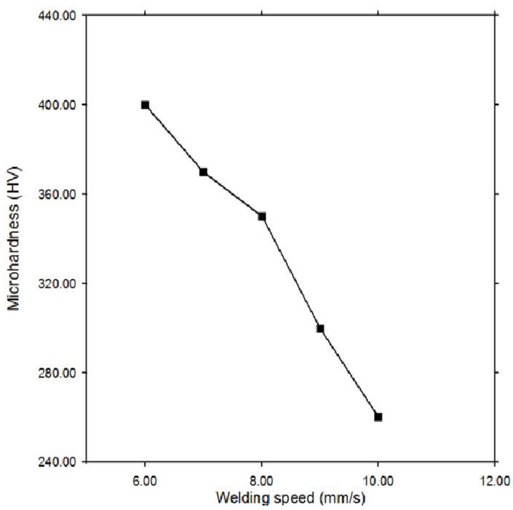

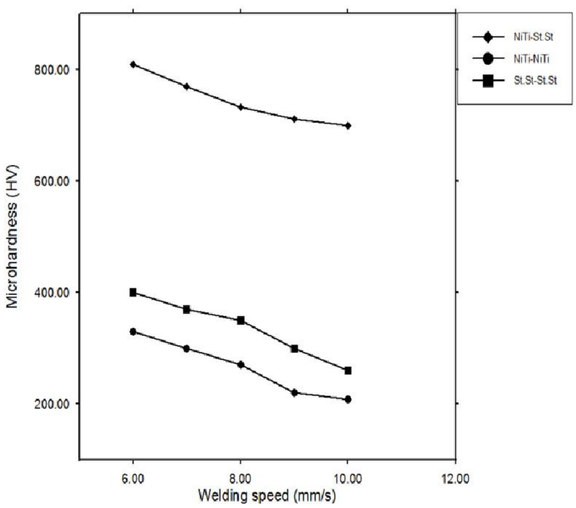

(c) (d)

Fig. (6): The relation between microhardness with welding speed (a) NiTi-St. St. (b) NiTi-NiTi (c) St.St.-St.St. (d) NiTi-NiTi, St.St.-St.St. and NiTi-St.St.

4. Conclusions

1- Microstructural examination in both NiTi-St.St. and NiTi-NiTijoints illustrates the solidification method along various the fusion areain different joints, where they become the planer shape to cellular and transformed the last to dendriticfrom intra-fusion welding area toward the center for alloy NiTi- St.St, but in St.St.-St.St.that showed dendrite microstructure.

2) A significant increase in the hardness values of the weld area across the base metal for similar alloys NiTi-NiTi, conversely decreasesin dissimilarNiTi-St.St. andsimilarSt.St.-St.St. joints.

3)The increase of the welding speed leads to decrease hardness for all three joints.

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