INFLUENCE OF BAKING CONDITIONS OF MMAW ELECTRODES ON WELD METAL MECHANICAL PROPERTIES

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ABSTRACT

Investigations have been carried out to study the influence of electrode baking temperatures and the duration of baking on the mechanical properties of the weldments with rutile and basic types of electrodes. It has been found that baking of rutile electrodes improves the weld-metal characteristics provided the baking is for short duration of 1 hour at 150°C. Higher temperature of baking leads to overall deterioration of mechanical properties. With basic type of electrode used for investigations, higher temperatures up to 350°C can be employed for shorter duration of one to two hours or 250°C for 2-3 hours baking, to achieve the optimum results i.e. good mechanical properties of the weld metal. Higher baking temperatures deteriorate the weld metal strength. The weld metal hydrogen content does not appreciably reduce beyond the baking temperature of 350°C basic coated electrodes.

INTRODUCTION

Basic flux covered electrodes are generally used where manual metal arc welding of high weld quality is required. With these electrodes the mineral coating is made to adhere to itself and to the core wire by means of a silicate binder, commonly sodium silicate. It is this binder that is the source of moisture from which the weld hydrogen comes[1-3].

Hydrogen is soluble in molten metal and is readily picked up in the weld metal during welding. In general more is the hydrogen present in the metal greater is the risk of cracking, the hydrogen is the most powerful promoter of embrittlement [4,5].

The need to avoid cracking problems by limiting the hydrogen concentrations developed in the weld metal, make it necessary to apply some form of drying or baking treatment to the electrodes before usage. Further, it is necessary to store the electrodes after baking in such a way as to maintain as far as possible the dryness that has to be achieved. The second requirement arises, since well dried electrodes will tend to take up moisture on exposure to atmosphere. Moisture that is picked up during exposure to the environment does not easily enter the binder structure and therefore, moisture picked up during exposure to atmosphere can be removed through a mild reconditioning treatment [6,7].

As the basic coated electrodes are low hydrogen electrodes, their baking requirements are more stringent than other type of electrodes[8]. Control of hydrogen level through consumables is very economically desirable as alternative methods (preheat or post heat) are costly both in terms of time and energy [9]. The electrodes that are exposed to prolonged baking temperature or excessive baking temperature may deteriorate. The possible effects of incorrect baking procedures are (i) Oxidation of deoxidants in the coating (ii) Breakdown of carbonates in the coating (iii) Effects on the silicate binding system leading to coating fragility.

A slight decrease in mechanical properties resulted from baking for 120 hours at 450°C. The reason for this is lower Mn and Si recoveries in weld deposits. The decrease in mechanical properties was more noticed in case of electrodes repeatedly baked at 450°C due to weak bondage of electrode coating at many places which caused ineffective shielding and coverage and are perhaps responsible for the poorer mechanical properties .The harmful effect of excessive baking is more

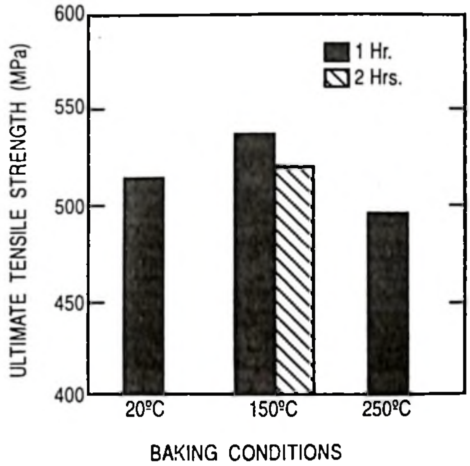

Fig. 1 : Influence of Baking conditions on ultimate tensile strength of rutile electrode welds.

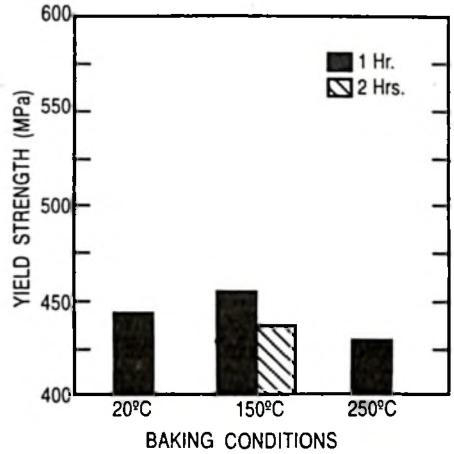

Fig. 2 : Influence of Baking conditions on yield strength of rutile electrode welds.

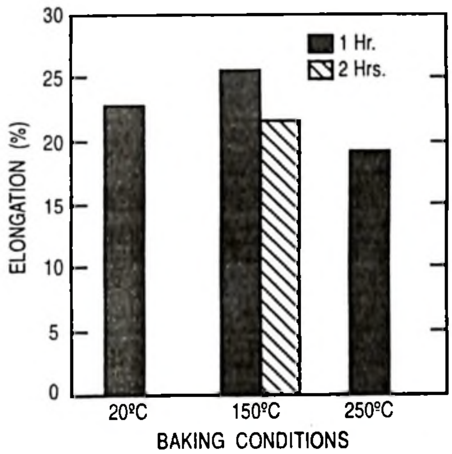

Fig. 3 : Influence of Baking conditions on % elongation of rutile electrode welds.

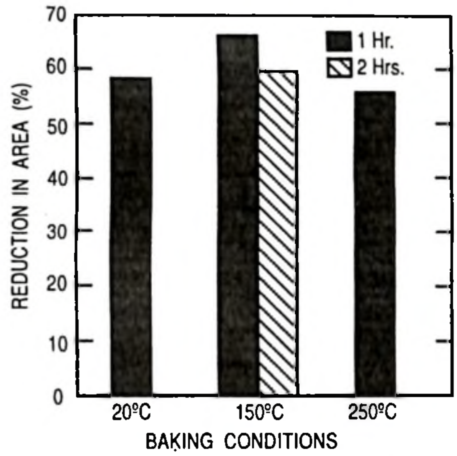

Fig. 4 : Influence of Baking conditions on % reduction in area of rutile electrode welds.

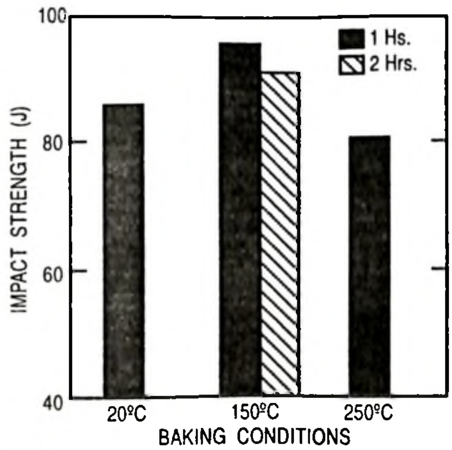

Fig. 5(a) : Influence of Baking conditions on impact strength at room temperature of rutile electrode welds.

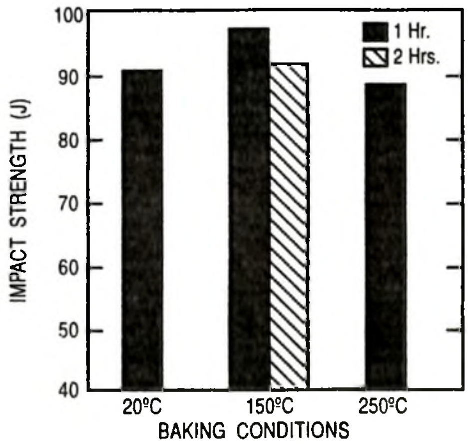

Fig. 5(b) : Influence of Baking conditions on impact strength at 0ºC of rutile electrode welds.

pronounced when specified baking temperature is exceeded or repeated baking is resorted to. The deleterious effects also depend to an extent on the coating constituents about which the users are not mostly aware. It is therefore, advisable to adhere to the recommended baking procedure and departure from this practise is not a wise proposition [10].

EXPERIMENTAL PROCEDURE

The experimental investigations have been carried out to evaluate the influence of baking conditions on mechanical properties of rutile and basic coated electrodes.

The welding procedure for testing of the mechanical properties of weld metal was carried out as per Indian Standard IS : 814-1991.

Apart from the above test, diffusible hydrogen content of the electrode was measured by glycerin method and converted to the standard value of hydrogen for mercury method.

The following electrodes were used for preparing the specimens. Electrodes of diameter 4 mm and length 450 mm have been used for electrode testing with specifications given below :

(a) Basic Type
IS 815:1974:E614514 HJ
AWS code : E7018

(b) Rutile Type
IS 815:1974:E307412
AWS code : E6013

(c) Baking Conditions
Electrode baking temperatures
150, 250, 350, 550^{o}C
Baking Times 1,2,3 hours

(d) Number of specimens
Two test specimens were selected for tensile test and 12 specimens for impact test at different temperatures (20^{o}, 0^{o}, –20^{o}, and –30^{o}C) for impact test in case of basic electrode and 10 specimens in case of rutile electrode for testing at 20^{o} and 0^{o}C.

(e) Mechanical Testing

The tensile test has been carried out at room temperature in accordance with the recommendations of IS : 1608 : 1972 and results evaluated accordingly. Impact test carried out at different temperatures –30^{o}C, –20^{o}C, 0^{o}C and 20^{o}C. The test temperature may vary in a short range of ±2^{o}C from the specified temperature. The sub-zero temperatures were achieved with liquid nitrogen. The testing is done in accordance with IS : 1757 : 1979.

(f) For measurement of diffusible hydrogen, mild steel specimens of sizes 38x12x10 mm were taken and a quick release copper jig was used for clamping the specimen and then welding was carried out. Within 10 seconds of completion of welding the specimen was quenched. Then specimen was flushed with acetone and dried in blast of cool air and inserted under glycerin. This set up was held in water bath at the constant temperature of 45^{o}C.

The volume of the hydrogen evolved was recorded after 72 hours. The amount of hydrogen was calculated to standard value by glycerin method and then it was converted to standard mercury method value using suitable expression.

Results

During the baking of the electrode, it was found that the coating was cracking if rutile electrodes were baked at 250^{o}C for longer duration i.e for more than 1 hour. Further, beyond 250^{o}C it was not possible to weld with those electrodes. So, rutile electrodes were baked only up to 250^{o}C. However, basic coated electrodes could be baked safely up to 350^{o}C and beyond this temperature up to 550^{o}C for a maximum duration of 2 hours only. Higher temperature baking also created certain problems like cracking of the coating during welding with basic coated electrodes.

Tensile Test of Rutile Electrode Welds

Figures 1-4, give the results of tensile tests of weldment produced by rutile electrodes. From the figures, it can be observed that the ultimate tensile strength, yield strength, % elongation and % reduction in area increase with the baking at 150^{o}C. However, 150^{o}C baking temperature with longer baking duration of 2 hours deteriorates these characteristics. For higher baking temperature of 250^{o}C, these values are even lower as compared to values with electrodes without baking.

Impact Test of Rutile Electrode Welds

Figures 5a and 5b give the results of the impact test at room temperature and 0^{o}C. From the figures, it can be observed that for rutile electrode, the notch toughness is maximum for 1 hour baking at 150^{o}C. If the duration of electrode baking is increased or baking temperature is increased up to 250^{o}C, then the notch toughness reduces. Similar tto tensile test, for 250^{o}C bakng of electrodes, the obtained notch toughness is even lower than that obtained for weldment produced by electrodes without baking.

Tensile Test of Basic Coated Electrode Welds

Figures 6-9 give the results of the tensile tests. From the figures, it can be

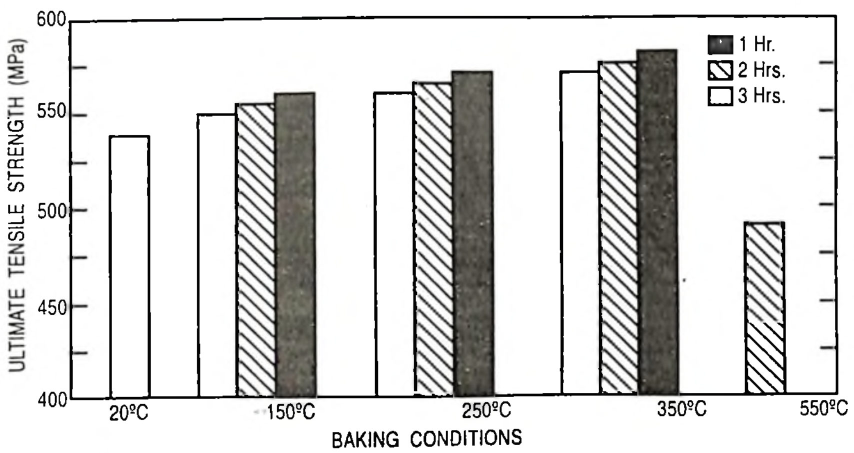

Fig. 6 : Influence of Baking conditions on ultimate tensile strength (U.T.S.) of basic coated electrode welds.

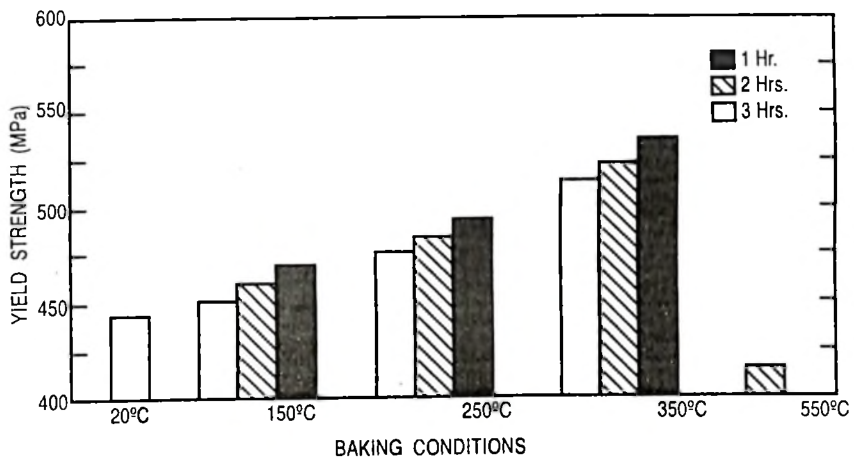

Fig. 7 : Influence of Baking conditions on yield strength (Y.S.) of basic coated electrode welds.

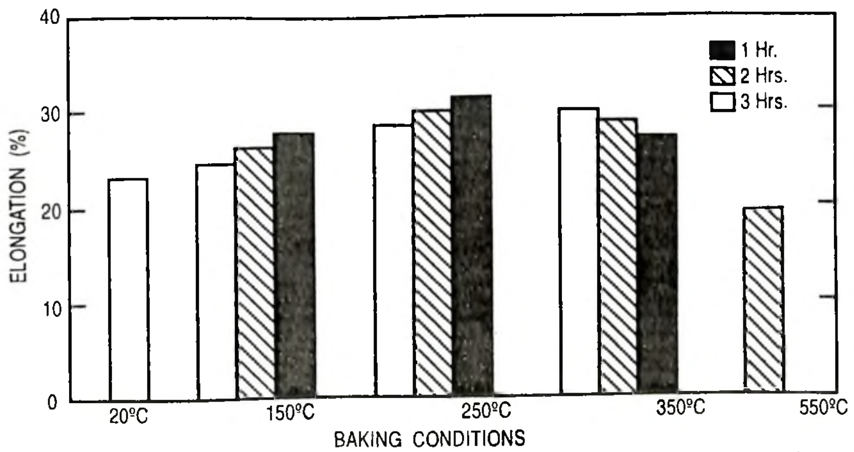

Fig. 8 : Influence of Baking conditions on % elongation of basic coated electrode welds.

observed that both the ultimate tensile strength and yield strength increase with the increasing baking duration and temperature up to 350^{o}C. If the electrodes are baked at temperatures beyond 350^{o}C, then both ultimate tensile strength and yield strength reduce appreciably and are even lower than that obtained without baking of the electrodes.

Both % elongation and % reduction in area increase with the increase in the baking duration and temperature upto 250^{o}C. However, beyond 250^{o}C baking, these start decreasing. For 350^{o}C baking of electrodes, both % elongation and % reduction in area are found to decrease with the increase in the baking duration, though this decrease is not appreciable. Further, for 550^{o}C baking temperature and 2 hour baking period, both these characteristics further reduce and are even lower than the values obtained for weldments produced with the electrodes without baking.

Impact Test of Basic Coated Electrode Welds

Firgures 10 and 11 give the results of the impact test for test temperatures 0^{o}C and –30^{o}C. From these figures, it can be observed that the notch toughness increases with the increase in baking temperatures up to 250^{o}C and duration up to 3 hours. Beyond 250^{o}C i.e. at 350^{o}C, the notch toughness starts decreasing with the increase in the baking duration. For higher baking temperature of 550^{o}C, the impact strength further decreases. However, it is higher than those obtained without baking of electrodes.

Diffusible Hydrogen Content

The weld metal hydrogen contents are depicted in figure 12 for basic coated electrodes. From the figure, it can be observed that the hydrogen contents in the weld metal decrease with the increase in both the baking temperature and duration. For the electrodes without baking and for baking at 150°C for 1 hour duration, the weld metal hydrogen contents are higher than the permissible limit of 15ml per 100 gm of weld metal by mercury method as per standard. However, beyond 150°C, 1 hour baking conditions the weld metal hydrogen content drops and reaches in the permissible limits. For baking temperatures above 350°C there is no appreciable change in the weld metal hydrogen content.

DISCUSSIONS

The electrodes absorb moisture even if they are kept in the best of storage conditions. The moisture leads to absorption of hydrogen in the weld metal leading to the deterioration of the mechanical properties of the weld metal. The rutile coated electrodes (general purpose elecrtodes) are normally used without baking because of the reason that high quality weldments are not required from these electrodes. But in the case of basic coated electrodes where the weld metal should be of high degree of quality i.e. with minium hydrogen content level, the baking of electrodes is essential to remove the absorbed moisture.

The results show that the baking of the electrodes up to certain degree improves the weld metal properties. However, beyond a certain level of baking, the weld metal characteristics start deteriorating. The probable reasons for deterioration of mechanical properties of weld metal beyond a particular level of baking can be assigned to changes in the coating occurring at higher temperature as well as for longer duration.

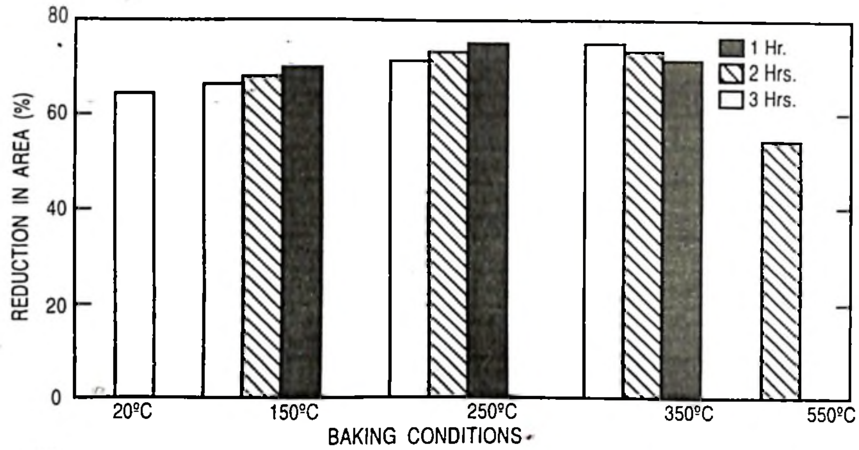

Fig. 9 : Influence of Baking conditions on % reduction in area of basic coated electrode welds.

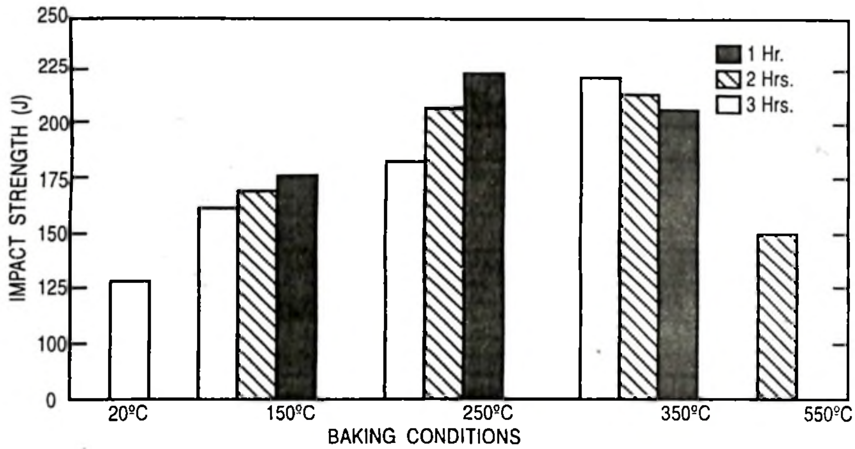

Fig. 10 : Influence of Baking conditions on impact strength at 0°C of basic coated electrode welds.

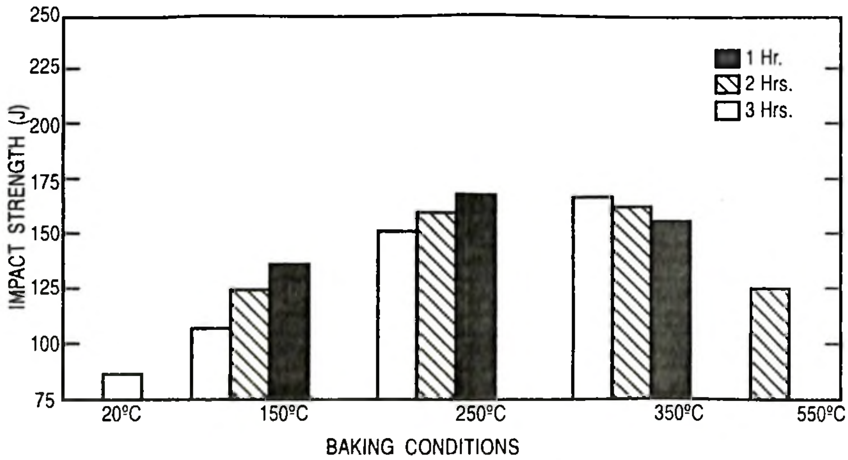

Fig. 11 : Influence of Baking conditions on impact strength at –30°C of basic coated electrode welds.

Perhaps, the following phenomena occur during the baking at above 350°C and for longer baking duration:

(a) The calcium carbonate $CaCO_3$ which is having decompositoin temperature in the range of 600°C may start decomposing at lower temperatures due to the presence of sodium potassium silicate which is normally used as binder. Due to this decomposition of $CaCO_3$ in the coating during baking, sufficient CO_2 may not be produced during welding to protect the arc and molten weld metal from the atmospheric gases and thus leading to poor quality of welds.

(b) As the baking is being carried out in the oven under the atmospheric conditions, the ferro-manganese and ferro-silicon which are added as deoxidisers and are in the form of fine particles in the coating, may get oxidised not only on the outer layers but also to some extent in the inner layers because electrode coating has sufficient porosity. This may reduce the deoxidising power of the electrode coating during welding and may lead to higher oxygen contents in weld metal and thus poor quality of welds.

In the case of rutile coated electrodes, the titanium dioxide and sodium potassium silicate seem to lose bond at elevated temperatures as may not be the case with the calcium compounds. Therefore, the coating starts breaking during baking for longer duration, if the electrodes are baked above 150°C; perhaps due to larger differences in the coefficient of contraction and expansion between the core wire and the coating, it may break at higher temperatures. This may be due to higher titanium dioxide percentage in the coating composition which may be around 50-55%.

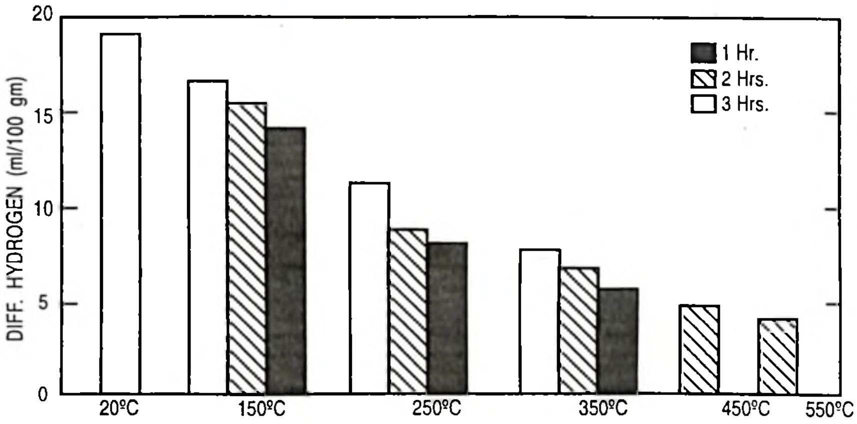

Fig. 12 : Influence of Baking conditions on diffusible hydrogen content of basic coated electrode welds.

Although the hydrogen contents decrease with the increase in the baking temperature and duration, which is very low at 550°C electrode baking, the impact strength of the weld metal is reduced. This may be perhaps because of weld metal oxygen content which increases due to the reason given earlier. However, it needs further investigations to find out the exact reasons for such phenomenon.

CONCLUSIONS

Baking of rutile electrode at 150°C for short duration of 1 hour improves the weld metal characteristics such as ultimate tensile strength, yield strength, % elongation, % reduction in area and Cv notch toughness. However, if baking temperature is increased or baking duration is increased then deterioration in the weld metal characteristic is observed.

For basic coated electrode the baking temperature in the range of 250 to 350°C improves weld metal characteristics. However, lower baking temperature such as 250°C with longer baking duration of 3 hours or for higher baking temperatures of 350°C with shorter duration of 1-2 hours, generally results into better weld metal characteristics except for ultimate tensile strength and yield strength which increase with increase in baking temperature and duration up to 350°C and 3 hours respectively.

At higher baking temperature of 550°C for basic coated electrode, weld metal characteristics, such as ultimate tensile strength, yield strength, % elongation deteriorate and are even lower as compared to the values obtained without baking of electrodes though the notch toughness is found to be higher.

The weld metal diffusible hydrogen content decreases with the increase in baking temperature and duration, but the decrease is nominal beyond 350°C baking temperature.

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