International Journal of Enhanced Research in Science, Technology & Engineering
ISSN: 2319-7463, Vol. 4 Issue 10, October-2015

Reduction of intergranular corrosion of (304) austenitic Stainless Steels during maintenance

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ABSTRACT

This paper discusses the reduction of intergranular corrosion which is called weld decay problem in Austenitic Stainless Steels (AISI 304) used in medical and food sectors. Currently, weld decay problem is being eliminated by proposing heat treatment, low carbon content or stabilized stainless steels. However, these methods have some limitations due to welding size, type or place of the part to be welded. In this work, a new approach has been proposed by using copper block which is placed under the welding joint. To decrease the temperature of the welding base metal water was passed thoroughly from the internal holes of the copper block. Moreover, our approach will shorten the formation time of sensitization since no sufficient time will be given for the interaction of carbon with chromium, which leads to hindering weld decay.

Keywords: Weld Decay, Austenitic Stainless Steels Welding, Chromium Carbide.

1. INTRODUCTION

Stainless steel (SS) is one the most important material in the medical and food industries especially 304 and 316 type austenitic stainless steels (ASS). As they have the best corrosion resistance, strong, easy to clean and sterilized properties [1]. The common welding problem with this type of (SS) is known as weld decay (or intergranular corrosion) which occurs in the heat-affected zone (HAZ). During welding of (SS) and when the weldment is slowly cooled at the range of 800°C to 500°C, local sensitized zones are often developed due to chromium carbide depletion in regions at grain boundaries [2,3]. If austenitic stainless steel is held for more than the specific time at the above mentioned temperature range, carbon rich chromium carbides grow often in the form of $Cr_{23}C_6$ at austenite grain boundaries [4].

This last is a type of inter-crystalline corrosion that causes the weld decay defect, which leads to sudden failure of the metals [5,6].There are some various methods used to reduce or prevent carbide precipitation during welding of austenitic stainless steels. Heat treatment method is known as a common solution. Weldment is heated in the range of 1000℃ to 1150℃ and rapidly cooled (by quenching) through the 800℃ to 500℃ range. Another remedy for the carbide-precipitation problem is to use stainless steels and electrodes having a low carbon content 304L, 316L (0.03% C) that no carbides can be precipitated. In [2-9] Stabilized (SS), which is a specification of a (SS) that containing a small amount of either Titanium or Niobium, have a higher tendency than does chromium for carbon, thus avoids the Cr-depletion problem .

The aim of this work is to reduce welding decay in (ASS), particularly those sections which do not make any conventional methods (Thermal Treatments, Low-Carbon (SS) and Stabilized Steels). This method was considered to solve different issues regarding the huge size, type or place of the part to be welded particularly that is used in a medical and food sectors. As well, the new method has the ability to eliminate the weld decay problem in (SS). The use of high thermal conductivity in copper to dispersion the heat from the (SS) pieces during welded. This feature will reduce the time required for forming of sensitization at a critical range between 500-800℃, and there is no enough time for the interaction to produce chromium carbide. Thus, the weld decay phenomenon is avoided.

2. EXPERIMENTAL DETAILS

The AISI 304 (SS) samples with chemical composition are given in table 1.

Table 1. Chemical Composition of Stainless steel Used in Experiment

C%	Si%	Cr%	Ni%	Mn%	S%	Mo%	P%	V%
0.058	0.668	18.00	9.09	1.10	0.002	0.07	0.013	0.03

By using tungsten Arc Welding (TIG), the welding surfaces and the tip of Tungsten electrode automatic GTAW welds were cleaned to remove any grease or dust. As an experimental input, the diameter of applied W-%2Th electrode was 1.6 mm, the internal diameter of ceramic nozzle was 12 mm, current 150 A, welding speed 5.3 mm/Sec and argon gas flow was 5 liter/minute. In the experiments, welding materials are placed on the copper block. The copper block consists of 20 mm thickness with 8 mm holes diameter. A copper tube is 7 mm diameter inserted in each hole to transmit the water from each channel in order to sustain the continues cooling as shown in Figure 1. Copper block was placed under the weldment. The work was on four stages as following:

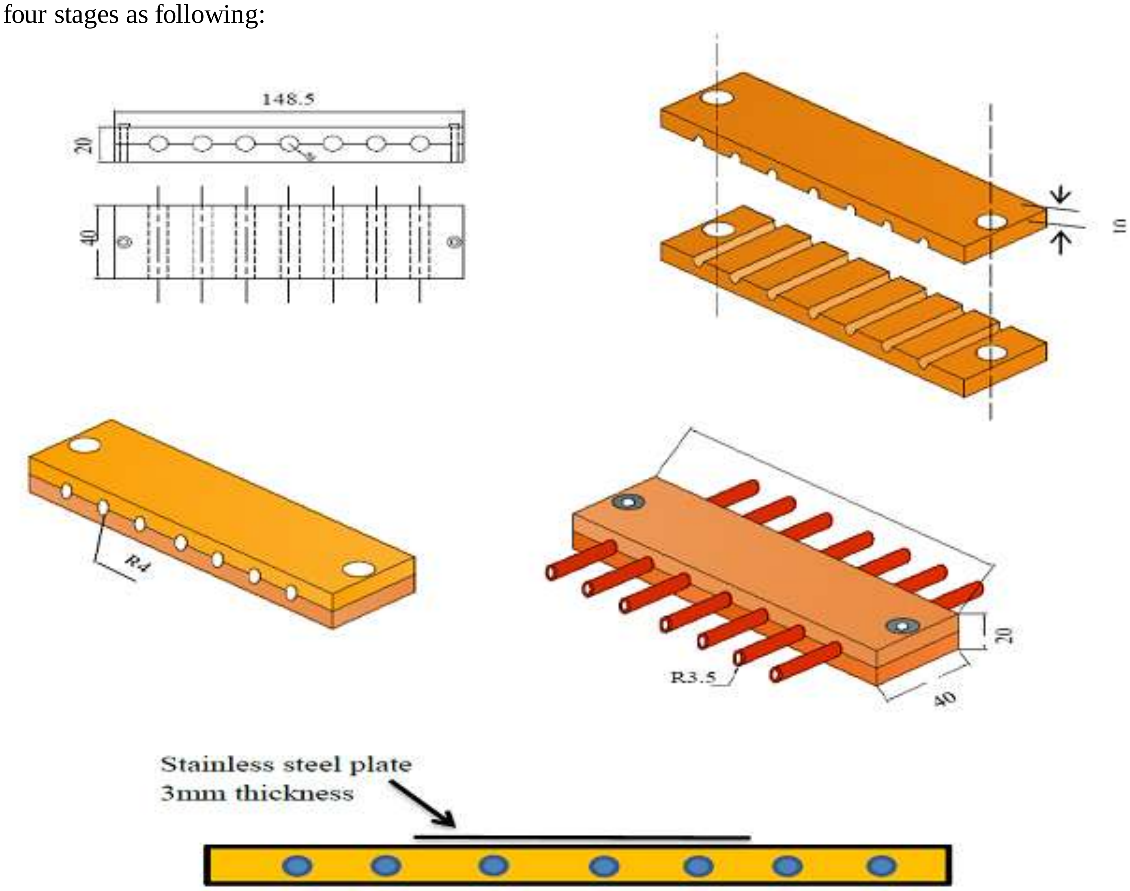

Figure 1: Sketch of Copper Block

-The first sample has been welded without copper backup to make this sample as stander and compare it with other samples. Temperature of base metal 10 mm away from the weld center was measured by thermocouples.

-The second sample has been welded by using copper block as backup strip. The sample (SS) has been fixed to avoid distortion.

-The third sample has been welded by using copper block as backup strip and pass through the copper block water at 25℃ by using a pump with flow rate V=1m/Sec, as shown in figure 2.

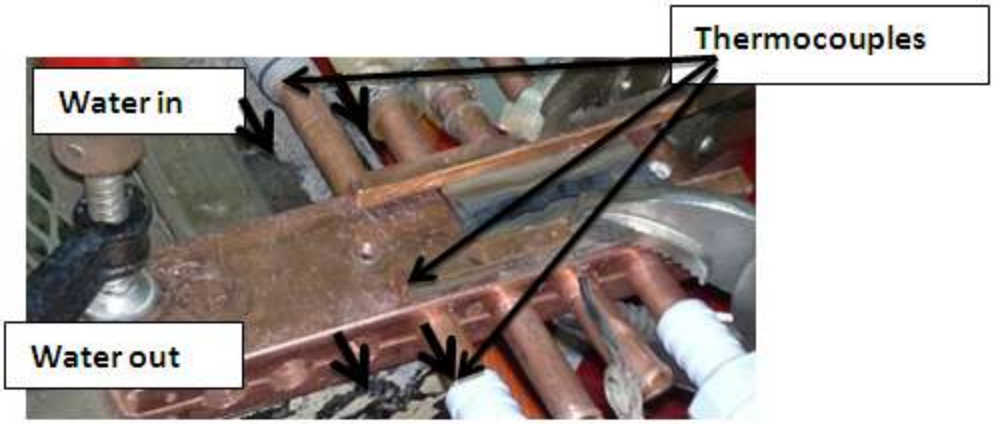

Figure 2: Water Pass through a Copper Block at 25℃ and5℃

-The fourth sample has the same welding conditions with the third condition, except inlet water temperature is 5℃ instead of 25℃. During welding, Temperature of welding zone was measured instantly by thermocouple. Welding four samples in different situations according to the following technique as shown in Table 2.

Table 2: Continues Cooling Condition

Case No	Type of samples	Water Inlet temp. (℃)	Water Outlet temp. (℃)	Base metal Temp. (℃)
1	Without cooling	-	-	248
2	Copper as cooling	-	-	150
3	Using copper and water at 25 ^{0}C	25	28	110
4	Using copper and water at 5 ^{0}C	5	8	70

2.1 MICROSCOPIC ANALYSIS

Surface layers damaged by cutting and welding removed by grinding. Mounted specimens are ground with rotating discs of abrasive paper. All samples were cleaned with acetone and grinded metallic papers from 60 grit to 1200 grit respectively. After the grinding step, Specimens were polished by polishing cloths with lubricant and progressively smaller diamond abrasives.

2.2 ETCHING THE SPECIMEN

Microscopic examination of a properly polished. Etching is used to highlight, and sometimes identify, microstructural features or phases present. The time required for etching as much as ten minutes after being etched the specimen is washed in running hot water at 40℃ to remove the chemicals used in the etching. All samples were chemically etched with; 10 cm3 Nitric acid, 20 cm3 Hydrochloric acid, 20 cm3 Glycerol, 10 cm3 Hydrogen peroxide mixture.

3. MATERIALS AND METHODS

Weld decay is induced by the sensitization caused by the precipitation of Cr carbide at the grain boundary, It is a type of intercrystalline corrosion which occurs in the region parallel to the weld metal in the HAZ of austenitic group stainless steels such as 304[10].The time for passing the temperature region for sensitization during the cooling process determined as figure 3[6,11].

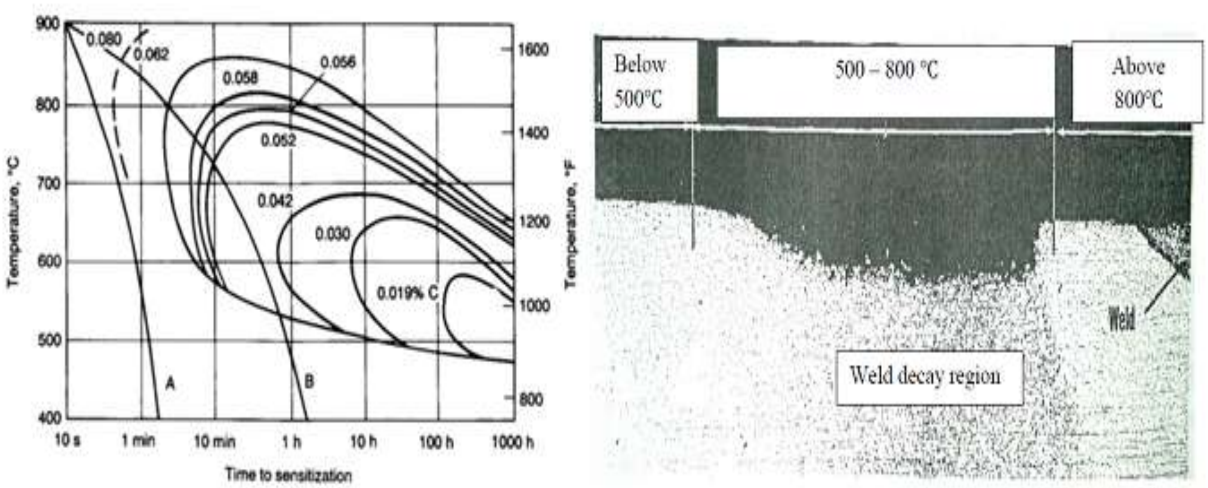

Figure 3. $Cr_{23}C_6$ Time Temperature-Precipitation Curve & Potion of Weld Decay in 304 Steel

4. RESULTS AND DISCUSSION

In this work, four different cases of TIG welding were performed. In order to clarify the weld decay defect, 3mm thickness of stainless steel was welded with convention method. This is named "case 1". Weldments were cut transversely to examine the microstructural changes. Microscopic and Scanning Electron Microscope (SEM) of the specimen is shown in Figure 4.

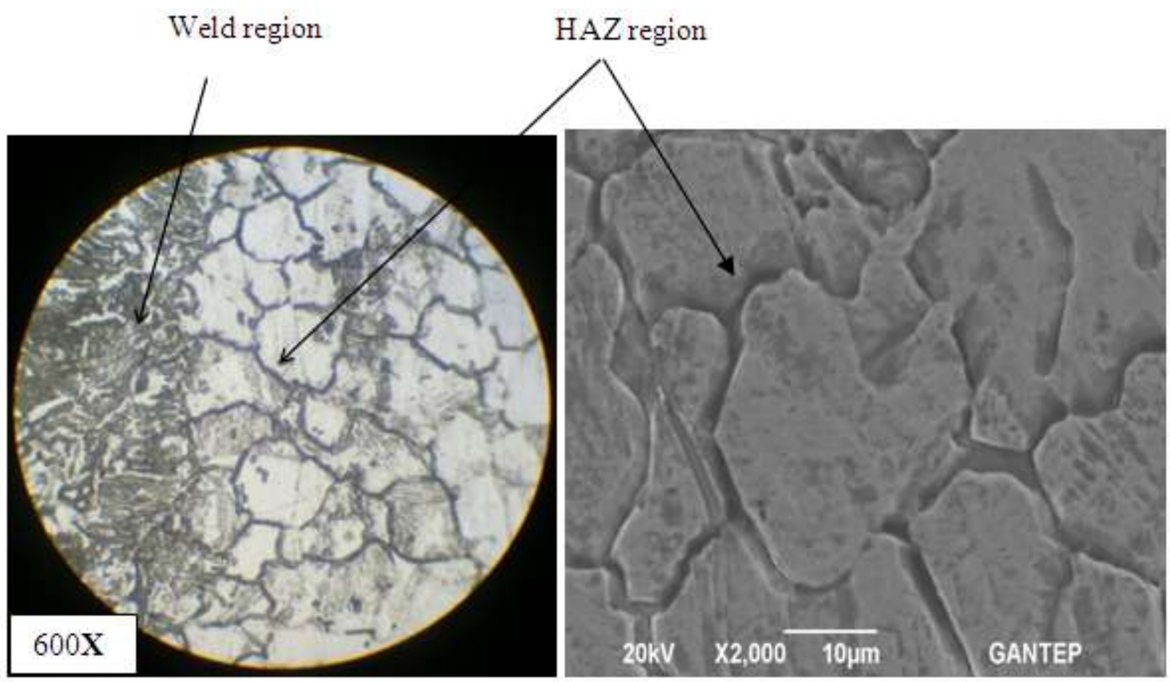

Figure 4. Weld Sample Without any Cooling in Weld & HAZ Region a) by microscopic b) by scanning electron microscope (SEM)

The samples welded without any cooling to made comparison with other samples. Weld decay at the grain boundaries is seen very clearly. Temperature in the base metal was 248°C. As a second case, copper block was placed at the bottom of the weldment to make easy the heat distribution. Weld decay again was observed, but it was less than the first case as shown in Figure 5.

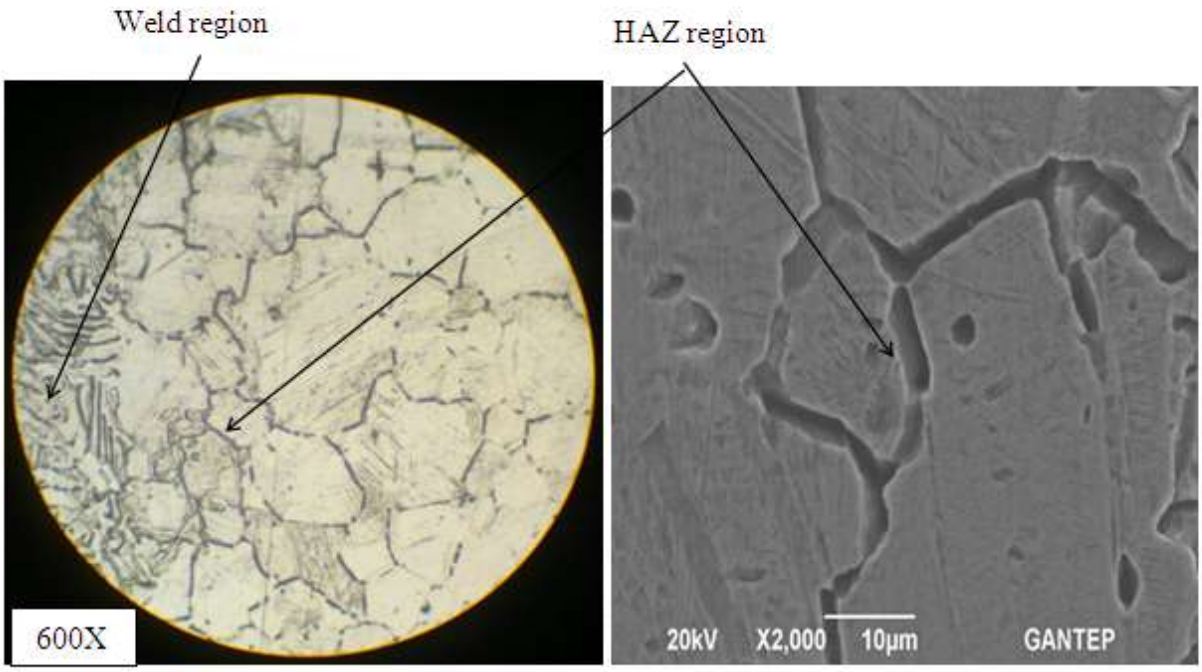

Figure 5. Weld Sample by Using Copper as Cooling Medium Weld & HAZ Region a) by microscopic b) by scanning electron microscope (SEM)

It means that the time has been reduced to prevent the sensitization or forming $Cr_{23}C_6$. It was noted that the base metal temperature was 248℃ in case 1. However, by placing a copper block under the weldment, the temperature was reduced to 150℃. As a third case, 25℃ water was passed through from the channels made in the copper block previously. The aim was to reduce the temperature in order to not allow enough time for the formation of weld decay. Weldment temperature was measured and recorded as 110°C. in figure 6,

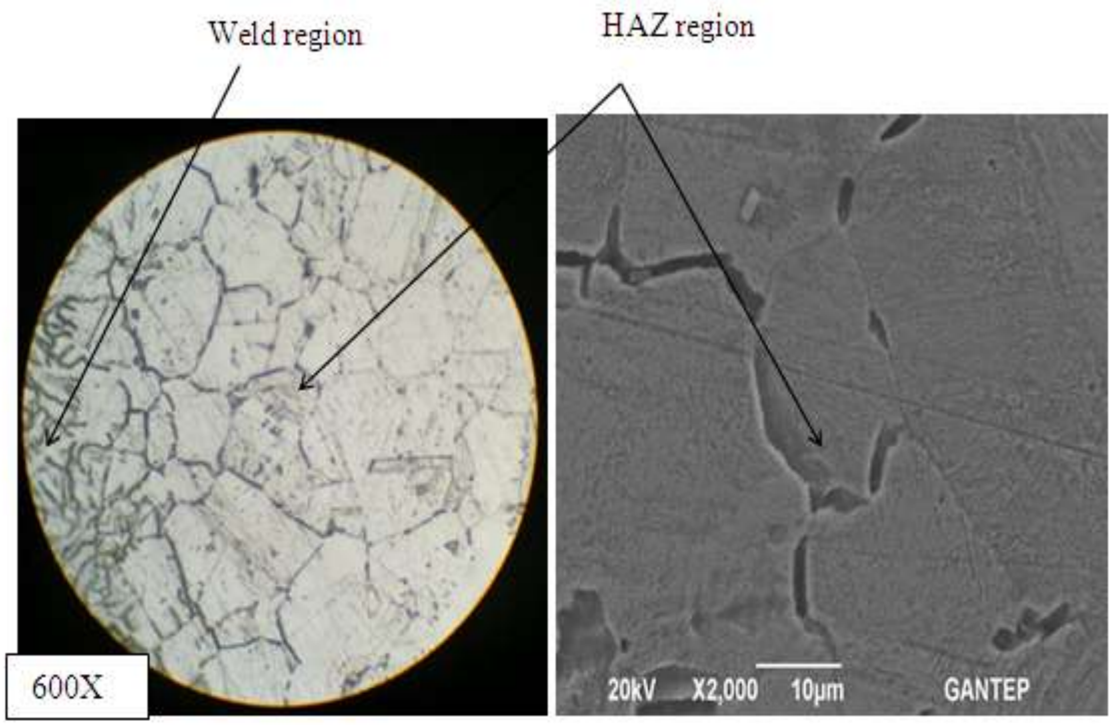

Figure 6. Weld Sample by Using Copper and Water at 25℃ as Cooling Medium Weld & HAZ Region a) by microscopic b) by scanning electron microscope (SEM)

It is clearly shown that weld decay is partly eliminated. Fourth case, Water temperature was reduced from 25℃ to 5℃. This caused reduction in base metal temperature to 70℃. Figure 7 shows the microstructure of case 4. It is very obvious that, there is no formation of $Cr_{23}C_6$ at grain boundary.

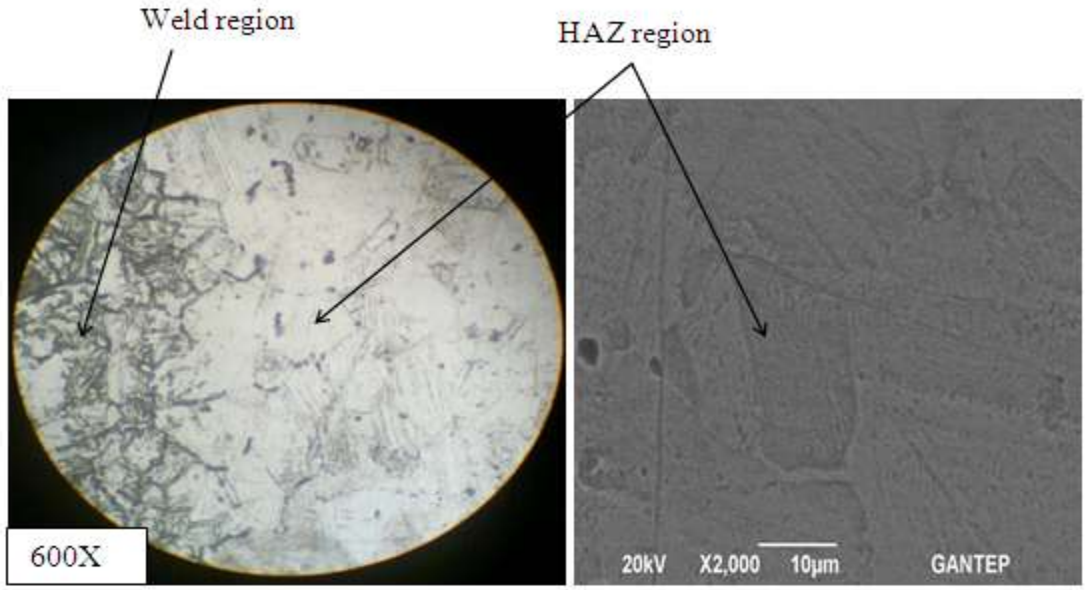

Figure 7. Weld Sample by Using Copper and Water at 5℃ as Cooling Medium Weld & HAZ Region a) by microscopic b) by scanning electron microscope (SEM)

Figure 8, shows the critical time in the HAZ region between (500-800℃), which indicate when the temperature kept more time in this rang that mean had a good chance of forming weld decay. In case 1 the temperature kept between (500-800℃) more than 6 minutes while when increase cooling rate the time at above range the temperature decrease to 2.3 minutes as in case 4. Forming weld decay decrease with increase cooling rate at (500-800℃) in HAZ region.

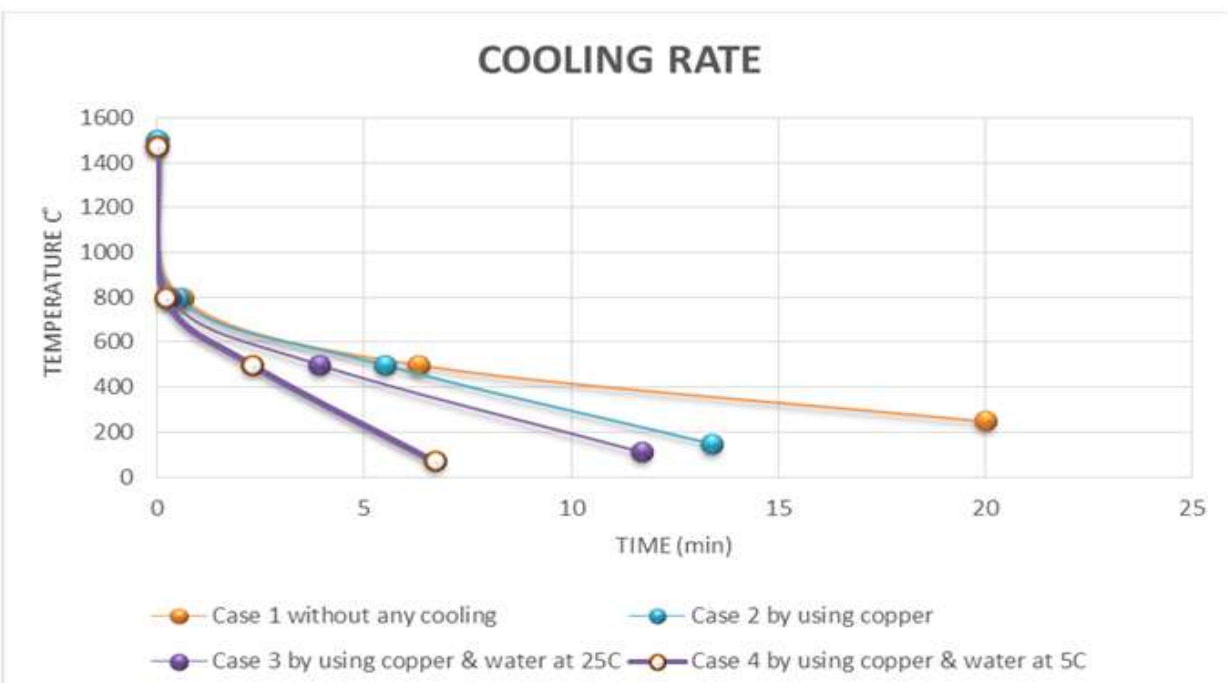

Figure 8. Critical Time To Forming Weld Decay Between (500-800℃) In HAZ Region

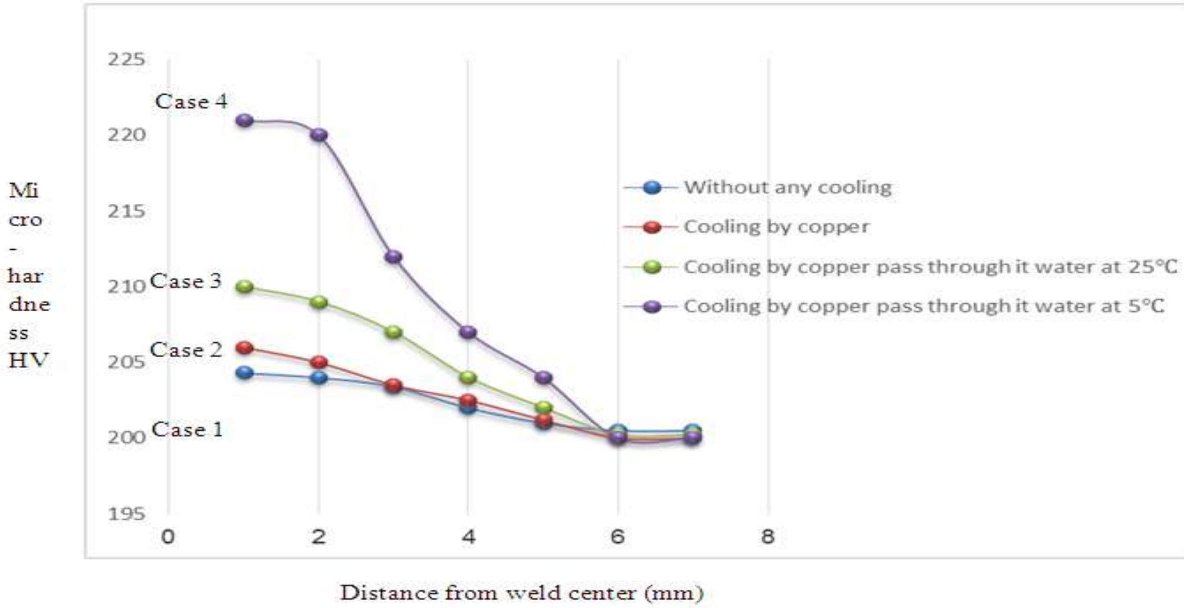

Figure 9. Micro-hardness Profile Showing Micro-hardness Values at Different Points.

4.1. MICROHARDNESS TEST

All tested all samples were subjected to micrhardness test. Microhardness measurements were taken from the center to outwards of the welding. Case four, 5°C waters passed through from the channels made in the copper block previously, has the highest hardness value which is due to the fact that cooling rate is relatively higher than the other cases. The values of microhardness increases with cooling rate in the weld and HAZ region, and it is almost constant in the base metal. Case 4 has the highest hardness value, because of the fast cooling rate on copper and thus sample, which effects on the grain size.

CONCLUSIONS

1- A new method has been proposed to eliminate the weld decay problem in stainless steels that is used in a medical and food sector.
2- Continues cooling method helps in solving the weld decay problem, especially in the maintenance work that needs to welding operations in large appliances that cannot make transactions by heat treatment.
3- Continues cooling method, doesn't need high equipment and it is low cost.
4- Copper block was used to assist the reduction of base metal temperature.
5- Corresponding hardness values were increased with cooling rate. This came from the change in grain size. So possible to control the cooling rate only in the range critical region to ensure the homogeneity of the crystals.

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