Effects of Excessive Re-drying On the Performance And Properties of Basic Coated Manual Metal Arc Welding Electrodes

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Electrodes in actual practice are more often than not subjected to drying procedures that are widely off from that recommended by the manufacturers. Sometimes they are dried at a lower temperature for a shorter time and sometimes they are over dried or repeatedly re-dried for a longer than recommended period. While, it is common knowledge that the basic purpose of re-drying is the removal of moisture and the detrimental effects of residual moisture are well known, not much is known as to what really happens when electrodes are subjected to higher temperature of re-drying, or longer drying time or both.

A lot of work has been done by the electrode manufacturers in India and abroad to find out the effects of various drying parameters on the performance and properties of electrodes in order to combat the increasing number of complaints from customers on the running and mechanical properties given by electrodes that are not always due to any deficiency on the part of the electrodes but arising out of faulty re-drying procedure adopted by the users.

In this paper, some of the findings on the work done to find out the effects of excessive re-drying of two widely marketed basic coated low hydrogen electrodes are presented with a view to throw some light on the detrimental effects, resulting from excessive re-drying of electrodes.

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Introduction

The electrodes that are exposed to prolonged drying times or excessive drying temperatures may deteriorate and the possible effects of incorrect re-drying procedures are :

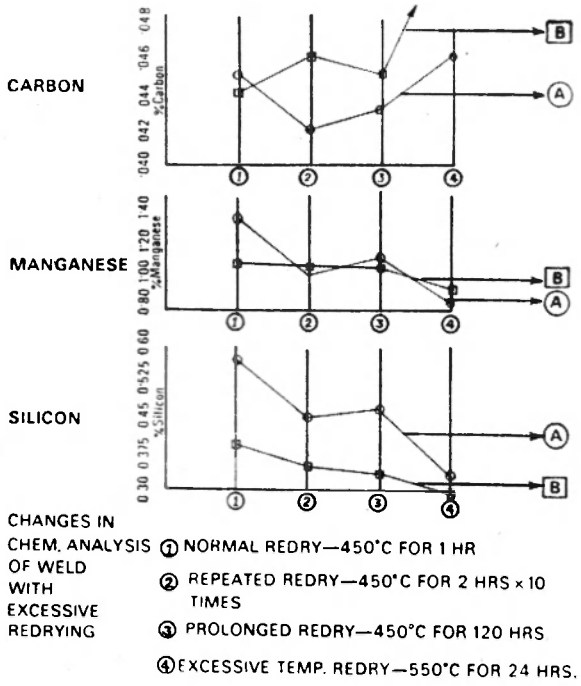
(1) Oxidation of the de-oxidants in the coating.

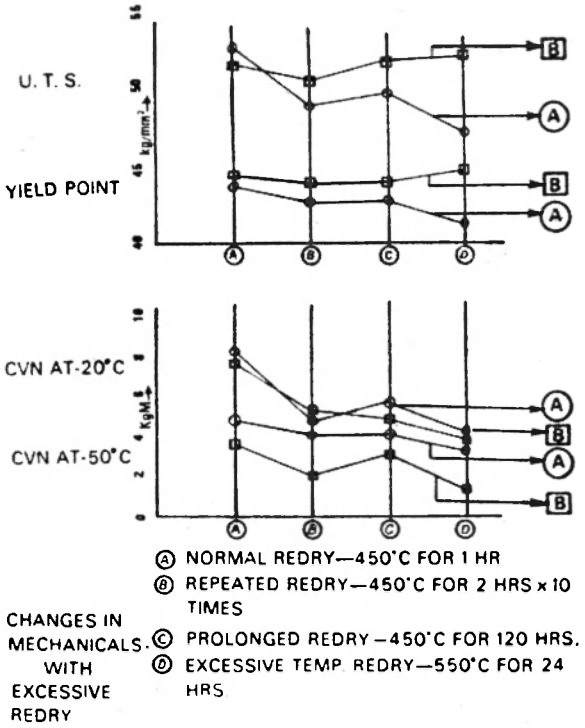
(2) Break down of Carbonates in the coating.

(3) Effects on the Silicate binding system leading to coating fragility.

It is obvious that the tot effect of the above factors would depend on the constituents and composition of the flux coating and would be varying from one brand of electrode to another. However the effects can be expected to be more or less general for the same class of electrodes.

For the present experiment, two brands of electrodes (A & B) were so chosen that they would represent





more or less the basic coated low hydrogen electrodes normally manufactured and marketed. Electrode 'A' was with iron powder and Electrode 'B' was without iron powder in the coating.

Experimental Procedure

3 types of excessive re-drying were carried out, viz :

(1) A re-drying of 450°C for 2 hours repeated ten times. In between, the electrodes were left in open air for 6 hours. The purpose was to study the effect of repeatedly re-drying the electrodes which may often take place in actual practice owing to change in job plans, delay in welding or power failure.

(2) A re-drying of 450°C for 120 hours. The normal re-drying practice for this type of electrodes is 1 hour at 450°C. Such a long period of re-drying was deliberately chosen to ensure that sufficient time is allowed for any deterioration in the electrode to take place so that the same can be observed with some elaboration.

(3) A re-drying at 55°C for 24 hours. An excess of 100°C over the normal drying temperature for a period of 24 hours was chosen so that the effect of accidental or unintentional increase in temperatures of drying ovens can be elaborately studied.

4.0 mm. size was chosen as this was the middle of the various sizes in which the electrodes are produced and also one of the most extensively used sizes.

The electrodes of Brands 'A' and 'B' were placed in a suitable oven where the temperature was preset at the desired level and the electrodes left for drying for the stipulated period.

Drying over, the electrodes were taken out and the following tests were carried out :—

(a) Visual examination of electrodes (Table-1).

(b) Drop tests to study the bond strength of excessively re-dried electrodes and comparison with electrodes re-dried as per recommended normal re-drying process, i.e. at 450°C for 1 hour. (Table-2).

(c) Running performance of electrodes, as compared to normally re-dried electrodes. (Table-3).

(d) All weld metal chemical analysis. (Table-4).

Table—1 : Appearance of Excessive Redried Electrodes

	Redried at 450°C for 1 hr.	Redried at 450°C for 24 hrs. 10 times	Redried at 450°C for 120 hrs.	Redried at 550°C for 24 hrs.
ELECTRODE 'A'	Usual Whitish Grey Appearance	Signs of cracks appearing on the coating surface	A few hairline cracks apearing here and there	Appearance of some cracks although less prominent compared to those appearing on repeated redrying at 450°C
ELECTRODE 'B'	Usual Whitish Grey Appearance	Signs of cracks appearing on the coating surface	No change	Appearance of a few cracks and spots on the surface of coating

(e) All weld metal mechanical properties. (Table-5).

(f) Radiographic soundness of the deposited metal. (Table-6).

Results

The results are presented in the annexed tables, at the end of the paper.

Discussion of Results

(a) *Appearance of Electrodes*

Re-drying at 450°C for 120 hours did not effect any appreciable change in appearance of the electrodes.

However on repeated re-drying at the same temperature, signs of cracks appear on surface of the coating indicating fall in bond strength.

On re-drying at 550°C for 24 hrs. there is not much of cracks appearing ; however some spots appear on the surface.

(b) *Bond Strength*

The drop test results indicate that the electrodes re-dried at 450°C for 2 hours repeated 10 times had the most detrimental effect on the bond strength ; Electrodes re-dried at 550°C for 24 hours was next in order in so far as detrimental effect is concerned. The electrodes redried at 450°C for 120 hours were the least affected.

In general, the phenomenon of deterioration of bond strength can be explained thus : The Mn and Si when oxidized, occupy greater volume than when unoxidized leading to higher compressive strain within the coating which is the cause of fragility.

In the case of repeated re-drying, the repeated expansion and contraction of various bonding materials enhances quick loss of bonding force.

At higher temperatures of 550°C, some change in the binding behavior of silicates perhaps takes place resulting in fragile behavior of coatings.

(c) *Effect on Radiographic Properties*

Due to failure of coating materials after repeatedly re-drying the electrodes at 450°C for 2 hours, the radiographic soundness was affected as shown in Table-6 ; Gross porosities appeared at the starting and re-starting points.

Start porosity was more or less a common factor all the excessively dried electrodes and again this can be attributed to fragility of the coating.

Table—2 : Running Performance of Excessively Redried Electrodes

Brand	Redried at 450°C for 1 hr.	Redried at 450°C for 2 hrs. Repeated 10 times	Redried at 450°C for 120 hrs.	Redried at 550°C for 24 hrs.
'A'	Smooth Arc, Fine Ripples, Good slag action and detachability	Owing to coating fragility the flux coating often comes off particulary during start and restart. Bead appearance not uniform.	No change in nature of deposit. But arc action sluggish and slag cover no longer full with concentration on the lower leg of H.V. fillet.	Arc action very much sluggish and slag detachability impaired.
'B'	Smooth Arc, Fine Ripples, good slag action and detachability.	Same as 'A'. However coating fragility less.	No change in the nature of deposit but slag coverage affected and arc action disturbed.	Arc action disturbed with occasional stoppage. Slag detachability impaired.

(d) *Running Performance*

For the electrodes repeatedly re-dried for 2 hours at 450°C, the arc striking and re-striking was difficult owing to breakage of the coating. The coating actually broke down before melting and hence the slag coverage was not proper and the bead appearance was not uniform.

For electrodes re-dried at 450°C for 120 hours, the slight deterioration in running characteristics was perhaps due to decomposition of $CaCO_3$ ($CaCO_3$—CaO—CO_2) during re-drying. This would result in less effective gas shielding. However gas shielding was perhaps still adequate to present porosities

Table—3. Drop Test Results

In the drop test an electrode is allowed to repeatedly fall from a height of 6 ft. until there is a breakage in the coating. The number of drops required before an electrode breaks is recorded as the drop test result.

6 Nos. of electrodes were tested for each of the Brands 'A' and 'B' and for each drying schedule and the results are recorded in the following table.

The running was found to be further affected with arc action becoming more sluggish and with occasional snapping out of the electrode after re-drying at 550°C for 24 hours. Slag detachbility was impaired which could be due to loss of Mn and Si resulting in an under-de-oxidized weld metal giving rise to this type of problems.

(e) *Effect on Chemical Composition*

The chemical analysis of weld metal of electrodes repeatedly redried at 450°C and the electrodes re-dried at 450°C for 120 hours showed lower levels of Mn and Si compared to the weld metal from electrodes normally re-dried.

This is probably due to the Mn and Si de-oxidants in the coating oxidising to form MnO. and SiO_2. Because of this, there is less "free" Mn and Si available for transfer into the weld deposits.

Electrode "A" lost more Mn and Si than electrode "B". Reasons for this behavior are :—

(1) Initial coating composition of Mn and Si were higher in 'A' as compared to 'B'.

Table—3 : Drop Test Results

Brand	Electrodes redried at 450°C for 1 hr.	Electrodes redried at 450°C for 2 hrs. repeated for 10 times	Electrodes redried at 450°C for 120 hrs.	Electrodes redried at 550°C for 24 hrs.
A	7,6,6,6,8,5 Av=6.33	2,1,3,2,2,2 Av=2	2,3,2,4,2,3 Av=2.66	2,2,1,1,4,5 Av=2.5
B	8,9,6,5,6,6 Av=6.66	2,2,1,2,3,3 Av=2.16	3,3,2,3,4,3 Av=3.00	2,1,3,4,2,3 Av=2.5

(2) Electrode 'B' contained more Fe-Ti as a de-oxidizer which was probably less affected by prolonged re-drying procedures. Hence the recovery of Mn and Si in the weld metal of 'A' was less compared to 'B'.

(3) Electrode 'A' contains iron powder and part of the de-oxidants are used up in de-oxidizing the iron powder present in the coating, thus preventing effective transfer of Mn and Si in the weld metal.

The extent of the loss in Mn and Si can be seen to be much greater when an excessive redry at 550°C is used. This is also not unexpected as at 550°C, the oxidation of these elements is thermodynamically easier.

Another interesting point to be noted is that with 24 hours re-drying at 550°C, there is an increase in carbon content of the weld metal although this phenomenon is absent in the case of 120 hours re-drying at 450°C ; Probably the break down of Calcium Carbonate—a reaction which is accelerated with temperature is responsible for this phenomenon.

Mechanical properties

A slight decrease in mechanical properties resulted from re-drying for 120 hours at 450°C. However the values obtained were still within specification.

Yield point and U.T.S. went down slightly ; However, there was no significant trend in change of Elongation and Reduction of Area values. Average C.V.N. impact values for both A and B was slightly more affected.

All these changes can again be attributed to lower Mn and Si recoveries in the weld deposit the reasons for which have earlier been explained.

Table—4 : Effect of Excessive Redrying on Chemistry of Weld Metal

Redrying Schedule	ELECTRODE 'A'					ELECTRODE 'B'				
	C	Mn	Si	S	P	C	Mn	Si	S	P
450°C for 1 hr.	.045	1.30	0.57	0.016	0.020	.044	1.06	0.40	.016	0.012
450°C for 2 hrs. repeated 10 times.	.042	1.06	0.45	0.020	0.017	.046	1.03	0.35	.020	0.013
450°C for 120 hrs.	.043	1.09	0.47	0.024	0.023	.045	1.04	0.36	.017	0.016
550°C for 24 hrs.	.046	0.84	0.33	0.024	0.025	.061	0.86	0.28	.022	0.019

Table—5 : The Effect of Excessive Redrying on Mechanical Properties

Mechanical	ELECTRODE—'A'				ELECTRODE—'B'			
	Redried at 450°C for 1 hr.	Redried at 450°C for 2 hrs. for 10 times.	Redried at 450°C for 120 hrs.	Redried at 550°C for 24 hrs.	Redried at 450°C for 1 hr.	Redried at 450°C for 2 hrs. repeated 10 times	Redried at 450°C for 120 hrs.	Redried at 550°C for 24 hrs.
Y.P.S. (Kg/mm^2)	43.56	42.60	42.82	41.30	44.37	43.80	44.05	46.00
U.T.S. (Kg/mm^2)	52.30	48.80	49.68	47.18	51.60	50.50	51.75	52.25
E% on 5.65 $\sqrt{A}$	28.0	25.0	26.0	25.5	29.0	25.0	26.5	25.0
RA %	73.5	70.5	72.5	72.0	72.0	70.0	70.5	71.0
CVN Value at —20°C (KgM)	8.8,8.8 8.2	4.8,5.4 5.0	6.0,6.0 5.4	4.4,4.5 4.3	8.6,8.8 8.0	3.8,5.2 5.4	5.1,4.8 4.8	4.2,3.0 5.8
'Do' Average (KgM)	8.6	5.06	5.8	4.4	8.46	4.8	4.9	4.33
CVN Value at —50°C (Kg M)	4.8,4.8 5.1	4.2,4.2 4.5	4.3,4.4 4.6	3.8,3.6 4.0	4.0,3.2 3.8	2.0,2.6 1.4	3.2,2.8 4.0	1.7,1.7 1.0
'Do' Average (KgM)	4.9	4.3	4.43	3.8	3.66	2.0	3.33	1.46

The decrease in mechanical properties was more noticeable in the case of electrodes repeatedly re-dried at 450°C. The Elongation and Reduction of Area Values were also affected and the C.V.N. impact values dropped down to figures just near the minimum specified. The weak bondage of electrode coatings at many places, which caused ineffective shielding and coverage are perhaps responsible for the poorer mechanical properties.

The effect of 24 hours re-drying at 550°C was most marked and are discussed in some detail below :

(1) *Yield Point*

Yield Point values for 'A' and 'B' were some what conflicting. While Yield Point of 'A' dropped slightly, that of 'B' actually increased after re-drying for 24 hours at 550°C. This increase is perhaps due to the loss of Mn and Si being offset by an increase in carbon content In case of 'A' the loss of Mn and Si was too high for the rise in carbon content to effect any increase in the Yield Point.

(2) *U. T. S.*

The effect of excessive re-dry at 550°C on U.T.S. was analogous to the behavior of Yield Point. The beneficial effect of re-drying on B was again due to increase in carbon content.

(3) *Elongation and Reduction of Area*

Neither parameter was altered to any significant extent when the electrodes were re-dried at 24 hrs.

(4) *Charpy Impact Value*

The C. V. N. impact values at—20°C dropped for both the brands and fell slightly below the specified range. The effect was more pronounced on the C.V.N. impact values at —50°C, and brand 'B' was more severely affected than brand 'A'. However none of the brands were designed for notch toughness at —50°C.

Table—6 : Effect of Excessive Redrying on the Radiographic Soundness of Weld Metal

Redrying Schedule	ELECTRODE 'A'	ELECTRODE 'B'
450°C for 1 hr.	No defect	No defect
450°C for 2 hrs. Repeated 10 times	A cluster of porosities at start and restart.	Porosities at start and restart, Some isolated inclusion.
450°C for 120 hrs.	2 fine inclusions near the centre of the weld.	Start and crater poroties. One group of restart pores and one isolated inclusion.
550°C for 24 hrs.	2 groups of restart prosities and one fine linear inclusion.	A group of restart defects and undercuts along the sides of the weld.

The increased carbon content of electrodes re-dried at 550°C for 24 hours which had some beneficial effect on Yield Point and U.T.S. values had the reverse effect on impact values. When carbon increases the strength of a metal, it does so at the expense of toughness. The notch ductility is therefore lowered. Carbon pick-up being more for 'B', the fall in notch ductility was more abrupt.

Conclusion

Coating fragility is one of the most adverse effects of excessive re-drying (especially, repeated re-drying) and there are also detriments in chemical composition and mechanical properties. Notch ductility of weldments at sub-zero temperature is the worst affected property. The overall effect has been projected in the annexed graphs.

Generally speaking, the harmful effect of excessive re-dry is more pronounced when the specified re-drying temperature is exceeded or repeated re-drying 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 re-drying procedure and departure from this practice is not a wise proposition.