Indian Stainless Steel Electrodes —Progress and Problems in their Manufacture and Use

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It is an acknowledged fact today that commendable progress has been made by indigenous electrode manufacturers almost continuously over the past sixteen years in the manufacture of stainless steel electrodes as also in a remarkably wide range covering numerous categories. As a result, only a very small portion of the country's needs has to be met through imports. Even this quantum is being progressively reduced with introduction of appropriate indigenous brands. In a way, this rapid progress towards self sufficiency represents a high degree of co-operation between electrode manufacturers and fabricators ; the former accepting the challenge of developing new types required by the latter ; and the latter, many a time, finding that the special type is already available with one or other electrode manufacturer and going ahead confidently to quote for the fabrication contract.

Range of Indian Stainless Steel Electrodes :

Before proceeding further, let us see what different indigenous stainless steel types are presently available in India in terms of the most widely accepted and used Standard Specification, viz : AWS A 5.4 :

E 308-16	E 309-16	E 310-16
E 308-15	E 309-15	E 310-15
E 308 L-16	E 309 L-16	E 310-Mo-16
E 308 L-15	E 309 L-15	E 310-Mo-Cb-16
E 347-16	E 309 Cb-16	E 312-16
E 347-15	E 309 Cb-15	E 312-15

E 316-16	E 309-Mo-16	E 410-16
E 316-15	E 309-Mo-15	E 410-15
E 316 L-16	E 309-Mo-Cb-16	E 430-16
E 316 L-15	E 309-Mo-Cb-15	E 430-15
E 317-16		
E 318-16		
E 318-15		
E 318-16 Elc		

A few others not covered by AWS Specification are for welding of :

(a) HV- & HV-9A Stainless Steels ;

(b) Carpenter-20 Stainless Steel ;

& (c) Armour Steel.

Several other special compositions can be made available at short notice, some of these being.

(a) a type containing 3-4% Si ;

(b) Nitrogen-bearing Stainless Steel.

Basic-coated Stainless Steel Electrodes :

Development, standardisation and application of basic-coated stainless steel electrodes, starting with the type E 308L-15, represent an important mile-stone in the progress towards self-sufficiency. E 308L-15 electrode have been approved by the Power Projects Engineering Division after rigorous testing. Furthermore, this class of electrodes have been used successfully in

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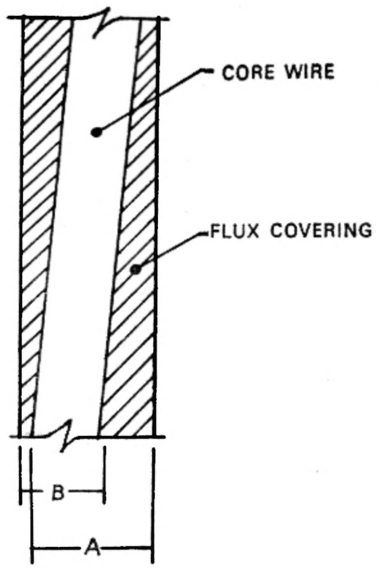
nuclear fabrication during the past one year. Electrodes manufacturers' accomplishment in this field is of tremendous significance for two reasons :

(1) The Atomic Energy Department does not have to depend on import of basic-coated stainless steel electrodes ;

(2) It has already saved a considerable amount of foreign exchange and will continue to save a few million rupees worth of foreign exchange in the next 5 years.

Due credit has to be given to the PPED for their progressive outlook in trying out indigenous materials. But for their whole-hearted co-operation, electrode manufacturers would not have had a chance to prove their capacity to meet the stringent specification of PPED. Electrode manufacturers have reason to feel proud of the contribution they had made in this field.



$A - B \ngtr \frac{3}{100}\left(\frac{A+B}{2}\right)$ for MI XXXXX electrodes

A = Core-plus-one maximum covering dimensions

B = Core-plus-one minimum covering dimension

Fig. 1. Permissible tolerance for flux covering.

Synthetic Stainless Steel Electrodes

Time to time there has been reference to the limitations of synthetic stainless steel electrodes. It will not be correct to say that limitations of such electrodes have not been made known to users. The advantages as well as disadvantages of synthetic stainless steel electrodes were explained by me at a great length in the paper read at the Welding Seminar held in Bombay on the 2nd and 3rd February this year. I would like to repeat from that paper the relevant points :

Advantages of Synthetic Electrodes

In comparing the synthetic stainless steel electrodes with the corresponding non-synthetic electrodes, the former offer the following advantages :

(a) The electrical resistance of the unalloyed steel core wire is much lower and this permits use of upto 40% higher welding currents, with the result that substantially higher deposition rates can be achieved.

(b) On account of the capacity for higher currents, electrodes can be manufactured in longer length i.e., 450 mm length, as against 350 mm length.

(c) Some of the operating characteristics are superb, e.g., arc stability, ease of arc re-striking, de-slagging, bead shape and appearance.

Disadvantages of Synthetic Types

Some of the inherent disadvantages are :

(a) The heavy and thick covering imposes limitation on use in positional welding, except for the smaller diameter electrodes.

(b) All the alloying elements are derived from the covering. These metal powders melt along with other ingredients of the covering and get transferred to the weld pool as the core wire melts. Thus, the regularity of the fusion of covering in relation to the core wire is absolutely necessary for obtaining the intended weld metal chemical composition in terms of Cr, Ni, Mo, Mn. In other words, uniform fusion of the core wire and the covering is of prime importance and this calls for extra care on the part of welder. This applies particularly in restriking of the arc of a partially used electrode. If in restriking, even a small piece of the covering drops off, it will disturb the ratio of covering to core wire and thereby the chemical composition of the weld metal at that spot. See Fig 2.

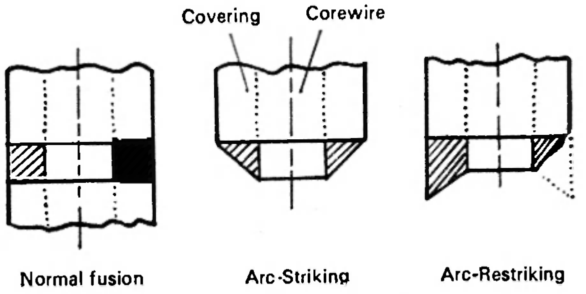


Fig. 2. Volumetric Proportion of core wire and covering of electrode.

Another noteworthy feature is the fairly wide scatter in the contents of alloying elements, especially Cr & Mn. This scatter is more pronounced along the middle of the bead than at the edges. (See Fig. 3) The Huey Test reveals the relatively lower corrosion resistance of the middle portion of the bead surface than at the edges.

In spite of these limitations, the synthetic types are widely used because these limitations become secondary in importance in several applications involving (1) build-up of large cross-section, (2) joining austenitic stainless steel tc carbon steel, in both of which corrosion resistance is not of primary importance.

While on the subject I wish to add that two factors contributed to the fairly wide acceptance of such synthetic electrodes over the past 16 years.

(a) Lower cost per 1000 pieces, as compared to that of non-synthetic types ; in terms of kg of weld metal the cost factor becomes even more favourable as a result of the higher metal recovery ;

(b) Import Policy of the Government of India which rendered it easier to import metal and ferro-alloy powders, such as Ni, Cr, Fe-Cr & Fe-Mo, than stainless steel core wire, during several years. Hence, electrode manufacturer could increase the output of stainless steel electrodes only in the category of synthetic types. Similarly, users had to accept such types for applications wherein they could be considered safe. Many of you will perhaps recall the serious shortage of non-synthetic stainless steel electrodes as late as in 1971, which was caused by grossly insufficient imports of core wire.

Quality Control for Concentricity

A check of concentricity of coating with respect to the core wire is an essential part of the quality control system prevailing in any electrode factory. Importance of preventing eccentricity in coating is known too well to need elaboration here and every electrode manufacturer strives to ensure it. IS-5206-1969, i.e. "Specification for Corrosion-resisting Chromium and chromium-Nickel Steel covered electrodes for Manual

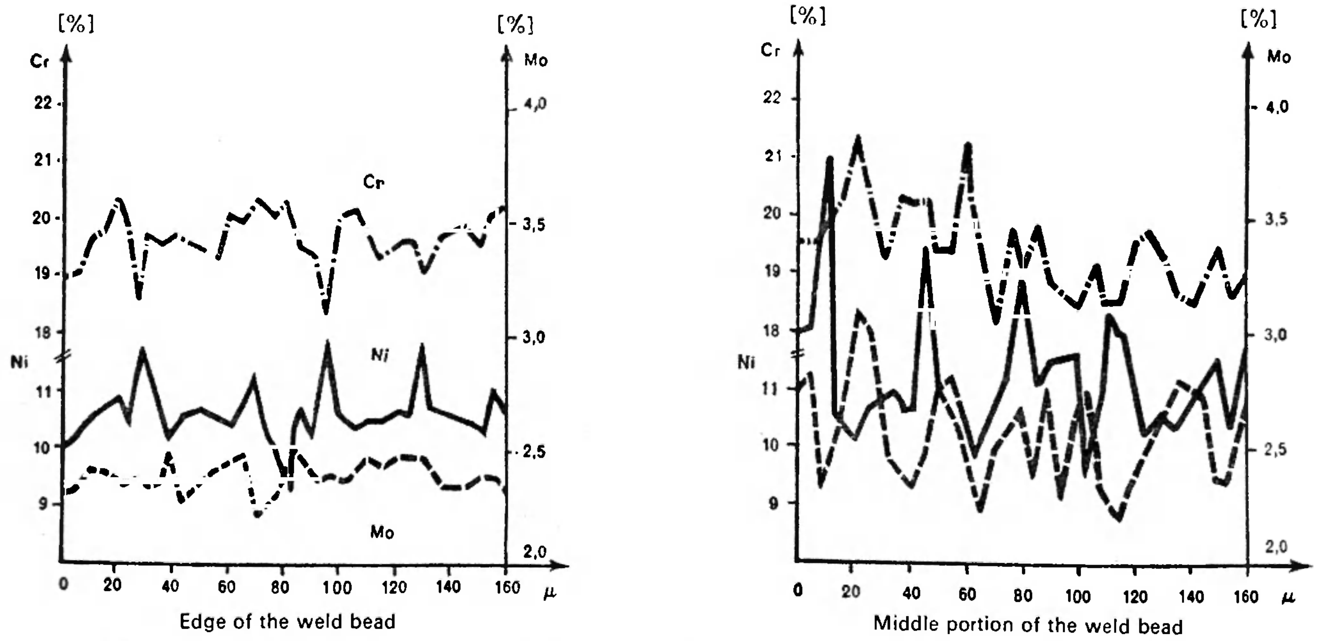


Fig. 3. Distribution of Cr, Ni, and Mo in the weld bead of a synthetic Stainless Steel Electrode.

Metal Arc Welding" lays down the limits for eccentricity. It states :

"The covering shall be uniform in outside diameter and in thickness. The tolerance permitted for uniformity of covering shall be such that the maximum core plus one covering dimension (see Fig-1) shall not exceed the minimum core plus one covering dimension by more than three percent of the mean of two dimensions".

However, it has to be admitted that in a mass-produced article, such as electrode, the possibility of a few pieces with eccentric coating escaping detection cannot be ruled out. In spite of the best quality control measures, such a thing might happen but very seldom. This is a problem which exists in all countries, including those which supply some special electrodes to India from time to time, But when this is detected on the shop floor, the Indian fabric ator seems to display a special tolerance, either out of courtesy for the foreign electrode manufacturer or as a matter of habit. After all, over several decades, we have learnt to accept anything foreign as superior. How can a foreign electrode be eccentric ? May be, the fault lies with the welder who has not handled the electrodes with extra care and attention which should be bestowed on a foreign product, which has been purchased with the country's limited and hence precious foreign exchange. As an electrode manufacturer, I, for one, do not mind such an attitude because it acts as a tonic, bitter though, for achieving improvements. Assuming that eccentric Indian electrodes have been supplied, whether to a large fabricator or a small road-side repair shop, the welder will be quick in complaining about the uneven burning. If he has no alternative but to use the lot of electrode at a given time, he will exercise due care in selection of electrodes from the lot or else in handling the eccentric electrodes to minimise the adverse effect on the welded joints. Practically, in every such case, the complaint, will reach the electrode manufacturers or the nearest office or representative. The major producers of electrodes in this country do have a net-work of not only dealers, but also technical representatives who, more often than not, attend to such complaints promptly and effectively.

Quality Control in Fabrication

No quality control system for stainless steel electrode manufacture can even be thought of without well-equipped chemical, physical and metallurgical laboratories. But then, does not the same hold good in fabrication of sophisticated stainless steel, or for that matter low-alloy steel, equipment ? May I ask how many reputed fabricators boasting of an annual turnover of several crores of rupees and handling some of the most complicated and difficult welded fabrication can boast, with equal pride, about their own testing facilities ? I would say the credit is all the greater that they are capable of turning out such top class equipment meeting the most strigent specification, such as those of the PPED. The major part of the credit should go to their welding and inspection personnel who are doing an excellent job. A small part of the credit should undoubtedly be reserved for the Indian stainless Steel electrodes, as also other types, especially those E 7018 Class which can match the finest available anywhere in the world.

It would be pertinent to point out here that in the absence of adequate testing facilities, the Indian electrodes become the first target of attack in the event of a problem/failure during fabrication. There have been instances wherein electrode manufacturers have had to suffer nightmares arising out of the blame placed on their electrodes for serious failures during fabrication or in service. It is only after prolonged and detailed investigations that the fault has been traced to the parent material—higher carbon content, segregation or laminations. The question then is why in the first place the plate material was not examined for any defect or deviation from the specification. The obvious answer is how such testing could have been carried out in the absence of testing facilities within the works. Facilities may be available outside, but they are limited and are time-consuming and very often the fabricator is hard pressed by clients to deliver the goods expeditiously.

What I have stated earlier with regard to imported electrodes also applies to imported base materials. There is a pronounced tendency to accept at a face-value the Test Certificates of foreign supplies and some of the fabricators, in spite of having well-equipped laboratories, do not consider it necessary to carry out quality checks, in some cases at least. Naturally, then it is found expedient and convenient to blame Indian electrodes, if any problem arises. This is where Indian electrode manufacturers feel the need for a change in the approach of fabricators ; a better degree of co-operation and a deeper understanding of the electrode manufacturers' problems.

Specification Limits :

Every fabricator likes to use the tolerance limits of his client's specification to maximum advantage.

This is perfectly in order. Will it then be fair to deny the same right to electrode manufacturers, when electrodes are indented as per any Standard specification ? Take for instance the AWS 5.4, which is one most widely used in the country. Following are the limits for chemical analysis of E 318, E 316L and E 308L as per AWS 5.4 :

	E 318 (%)	E 316 L (%)	E 308 L (%)
Carbon	0.08	0.04	0.04
Manganese	2.5	2.5	2.5
Silicon	0.90	0.90	0.90
Chromium	17.0-20.0	17.0-20.0	18.0-21.0
Nickel	17.0-14.0	11.0-14.0	9.0-11.0
Molybdenum	2.0-2.5	2.0-2.5	—

How many Indian fabricators have till this day drawn up their own specification based on experience and realistic job assessment ? The tendency is to adopt AWS Specification somewhat blindly, if I may say so. It is for the fabricator to indicate narrower range in respect of chemical analysis of the important elements, if he desires so. Once such a specification is drawn up by a fabricator and accepted by electrode manufacturer, the former has a right to demand adheıance to the limites.

Progress in welding technology has been so rapid that welding standards do lag behind and thereby act as a hindrance to prompt and full utilisation of results of research and practical experience. A typical example of this is the upper limit of 2.5% fixed for Mn content in the Classification E 310 of SF A 5.4 of ASME Section II C. Beneficial effect of 5-5% Mn in preventing hot cracks in welds of 310 Grade has been well established. And yet, the SFA 5.4 imposes a limit on Mn content which compels us to ignore the advantage of higher Mn content. On the other hand, the German Standard Din 8556 does not mention any limits, lower or upper, for Mn, thereby leaving the electrode manufacturers free to develop and market types possessing superior mechanical properties derived through a relatively high level of Mn. (see table 1) Both electrode manufacturers and fabricators in this country are helpless because the inspection agency will go strictly as per the ASME Code once the client stipulates adherance to this code. This is therefore an issue which can only be tackled over a period of time through a co-ordinated effort by electrode manufacturers, fabricators, inspection agencies, the Indian Standards Institution and, above all, the Indian Institute of Welding, which can bring all parties together with a definite objective of rationalising the standards and, if necessary, improving upon foreign standards, instead of simply adopting them and thereby absorbing the limitations.

Table 1

Comparison of specifications for chemical composition (%) as per AWS and DIN standards.

Classification	C	Mn	Si	Cr	Ni	Mo
AWSE 308L	0.04 max	2.5 max	0.90max	18-21	9-11	—
DIN 199 nc	0.04 max	—	—	17-20	8-11	—
AWSE 316L	0.04 max	2.5 max	0.90max	17-20	11-14	2.0-2.5
DIN 1992 nc	0.04 maz	—	—	17-20	9-12	2.0-2.5

Ferrite Content :

The subject of 'Ferrite Content' is quite a hot topic of discussion between electrode manufacturer and fabricator. It is but natural that with the increasing sophistication in welded fabrication, the ferrite in austenitic stainless steel has made its importance felt and has been receiving due attention. In fact it can, and should, form the subject matter of a separate paper. (I intend reading such a paper at a Technical Meeting of Bombay Chapter of IIW during next year).

Range of Ferrite Content :

What I have stated earlier about the specification limits for chemical Analysis also holds good for ferrite content. While both are closely related, it is necessary that the fabricator lays down definite limits, lower and upper, of ferrite content in weld deposit of electrodes. Such a specification for ferrite content enables the Fabricator to obtain electrodes with a narrower range of chemical composition. But, here again the fabricator tends to be somewhat vague. Following are typical examples of such specification laid down by fabricators :

(1) "E 308L Electrode for Nuclear Applications ; Ferrite content should be 6 to 8% min".

What then is the lower limit? Should it be 6% or 8% ? How about the upper limit ? Is it not necessary to make it clear ?

(2) "E316L Electrode"

Upper limit of 5% is prescribed only after electrodes have been specially manufactured and delivered.

Obviously, the normal ferrite content for E 316L would be higher than 5% and unless the electrode manufacturer is informed in advance how would he think of restricting ferrite content below 5%. Thus, those electrode manufacturers who are willing to accept new challenges for satisfying fabricator, even at a loss find themselves in an unenviable position and find such efforts unrewarding. My plea to fabricators is to be sure of what they want before asking electrode manufacture to go ahead with any new type.

Measurement of Ferrite Content :

The next point relates to measurement of ferrite in weld metal. This again is an issue which has been debated and discussed at great length in the meetings of International Institute of Welding. The effect as well as measurement of ferrite have been the subjects of numerous article and research papers which have appeared in foreign welding journals. It has been clearly established that different values of ferrite will be arrived at, depending on the method used for its determination even on the same specimen of weld deposit. This situation is further aggravated by the effect of a number of variables during welding. Therefore, without going into further details of this issue in this paper, it can be surmised that the results obtained in the laboratories of an electrode manufacturer and a fabricator with the same batch of electrodes may differ and give rise to disputes between the two. This being a clear possibility, it is not enough if electrode manufacturers equip themselves with the necessary testing instruments. It is as much important that fabricators also have the same testing facility. Moreover, for the purpose of obtaining uniform results and thereby avoiding disputes, both should have the same types of testing instruments. I am sure that the leading electrode manufacturers in this country have either already acquired the testing instruments of one or other type, or have made necessary arrangements for importing the same. What is noteworthy however is that both electrode manufacturer and fabricator should mutually arrive at an understanding as to :

(a) instruments to be used for determining ferrite :

(b) standard welding conditions for preparing the the test deposits ;

as otherwise long drawn-out disputes may arise as to the findings and vitiate the very atmosphere of co-operation and cordiality which we are trying to creat through today's discussions.

Stainless Steel Electrodes for Cryogenic Applications :

Three fabricators in India have already embarked on programme of fabricating cryogenic vessels of stainless steel requiring testing of welds for impact values at temperatures down to Minus 196°C. Appropriate electrodes for these applications as well as data on impact values of welds are already available with one or two indigenous electrode manufacturers. Some of these types have been thoroughly tested and approved and before long these approved brands will be put into use on large scale. It will not be out of place to mention here that such electrodes were ready much before the fabricators had started examining the relevant specifications for cryogenic vessels. The data on impact values at Minus 196°C for these brands was also available with the manufacturers and was promptly furnished to the fabricators who have enquired about availability of suitable electrodes. This therefore gives an indication of the far-sighted and long-term research & development programme undertaken by some of the indigenous electrode manufacturers. It also shows that some fabricators do know whom to approach for such special electrodes and thereby save considerable time and make their own task somewhat easier. A few others probably do not approach the right people and, having been disappointed, shift the blame on to the electrode manufacturers. The Research & Development programme of some of the leading electrode manufacturers has advanced at such a pace and to such a stage that these manufacturers are in a position to say to Indian fabricators 'ASK AND YOU SHALL RECEIVE'

Conclusion :

It will be readily conceded by all those associated with the welding industry that the leading electrode manufacturers have made a very substantial contribution in propagating knowledge of welding technology in this country, especially at a time when the standard of knowledge and experience available with the Indian fabricators could not be termed as high. electrode manufacturers did play a dominant role in creating quality consciousness among the fabricators. The technological gap referred to by Mr. Prabhakar can be attributed to the different rates of progress achieved by electrode manufacturers and fabricators at different times during the past fifteen years. This gap can be fully covered and the welding industry can make more rapid strides for meeting the challenges of our times only through a joint effort by understanding each other's problems and by giving due recognition to each other's contribution.