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INVESTIGATION OF SINGLE FILLET WELD FOR BUILT-UP MEMBERS

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ABSTRACT

The main purpose of this study is to investigated the single fillet weld design for built-up members by using fusion welding and find the effects of welding power input on that design for member. In this work, investigation of welding metal for Low carbon steel plate type St.52-3, thickness 6-8 mm, which is to ensure good mechanical properties under high stresses for (Welding metal , heat affected Zone (HAZ) and base metal). Also it can be explain, that the effects of welding processes on the deformation and changes in mechanical and metallurgical properties due to high thermal energy, results from welding process. This study involved: weld design, selection of suitable electrode, evaluation of mechanical and metallurgical properties, the maximum allowable value of sweep of welded mamber after (fabrication and erection) has been calculated, also leg and through length have been calculated for the welded Zone. The main results of this study are :

- The value of sweep which occur before the erection and tightening is (29 mm.).
- The leg and through length of welding metal which welded by electrode type (E 7018 = OKUS), its found equal to (4 mm.).

The study results can ensure good mechanical and metallurgical properties for signal filled weld (Built-up members).

الخلاصة

الهدف الرئيسي من هذه الدراسة تقصي تصميم اللحام الزاوي للعتبات المتراكبة (الهياكل المعدنية) بأستخدام اللحام الأنصهاري وأيجاد تأثير الطاقة الحرارية الداخلة على تصميم تلك العتبات . الجانب العملي أستقصى معدن اللحام لصفائح الفولاذ الواطئ الكاربون نوع St. 52-3، سمك (6-8 mm.) الذي يؤمن خصائص ميكانيكية جيدة تحت أجهادات عالية (معدن اللحام ، المنطقة المتأثرة بالحرارة ، والمعدن الأساس) وبيان تأثير عملية اللحام على التشوهات الحاصلة والتغيرات في الخصائص الميكانيكية والميتالورجية بسبب الطاقة الحرارية العالية الناتجة من عملية اللحام . تضمنت الدراسة : تصميم وصلة اللحام ، أختيار سلك اللحام المناسب ، تقييم الخصائص الميكانيكية والميتالورجية ، حساب أقصى هطول (Sweep) مسموح به في العتبات المتراكبة الملحومة بعد التشكيل والتركيب وكذلك أبعاد منطقة اللحام (Leg & through length) .

نتاج هذه الدراسة بينت ان :

- مقدار الهطول (sweep) المسموح به بعد التشكيل والتركيب يساوي (29 mm.) .

- أبعاد منطقة اللحام للمعدن الملحوم بواسطة سلك لحام نوع (E7018) المكافئ الى سلك لحام نوع (OKUS) تساوي (4mm.).

نتائج الدراسة تؤمن خصائص ميكانيكية وميتالورجية جيدة للعتبات المتراكبة (الهياكل المعدنية) الملحوم بطريقة اللحام الزاوي من جهة واحدة .

KEY WORD
Single Fillet Weld, Built-up Members, FEM, ANSYS

INTRODUCTION

One of the most difficult problem encountered in fabrication by fusion welding is in fact that due to concentrated heat applied in various part of the structure under construction which causes different expansion, the contraction and distortion, lies in predicting the final size and shape of the fabrication. [David, 1988]

Weld joint design should be selected primarily on the basis of load requirements. However, variables in design and layout can substantially affect costs. As a guide, the joint design that requires the least amount of weld metal should generally be selected. Oversized welds may cause excessive distortion and higher residual stress without improving suitability for service; they also contribute to increased costs.

Where a design permits, using fillet welds is a good suggestion. Fillet welds are made easily, are dependable using single fillet welds to reduces weld size and then reduces heat input and therefore reduces all form of distortion and internal stress. [David, 1988]

According to AWS "American Welding Society" sec.2.15, if two or more plates, rolled shapes are used to built up a members, sufficient welding (of the fillet, plug, or slot type) shall be provided to make the parts acts in union but not less than that which may be required to transfer calculated stress between the parts joined, this sec. of AWS dose not state the welding must be provided on both sides of web. [American Welding]

MATERIALS, EQUIPMENT AND EXPERIMENTATION

MATERIALS

Specification of Welded Parts

Chemical and mechanical (AISI) specifications of parts used in this work have been tested to compare with the standard specifications of the materials, which are suitable for these applications (low carbon steel St. 52-3).

Table (1) showed the standard specifications of (St.52-3), and **Table (2)** showed the specifications of the material used as built-up members in this work after a sample have been tested.

The test samples should be taken from thickest parts of the members, since these areas usually exhibit the greatest property fluctuation .One of the main purpose of the chemical test is to check the carbon content and other ingredients of structural steel. Three of the ingredients have considerable effect on steel weldability: Carbon- too much of which results in high hardenability and eventual loss of ductility, excess phosphorus which increases brittleness, and high sulfur which results in porous welds. If the chemical properties of the steel are known, the weldability can be determined by the *Carbon equivalent.*

The weldability of the steel used in this work have been determined using the following Carbon equivalent formula [David, 1988]:

Carbon Equivalent = C+ (Mn+Si) /6+ (Cr+Mo+V) /5+ (Ni+Cu) /15

A Carbon Equivalent have less than (0.48) in this formula generally assures good weldability.

Table (1) Chemical properties & Mechanical properties of St 52-3

C	Si	Mn	P	S	Ni
0.2 Max.	0.55 Max.	1.6 Max.	0.04	0.04	0.009

Yield stress (N/mm^2)	Tensile strength (N/mm^2)	Elongation %
355	510- 680	22

Table (2) Chemical and Mechanical Properties
of the material used as built-up members

C	Si	Mn	P	S	Ni
0.01792	0.2941	>1.3	0.001	0.0208	0.0001

Yield stress (N/mm^2)	Tensile strength (N/mm^2)	Elongation %
443.19	571.22	22.5

Specification of Welding Electrodes

In this work welding electrodes type (E7018), which is equivalent to (OK 45), have been selected to weld the built-up member. These electrodes have the following properties in addition to the ability to crack resistance and carrying high tensile loads: -

Table (3) Chemical and Mechanical Properties of electrodes type (E7018)

C	Si	Mn
0.1	0.5	0.9

Yield stress (N/mm^2)	Tensile strength (N/mm^2)	Elongation %
410-450	510-550	30

Welding Machine

It is an automatic welding machine, type ESAB –A6-SFD. It can used for arc welding of butt, fillet and clad welding over –lay.

It is fitted with control box for setting and checking of welding parameters, namely, voltage, current and travels speed. The main characteristics are:
- Amperage AC / DC 100% Eff. 1500 A.
- Electrode diameter – solid single wire (3-6mm).
- Voltage (42) V.
- Wire feed speed (0.33-7.5) mm/sec.

Welding Procedure and Weld Joint Dimensions

Welding procedure used in this work shown in **Fig (1)** in which single fillets welds have been used. This type of weld used because the thickness of plate was small (8 mm) and from the technical point of view this type of welding is acceptable according to AWS (sec.2.15). [American Welding Society]

Leg Length and Through Length of Weld Joint

After the welding procedure have been done, leg length and through length of welded joint have been calculated.
Leg length and through length of weld joint is depend on the thickness of used plate and for safety. These must be large or equal the thickness of welded plates.
In this work the leg and through length of welded joint must be greater than (3 mm) according to AWS (sec. 4.8.1 Qualification /107). [American Welding Society]

Sweep Calculation

The overall sweep of the member must be calculated after fabrication and erection with tightening by torque spanner, this value of sweep must be less than the value calculated using the following equation: - [American Welding Society]
Sweep = [0.25 (in.) * L] / 10
Where L = length of member (ft)

EXPERIMENTAL METHOD

Mechanical and Structural Properties of Welded Joint

To evaluate the mechanical and structural properties of welded joint, a sample from the welded joint have been prepared and the following tests have been conducted: -

Hardness Test

Hardness tests showed the variation in hardness occurred. Using a load – indenting macro-hardness tester the hardness was more closely measured, taking measurement every (0.5 mm), **Fig (2).** To evaluate the tensile strength the value of hardness is used.

Impact Test

A simple on site test can be made by weld a lug of weldable steel to the member and beating it with a hammer. Refer to the fillet bend test, if the weld deforms without fracturing, the steel can be considered weldable if the weld separates from the base metal at the junction of the weld and base metal it indicates the base metal is subject to hardening.
In this work, the method of impact test was used for the first time for the indirect evaluation of the impact strength at room temperature. **Fig (3).** Where it's found that the impact energy for the base metal equal to (92.5 J), and the impact energy for the weld metal equal to (98.0 J).

Microstructure Examination

During welding, the metal nearest the weld heats above the (A1=1333 °F) temperature and austenite forms. During cooling, the austenite in this heat effected zone transforms to a new structure, depending on the cooling rate and the CCT diagram for the steel. Plain low carbon steels have such a low hardenability that normal cooling rates seldom produce martensite. However, alloy steel may have to be preheated to slow up the cooling rate or postheated to temper any martensite that forms. **Fig (4).** [David, 1988, R. A. 1983]

In this work a sample of microstructure have been prepared to examine the microstructure of the welded joint in different points (base metal, heat effected zone and weld joint). **Fig (5)** explain the points of microstructural examination.

Finite Element Analysis

Finite Element Analysis (FEM) has been conducted to find the temperature distribution in welded joint and in base metal using ANSYS software. The initial condition are temperature equal to 80 °F and the applied load temperature equal to 2875 °F.

By using proper mesh size **Fig (6)** and transient solution, the temperature distribution in selected nodes **Fig (7)** has been investigated, **Fig (8,9).**

At different time periods the temperature contour have been observed. **Fig. (10,11,12,13).**

RESULT AND DISCUSSION

1- The approximate values of tensile strength of welded joint have been calculated from the values of hardness test (HB). The following results have been found: -

Table (4) Hardness value (HB) & approximate Tensile strength (N/mm2) of welded joint

Test direction & test point	1	2	3	4	5	6	7	8	Tensile strength (N/mm^2)
A	180	174	202	195	187	195	167	167	660
B	174	167	219	180	195	195	167	167	560-570
C	164	164	195	195	187	-	-	-	560-570

2- Weldability Test: According to chemical composition in **Table (2)** the Carbon Equ. is (0.283), therefore the steel has good weldability.

3- Sweep calculation: For the member of this work the value of sweep which occur before the erection and tightening is (29 mm) and from the experience this can be avoided by using sufficient torque for tightening process.

4- Leg and through length: For this work, leg and through length have been calculated for the welded joint used and it's found equal to (4 mm).

5- The microstructure examination and the temperature distribution of welded joint give the same trend of the final structure of welded steel,

Fig (14). shows the microstructure of (base metal, weld pool & heat effected zone) . This is also resulting of formation of a cast metal whose close to the mean composition of the welded steels. Taking into account the instability of the properties and structure characteristic of the welded joints produced by fusion welding, it may be expected that more defects and imperfections of a different type will appear in the joint zone. One of these defects formed in weld zone and completely disrupting shaped form is shown in **Fig (15).**

CONCLUSION

From this study for single fillet weld of built-up members some results can be found: -

1- Single fillet weld can be used for built-up members in condition that this welded joint must be done along the overall length of the member and in condition that the member dose not used in fabrication of bridge cranes.

2- Electrodes type (E7018) which equivalent to (OK 48) can be used with good mechanical and structural properties.

3- Leg and through length of welded joint must be done not less than (4mm).

4- Maximum value of member sweep must be not less than (25mm) after fabrication and erection using the desired torque otherwise reinforcement parts and joint must be used.

5- The alternative way for impact test used in this work give based on fillet bend test give good indication of toughness of the weld joint

6- The temperature distribution analysis and experimental results are in significant agreement. This is attributed to the find the temperature distribution in welded joint and base metal by using Finite Element Method "ANSYS software" to the material properties, heat generation, and heat dissipation, this may be attributed to the following:

- The material behaves as visco-elasto plastic material when its temperature is close to the melting point.
- The finite element mesh should be refined close to the welding line with the smaller time step.
- Finally if all these things can be accomplished successfully, the revitalized structure should provide many added years of service life.

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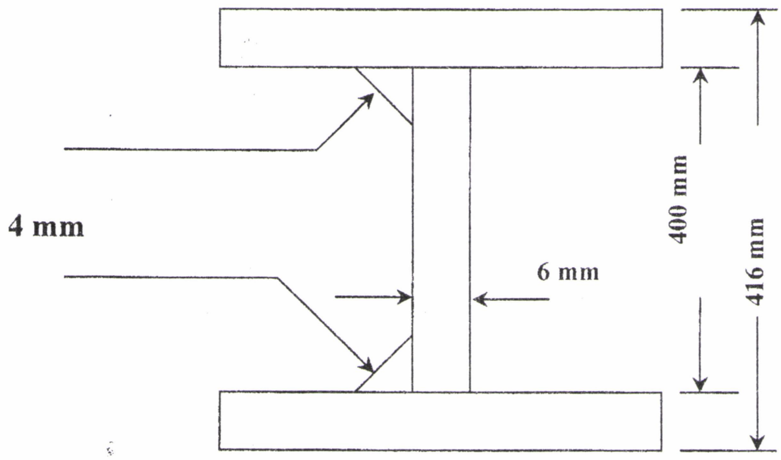


Fig (1) Single Fillets weld

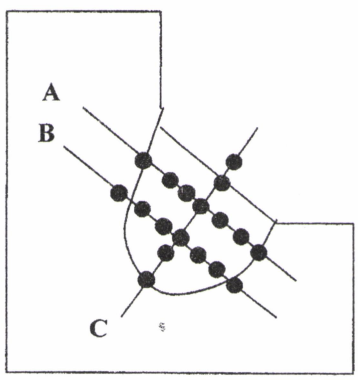


Fig (2) Hardness Test Position

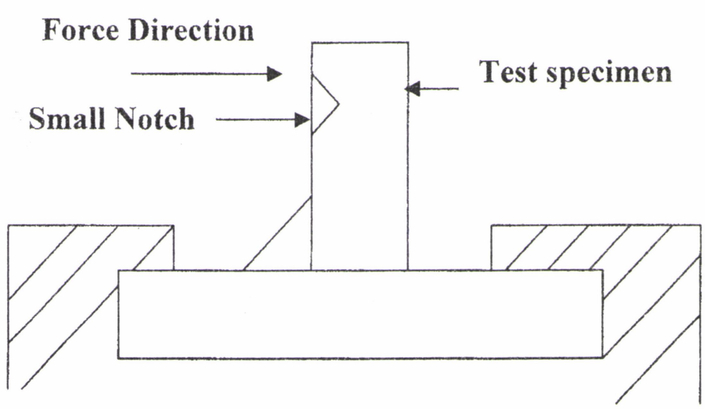


Fig (3) Impact test Arrangement.

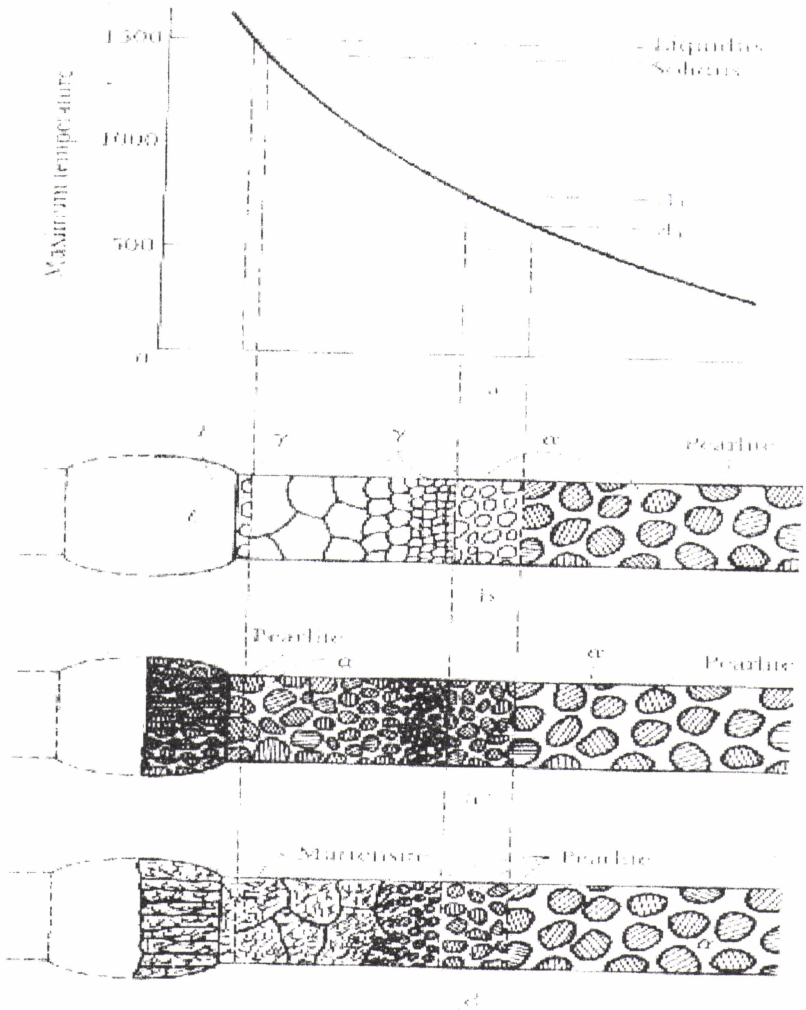


Fig (4) The Development of the heat effected zone in a weld.
(a)- The Max. Temp. at any point. (b) – The structure at the max, temp. (c) The structure after cooling in a steel of low hardenability, (d)- the structure after cooling in a steel of high hardenability.

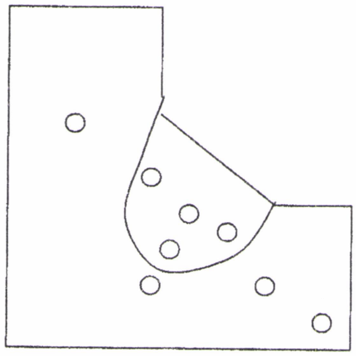


Fig (5) Points of Microstructure Examination

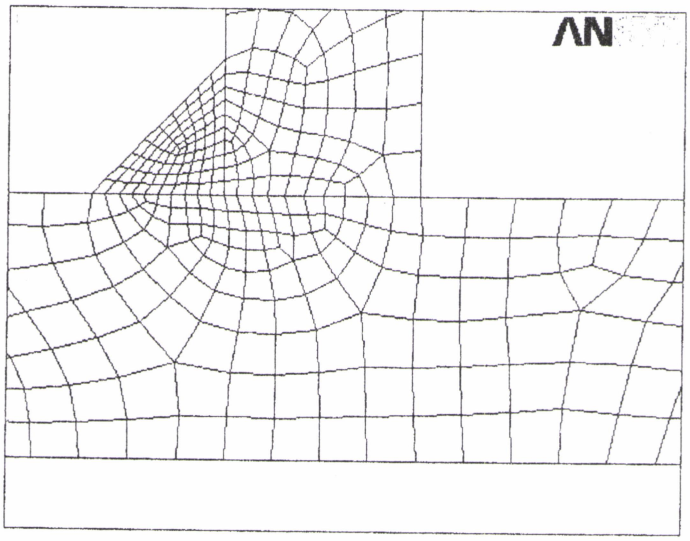


Fig (6) Finite Element mesh of Welded Joint

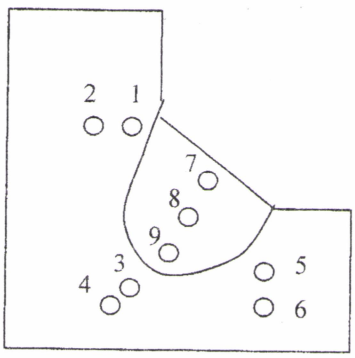


Fig (7) Points of Temperature Distribution examination

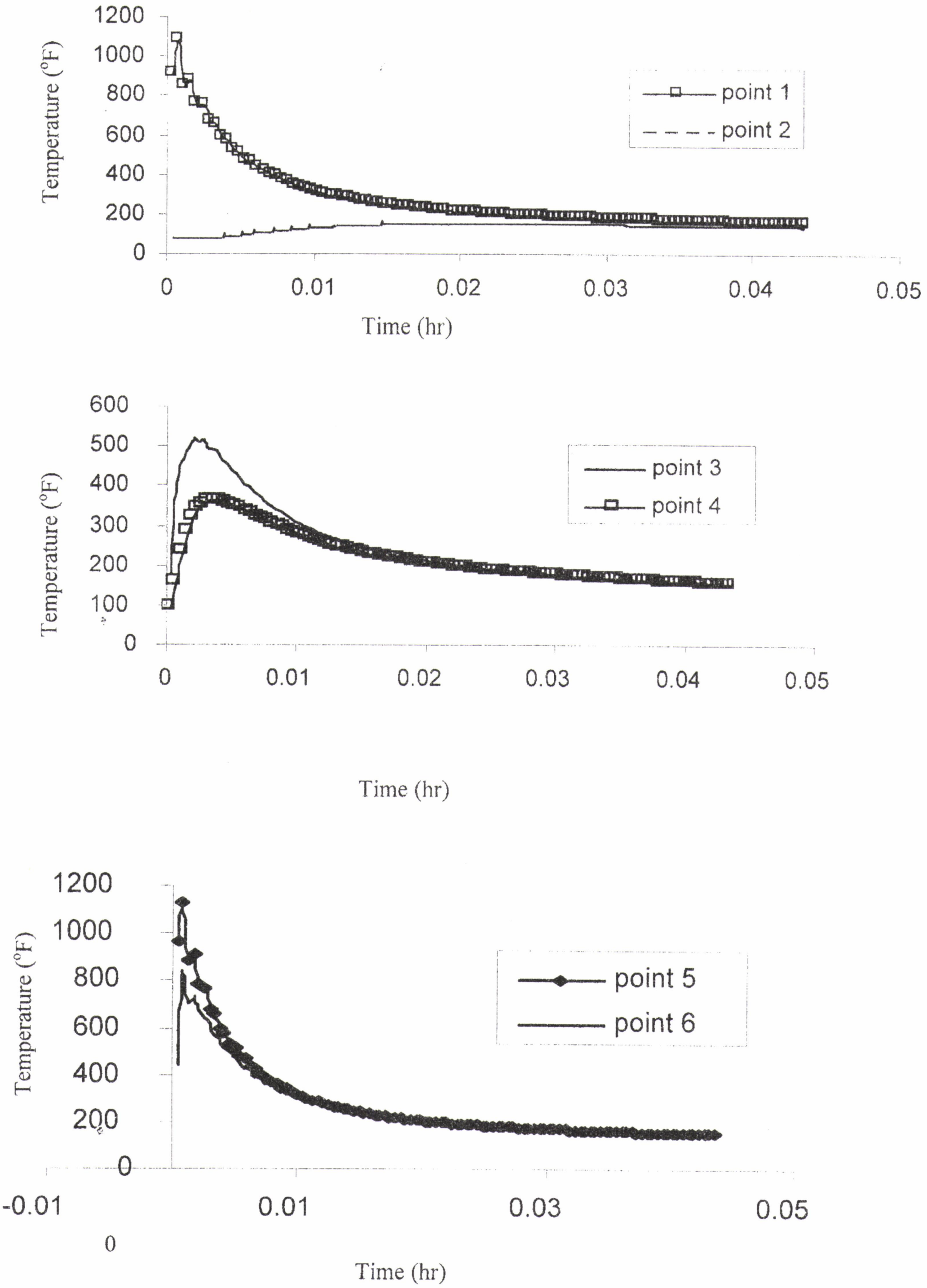


Fig (8) Temperature Distribution in heat effected zone & base metal ΔT=0.001 Hr.

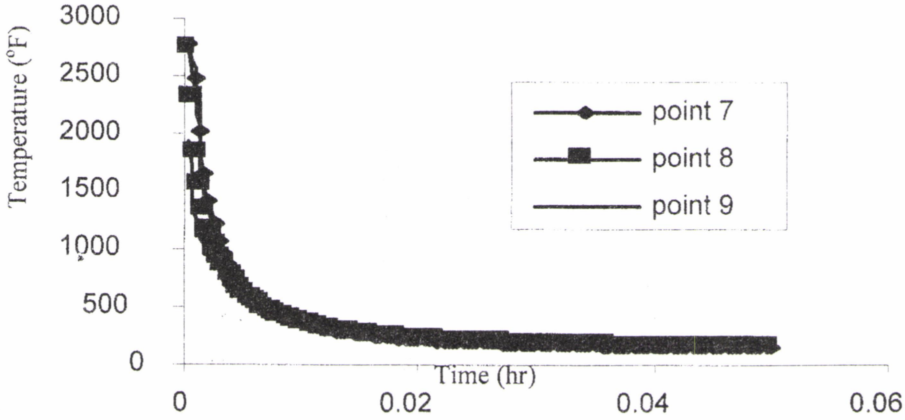


Fig (9) Temperature Distribution in Weld pool ΔT=0.001 Hr.

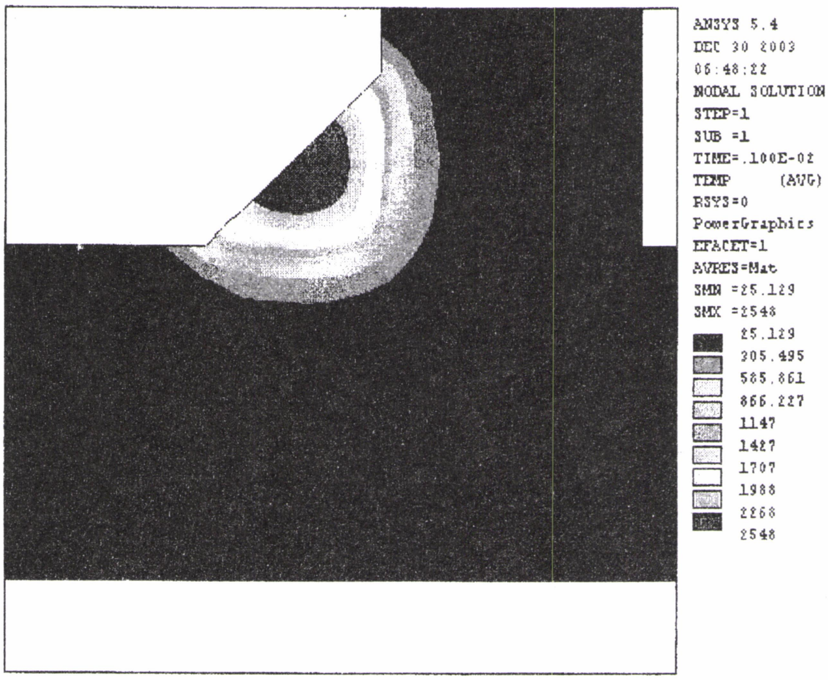


Fig (10) Temperature contour at time 0.002 hr.

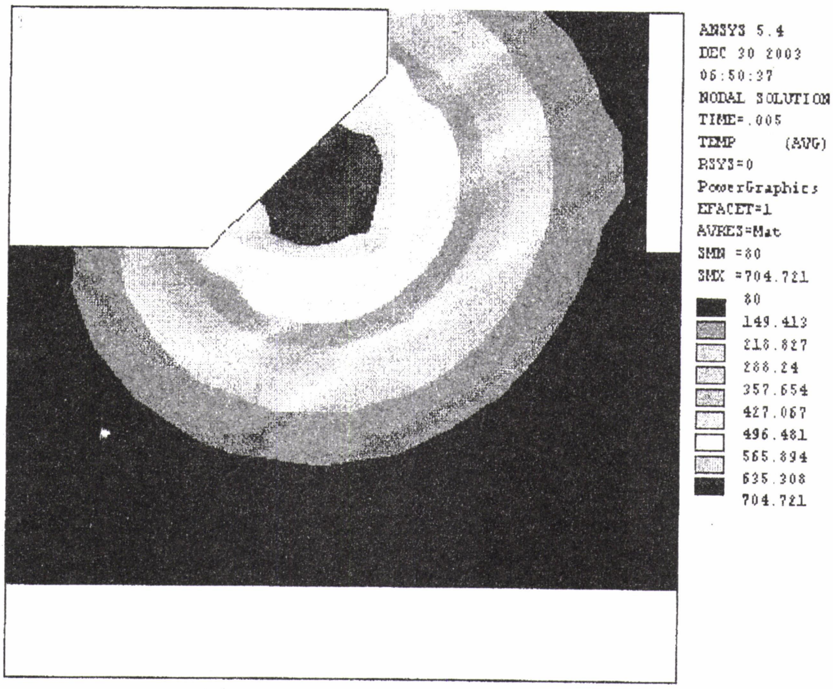


Fig (11) Temperature contour at time 0.005 hr.

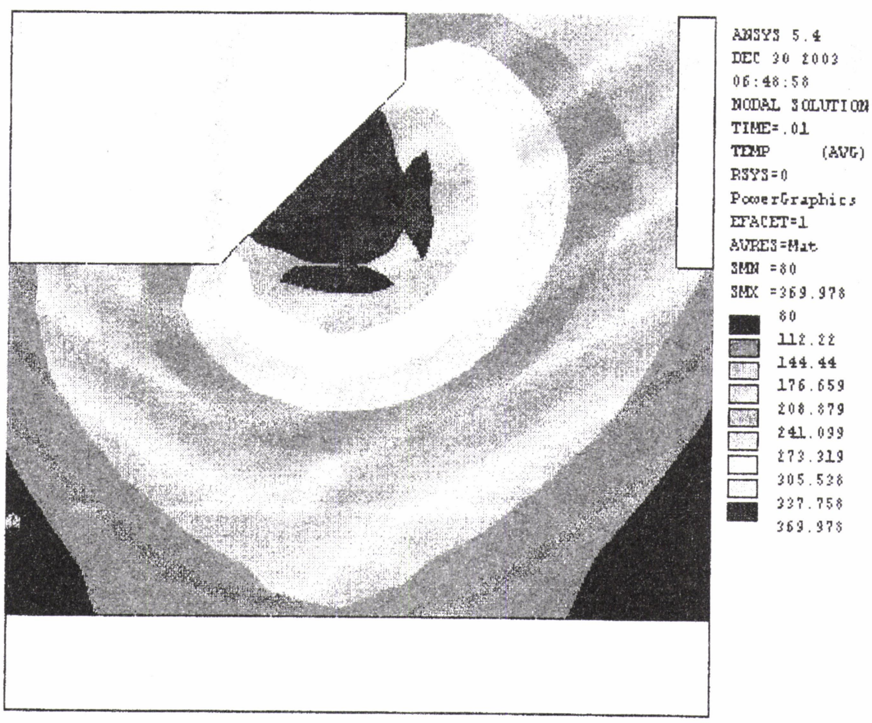


Fig (12) Temperature contour at time 0.01 hr.

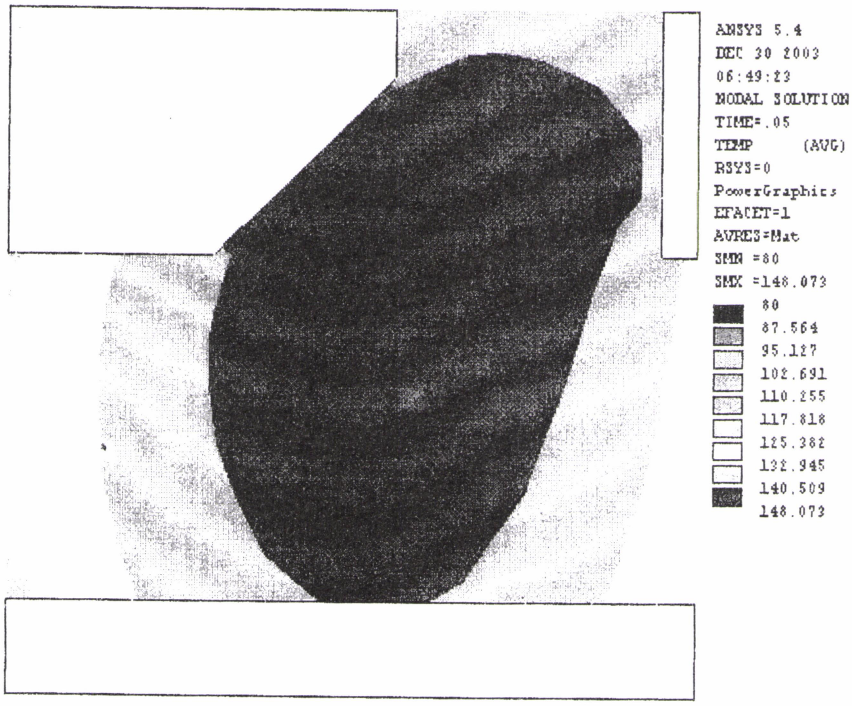
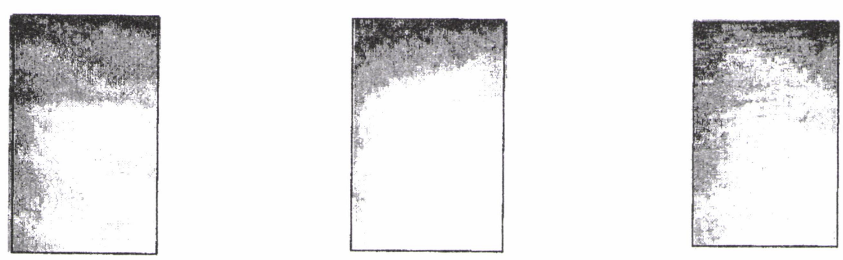


Fig (13) Temperature contour at time 0.05 hr.



Weld Pool (X 200) **HAZ (X 100)** **Base Metal (X100)**

Fig (14) Microstructure Examination of welded Joint

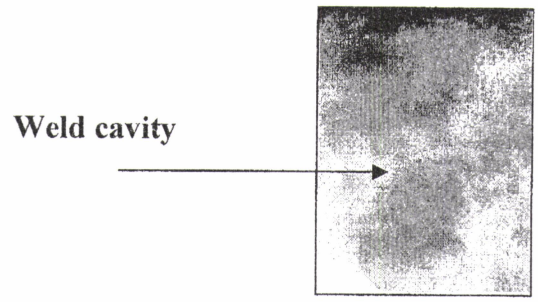


Fig (15) Micro-defect Examination of welded pool