Microstructure Characteristics in the Interface Zone of Gray Cast Iron Solid State Bonds

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ABSTRACT

In the present study, gray cast iron was diffusion bonded under air atmosphere and in inert environment (argon). In air it was carried out at the temperatures of 700, 750, 800, 850, and 900 °C under UN pressing load of 1 and 2 ton for 15, 30 and 60min. After diffusion bonding, experimental studies were adopted. As a result, Vickers micro hardness testing was carried out to measure hardness distribution in gray cast iron joint. The results observed from Vickers micro hardness test show that the hardness increases with increasing bonding temperature due to formation of hard phased iron carbides (Fe_3C)the maximum value were observed at 850°C for 60 min holding time under 2 ton is 310 HV. The microstructure results show the formation of carbide and the carbide precipitation increases with increasing the bonding temperature and time.

دراسة البنية الدقيقة للاسطح البينية لمنطقه ربط الحديد الزهر الرمادي

الخلاصة

يتضمن البحث دراسة الربط الانتشاري لحديد الزهرالرمادي بالظروف الجوية وبوجودغاز خامل(أركون).تحت ظروف جوية عادية تم الربط باستخدام درجات تسخين مختلفة700,750,800,850,900°م, وباستخدام قوة كبس 1,2طن بأزمان مختلفة 60,30,15 دقيقة لإيجاد الظروف العملية المناسبه التي تؤثر على مقاومة الربط. أجريت دراسات باستخدام قياسات الفحص المجهري والصلادة الدقيقة(Micro hardness). حيث اجريت فحوصات الصلادة على السطح الفاصل للوصلة.حيث تبين إن الصلادة تزداد مع زيادة درجه الحرارة حيث أعلى قيمه للصلادة تم الحصول عليها عند درجه حرارة 850°م لفترة 60 دقيقه تحت ضغط 2 طن هي310(HV).وتبين من اختبارات الفحص المجهري تكون أطواركاربيدية (Carbides)وترسيبها على سطح العينة وداخل السطح البيني.

INTRODUCTION

Solid State bonding is a joining process in which two nominally flat surfaces are held together, under applied pressing load at an elevated temperature typically above 0.6 T_m (melting temperature) for a period of time until a bond is formed. This process is relatively simply when two identical materials are to be joined, but when joining dissimilar materials, there are many potential complications. Solid state bonding of metals has a long history; it was one of the joining technologies developed by Kazakov [1].

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The solid state bonding process consists of three stages. At the first stage, the contact area increases by localized deformation and creep. At the second stage, diffusion takes place at the contact area and eliminates the voids at the original grain interface. Finally, the grain boundaries on the interface migrate and grain growth occurs. The main parameters of this method are temperature, time, pressing load, surface roughness and bonding atmosphere. Mechanical properties such as shear strength, micro hardness, and tensile strength, and microstructural properties such as grain size, present of phases, recrystallization temperatures are the other important parameters of the method [2].

Gray cast irons are in essence iron-carbon-silicon alloys containing small quantities of other elements. The metallurgy of gray cast irons is extremely complex because of a wide variety of factors that influence their solidification and subsequent solid-state transformations. In spite of this complexity, gray irons have found wide acceptance based on a combination of outstanding castability, excellent machinability, economics, and unique properties. However, cast iron is known as a hardly welding material. The poor weld ability of cast iron can be attributed to two factors: the formation of marten site in the heat affected zone (HAZ), and the development of hard, brittle iron carbide in the zone of partial fusion [3].

MATERIAL AND METHOD

Material

In this study, a gray cast iron and gray cast iron were diffusion bonded. Table (1) shows the chemical compositions of this material where the type of gray cast iron is G2 class 40, and this was examined by using spectroisort (portable) device, Germany and this is well agreed with published data [4].

Table (1) the chemical composition of gray cast iron specimen.

C (%)	Si (%)	Mn (%)	Cr (%)	Ni (%)	Mo (%)	Al (%)	Cu (%)	Co (%)	Ti (%)	Nb (%)	V (%)	W (%)	Fe (%)
≤2.64	**~1.72**	**0.661**	**0.397**	**0.25**	**0.082**	**0.07**	**0.361**	**<0.05**	**<0.05**	**<0.05**	**0.05**	**0.05**	**92.3**

Method

Diffusion bonding were performed using the samples of gray cast iron, those samples were cut into rectangular shape with dimensions, 20 mm x 20 mm x 18 mm. Using hydraulic cutting machine and then subjected to grinding and polishing before attempted the solid state bonding experiment. Pressing load to the workpiecesduring bonding is typically obtained through the use of hydraulic press. Fixture in special design were generated to transfer the load to the work pieces. The fixtures were made of plates from high temperature resistance material Inconel 600 (5 mm thickness, 100 mm length, 1.5 mm width) and were used to transfer the load to the samples by using the compression machine. The pressing load of1 and 2 ton at temperatures of 700, 750, 800,850, and 900 °C were utilized. Once the bonding process was completed, the samples cooled in furnace to room temperature before removal from the furnace. Certain type of equipment has been utilized for solid state bonding experiments. Vickers hardness measurements were carriedout on a Vickers hardness tester using a 0.9 Kg load and loading speed is 1 min.

In this research, two heatingchambers were used: the first heating chamber is designed to achieve solid state bonding under inert gas (Argon) environment to avoid oxidation of gray cast iron at high temperature. The bonding parameters for this experiment were 900°C heating temperature, 1 ton pressing load and 60 min holding time. Vertical furnaces with maximum temperature 1150°C were used. The gastube was connected to a pressing load gage to provide an exposure to argon, the pressure gage were connected to argon container with (140 Bar) pressure.

To reduce the cost of joining gray cast iron by solid state bonding, atmosphere furnace of 1200°C maximum temperature was used to achieve reliable joint during solid state, the bonding temperature range during the experiments was 700, 750, 800, 850, and 900°C for duration time 15, 30, 60 min.

RESULTS AND DISCUSSION

Solid state bonding joints between gray cast iron and gray cast iron were tested for Vickers hardness variation by utilizing a load of 0.9 Kg. On basis of Vickers hardness testing, the average length of the diagonals of indentation is made by hard pyramid. The hardness value of gray cast iron without heating is (177 HV) is measured by Vickers hardness and this agrees well with the results reported in the study [5]. The Vickers hardness measurements taken across the surface of specimen. It can be seen that the hardness values increase with increasing temperature as shows in Figures (1-4). Increasing hardness value is due to brittleness and the higher the temperature and the longer the time available for carbon to diffuse [6].

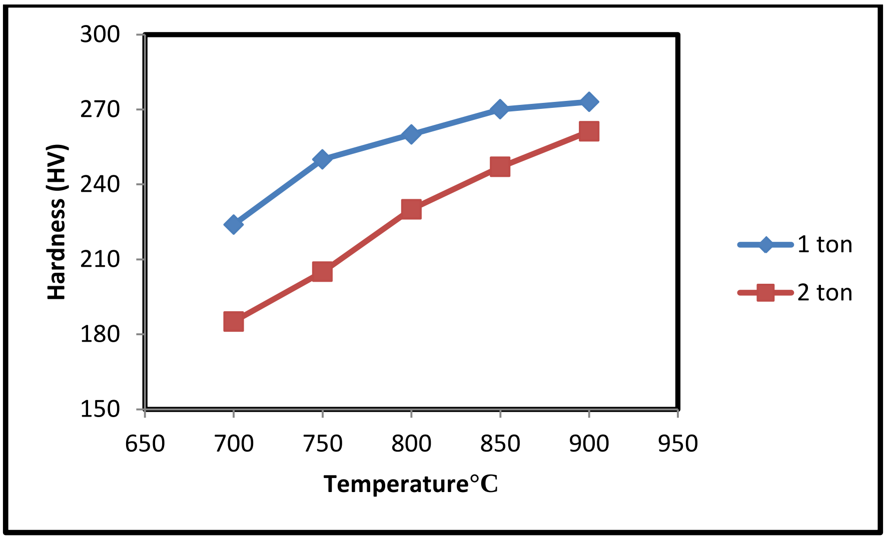

Figure (1) Hardness-temperature relationship for gray cast Iron joint at 15 min, 1ton.

Figure (2) shows the change in Vickers hardness with temperature, it is observed there is increase in microhardnss with increasing temperature; this can be due to by mutual migration of carbon, chrome and alloying elements toward to interface causing harden ability [7], and due to the formation of carbides [6]. As shown in Figure (3), the microstructure of specimen was bonded at 800°C for 30 min under 1 ton. We could infer from Figure (2 and 3), the hardness decreases with increasing time, because prolonged bonding times caused the graphite flakes to become thinner, the pearlite island around the graphite flakes dissolves rapidly until it compensates the stress gradient around the flakes [2].

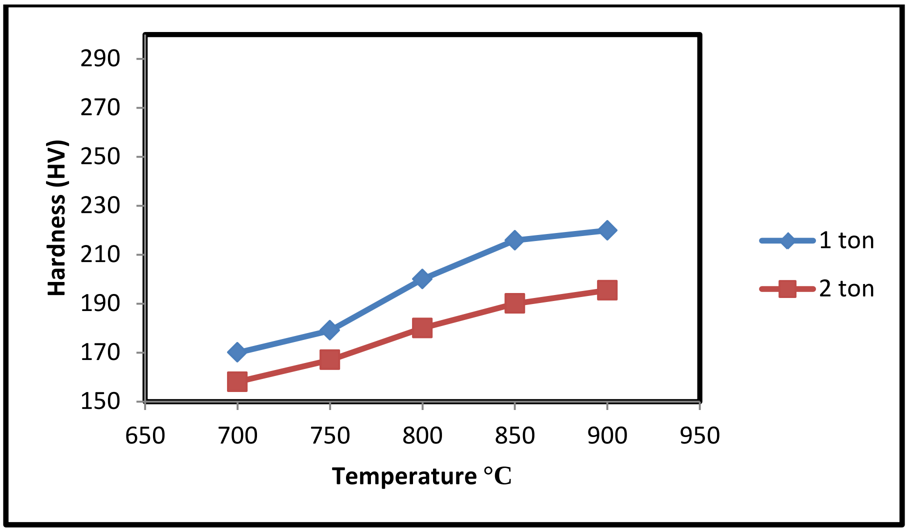

Figure (2) Hardness-temperature relationship for gray cast Iron joint at 30 min, 1ton.

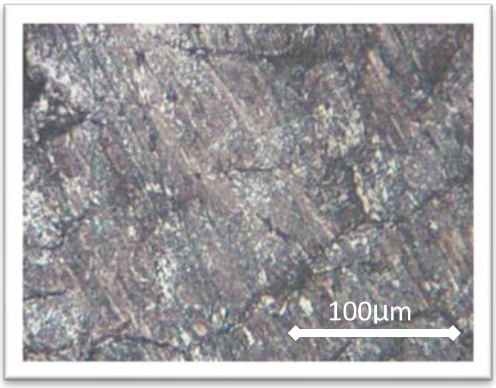

Figure (3) Microstructure of the specimen bonded under A pressing load of 1 ton for 30 min at 800°C.

The highest value of hardness is (310 HV) obtained at 850°C for 60 min under 2 ton as shown in Figure (4d) this is agree well with published data[8]. High hardness value can be related to the presence of high amount carbide [9].as shown the microstructure in Figure (5).

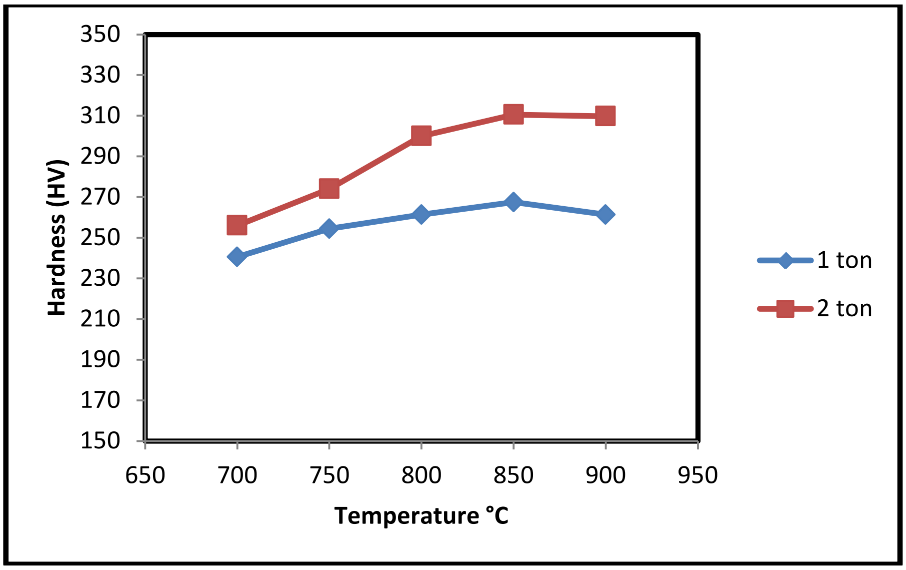

Figure (4) Hardness-temperature relationship for gray cast iron joint at 60 min, 1ton.

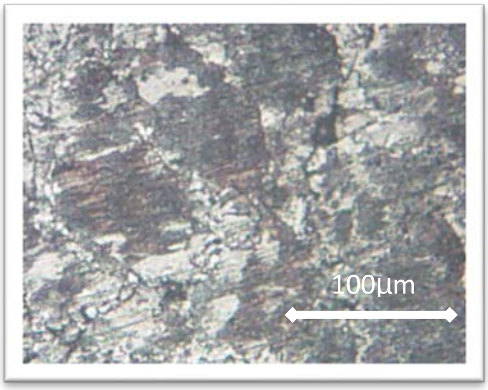

Figure (5) Microstructure of the specimen bonded under A pressing load of 2 ton for 60 min at 850°C.

Fracture surface of the shear tested joint at different solid state bonding conditions was examined. Gray cast irons contain uncombined carbon in the form of graphite flakes in the matrix which is commonly pearlite, ferrite or their mixture, as shows in Figure (6). Graphite flakes in gray cast irons display the greatest tendency to dissolve in austenite because of their relatively large surface area [10]. The flake-like shape of graphite in gray cast iron is shows in Figure (6) exerts a dominant influence on its mechanical properties, the graphite flakes act as stress raisers [11].

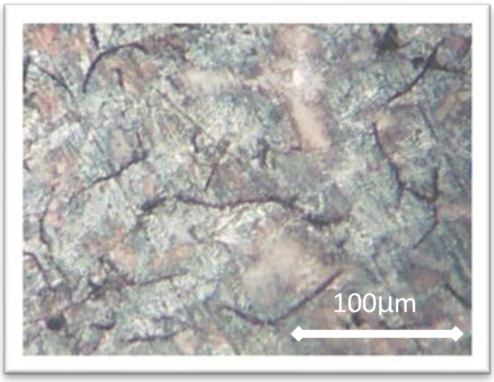

Figure (6) Microstructure of gray cast iron specimen before joined. Structure: Graphite flakes in the ferritic and pearlitic matrix.

The shape and surface area of the graphite affect solid state bonding behavior of the cast iron; it was observed that graphite flakes increase the diffusion rate. Therefore, it is concluded that the second phase and graphite with irregular shape can work as stress risers inside the material and increase the diffusion rate of the region. It was determined that the sizes and shapes of the microelements like carbides, graphite and secondary phases affect the diffusion rate inducing high stress region or local stress concentrations [2].

Carbides in cast irons may have the general formulae M_3C, or M_7C_3, these carbides may occur as lamel, rod, or continuous matrix in unalloyed cast iron. The microstructure of the unalloyed iron generally consists of M_3C carbides and pearlite [12].

Figure (7) shows that the microstructure contains high amount of carbide plus some graphite. Therefore, at this temperature (800°C for 60 min), the graphite flakes begin to dissolve in the austenite producing a carbon gradient from the graphite flakes into the austenite, resulting in the gradation of transformation products within this region, the diffusion rate of carbon in most cases in order to eliminate the massive carbides and thus reduce hardness and brittleness [9].

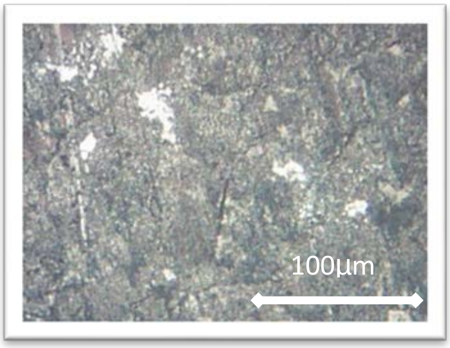

Figure (7) Microstructure of the specimens bonded under A pressing load of 1 ton for 60 min at 800°C.

It was shown in Figure (8), that the microstructure of gray cast iron are bonded at bonding temperature of 850°C under pressing load 1 ton for holding time for 60 min, it exhibited massive carbide and with increasing temperature the precipitated carbide increase [9] and grain growth is observed at elevated temperatures [13].

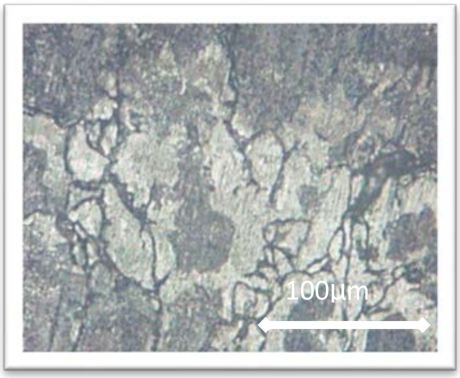

Figure (8) Microstructure of the specimen bonded under a pressing load of 1 ton for 60 min at 850°C.

Figure (9), it can be seen that the secondary particles (carbides) have precipitated at the sub-grain and grain boundaries. The parameters, such as temperature, and cooling rate, have significant influence on the microstructures [9].

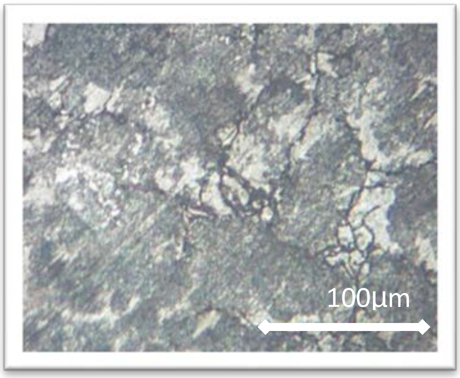

Figure (9) Microstructure of the specimen bonded under A pressing load of 1 ton for 60 min at 900°C.

CONCLUSIONS

1. In this research, the gray cast iron / gray cast iron couple is bonded successfully at the temperatures of 700, 750, 800, 850, and 900 °C under UN pressing load of 1 and 2 ton for 15, 30 and 60min.
2. The maximum hardness is achieved at high temperatures 850, 900 °C; the values were 265 Hv and 310 Hv respectively.
3. Increasing the bonding time increases the hardness of the joint.
4. The pressing load of 1 and 2 ton has slight effect on the hardness for most bonding temperatures and time.
5. Optimum Vickers hardness of gray cast iron / gray cast iron joints is (310 Hv) at 850°C for 60 min under pressure 2 ton.

6. Phases such as iron carbide (Fe_3C) are formed in the gray cast iron/ gray cast iron interface.
7. The diffusion of C from graphite in gray cast iron to interface increases with increasing temperature especially at 850, 900°C.
8. The quality of the coalescence at interfaces increases at elevated temperatures under confined and experimented conditions. On average, the best properties were observed in specimen bonded at 850, 900°C.

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