STATUS ON CO_2 WELDING CONSUMABLES IN INDIA

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INTRODUCTION

Liberalisation of Indian economy has suddenly exposed industry to increased competition. To survive in the global market, the companies must look for more productive means of achieving the targets. Though CO_2 welding process had gained much popularity all over the world, Indian industries are still sceptic about the process due to various reasons. To compete with the global leaders, efforts are required from Indian industries at all levels to maximise the benefits of the higher productive processes.

This article gives some idea about the recent developments that are taking place all over the world in the field of CO_2 welding consumables and the present status of the consumables in the Indian context.

International Scenario on Consumables

A requirement of 70,000 T weld metal was estimated for 1989-90. In this, the share of CO_2 was estimated to be approximately 10%. The share of other processes was estimated to be around 82% by SMAW, 7% by SAW and 1% by GTAW. But the present status (Fig.1) indicates that the share of CO_2 process is well below the target value.

In order to have global perspective let us look at the pattern in few other countries.

1) It can be seen that the share of solid & cored wire consumption has been increasing steadily.

2) Welding with covered electrodes is on the decline in the industrialised countries. In Japan and Europe, the consumption of covered electrodes has fallen to half of all the cunsumables that are used.

   In developing countries like China & Korea, the percentage of covered electrodes is as high as 75% while CO_2 welding process accounts for 15%.

3) The proportion of welding using covered electrodes will stabilize at a level of 30% during the coming decade.

4) MIG/MAG welding using homogeneous wire and tubular wire is increasing, especially in the industrialised nations and it often accounts for 50% of the total consumption.

Thus even though few select industries in India have turned to CO_2 in a big way, over all, on an all India basis, share of the process is still insignificant, in comparison to that attained in developed countries.

One of the fabricators in India presently deposits 5% weld metal by CO_2 process. In the rest, 56% by SAW and 36% by SMAW. The figures 3 years back were 3% by CO_2 process, 22% by SAW and 72% by SMAW (Fig 2).

In one of the leading Earth Moving fabricator, 88.5% of CO_2 welding used with 9.9% SMAW and 1.6% SAW.

Developments in CO_2 welding consumables

Consumables for MIG/MAG Welding

There are several types of consumables available for MIG/MAG Welding. Based on the wire and gas combination, the process is categorised into three groups (Fig 3) and are listed below

a. Solid Wire
b. Gas shielded cored wire
c. Self shielded cored wire

Solid Wires

Solid wires are always used with an externally supplied shielding gases like Ar/CO_2/He and mixtures of Ar/CO_2/He/O_2 etc. Solid wires are available for various materials like carbon steel, low alloy steel & stainless steel and in diameters ranging from 0.8 mm to 2.4 mm. AWS classification for C-Mn steels and low alloy steels is given in Table No. 1

Production of solid wire

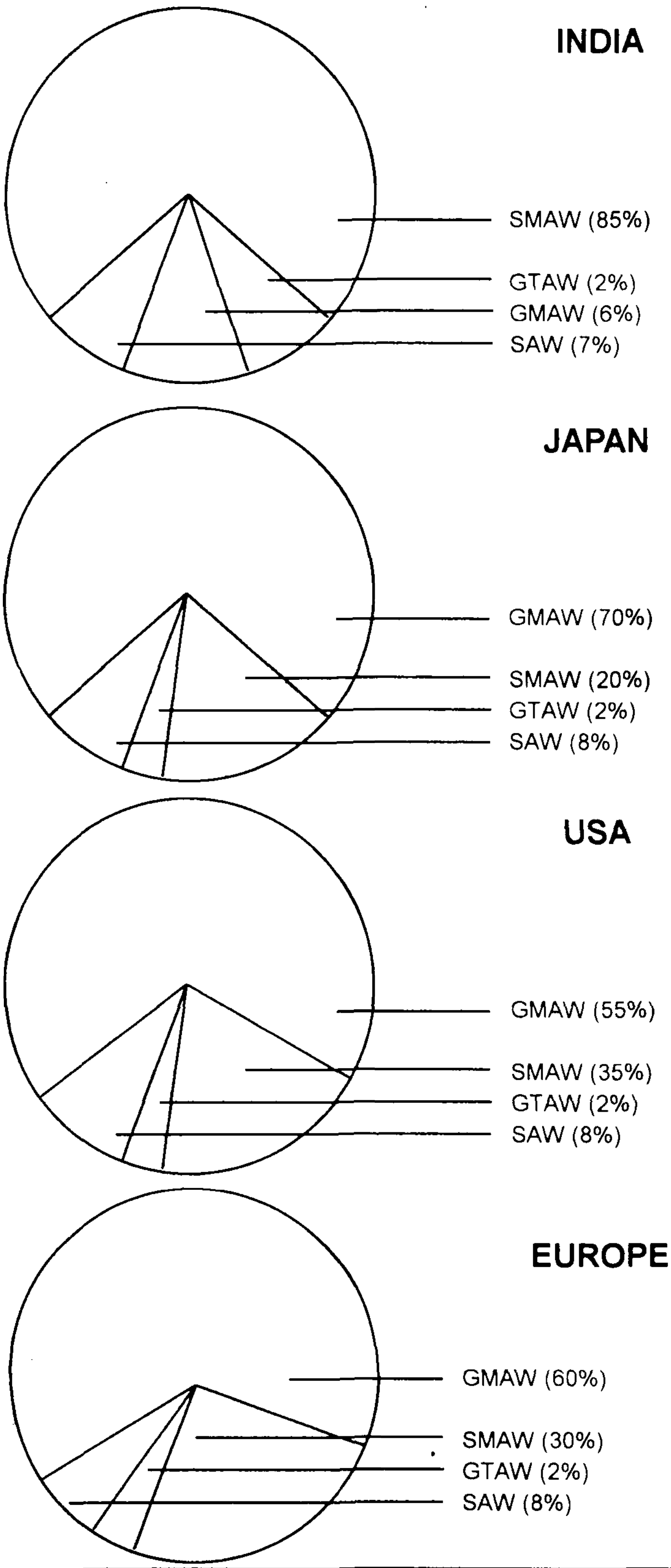
Solid wire is drawn from rod, tempered and copper coated followed by winding on the spool.

Gas shielded cored wire

Gas shielded cored wires can be divided into the following sub groups. The AWS classification of these wires is given in Table No.2

1. Rutile
2. Basic
3. Metal Powder cored wire

Fig 1 : Process share of weld metal for various countries



Rutile cored wires

During 1950's amd 60's, smallest diameters commercially produced were 2.0 mm and 2.4 mm. These wires were limited to flat and horizontal welding. These wires used an acidic slag system which provided good arc stability and weld appearance with deep penetration but produced somewhat limited low temperature impact properties. Over the following years, there has been a move towards smaller diameters such as 1.2 and 1.4 mm and this has improved the level of impact strength as well as making it possible to weld in vertical position. The reason for this is the general tendency not only in the case of cored wire welding but also for welding processes to reduce the heat input (Ref.1)

Basic Cored Wire

Despite considerable improvements in the impact strength as a result of the new types of micro alloyed rutile cored wire, the highest impact strength level can be most safely obtained by using a basic slag system. The high level of impact strength is still maintained even if subsequent heat treatment is required since the microstructure does not change. These are characterized as E 70T5 according to AWS specification.

Cored Wire filled with Metal Powder

This type of cored wire is characterized by the fact that it contains metal powder and has virtually no slag forming elements. The use of this type of cored wire is growing to a marked degree. Cored wire filled with metal powder is being developed for welding with mixed gases of 80% Ar + 20% CO_2 type. Cored wire filled with metal powder is ideally suited to fully mechanised welding since it does not form any slag (Ref.2)

Fig 2 : Process share of weld metal for a fabricator in India

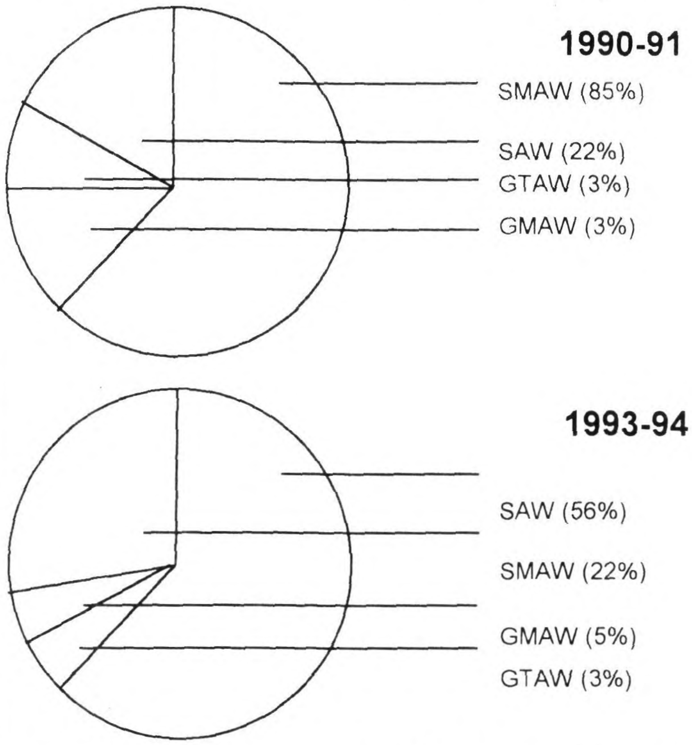
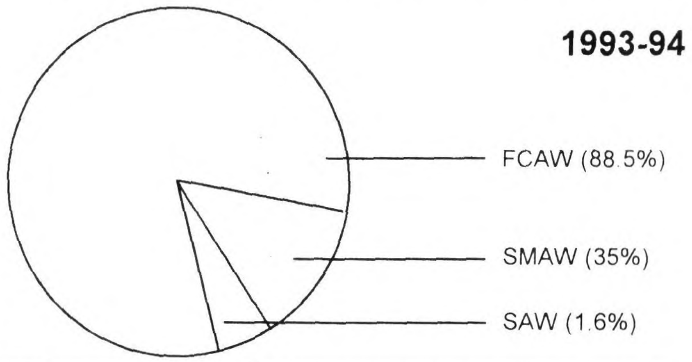


Fig 2(a) : Process share of weld metal for a fabricator in India



Self Shielding Cored Wire

In self shielded flux cored wires, the flux provides sufficient sheilding to protect the moltenmetal droplets from atmospheric contamination This normally contains a basic slag system but also features powerful oxide and nitride forming elements such as aluminium and magnesium In addition to its shielding action, the flux also helps in arc stabilisation (Ref 3)

Production of flux cored wire

The consumable used in FCAW is however, of tubular construction and contains a core of metal powder of flux as shown in Fig 4, Shielding of the arc may be provided by gases generated by the decomposition of the flux, but in many cases an additional shielding gas is provided in the same manner as that for GMAW

The most common production technique used to produce the wire involves folding a thin meal strip into a 'U' shape, filling it with flux/metal powder constituents, closing the 'U' to form a circular section and reducing the diameter of the tube by drawing or rolling The seam is closed during the reduction process The process is illustrated schematically in Fig. 5 (Ref 4).

Alternative configurations shown diagrammtically in Fig.6 may be produced by lapping or folding the strip or a seamless consumable may be made by filling a tube with flux followed by a drawing operation to reduce the diameter The recent development in the flux cored wire is shown in Fig. 7

In this method, the wire is double folded type (having two layer structure) flux core wire, containing the metallic flux such as deoxidisers, alloys and arc stabilisers in the inner layer and oxide and fluoride type flux in the outer layer to produce excellent arc stability and mechanical properties (Ref. 5).

Sizes of filler wire for carbon steel and low alloy steels

Various sizes of cored wires that are available 1.2, 1.4, 1.6, 2.4, 3.2 mm In 1984, a ultra small, 0.9 mm diameter mild steel flux cored wire was developed

Cored Wires for Stainless Steel

Ten Years ago 2.4 mm was the most widely used size of cored wire and many stainless steel types were not available. Recent years have seen rapid growth of small diameter stainless tubular wires ranging from 1.0 mm to 1.6 mm

Cored Wires for hard facing alloys

Solid as well as cored wires available for many hard facing applica-

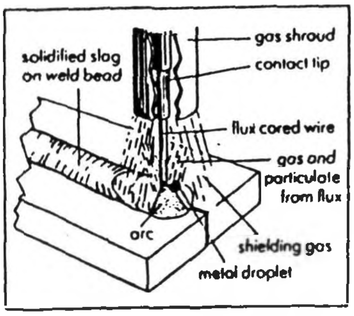


Fig 3 Flux cored arc welding-principle of operation

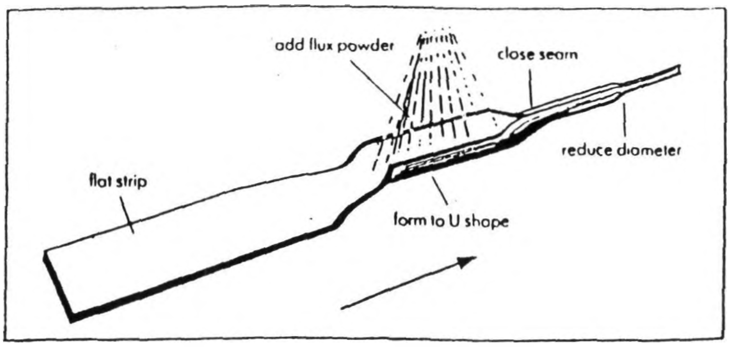


Fig 5 Flux cored wire production

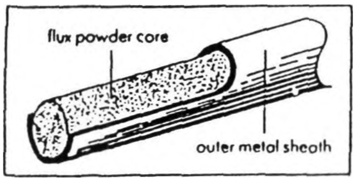


Fig 4 : Flux cored wire construction

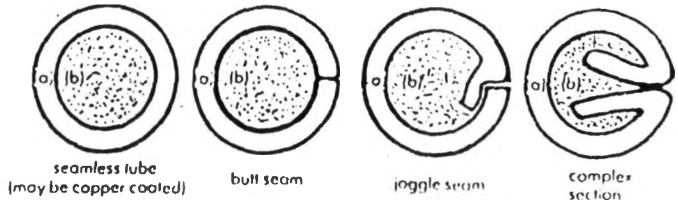


Fig 6 Flux cored wire configurations (a) = outer sheets. (b) = flux powder.

tions. They are basically Fe based, Ni based, Cobalt based alloys. Various diameters are available in the range 1.2 mm to 2.8 mm (Ref. 6).

Properties of CO_2 welding

Though deposition efficiency of CO_2 is more, due to various problems encountered, the process has not picked up. Gas shielded flux cored wires are often easier to use than the solid wire GMAW process, but certain differences exist in operating technique. The sensitivity of these consumables to stick out has been observed. The General properties of solid/cored wires are given in Table No. 3.

Status of filler Wires

In India both solid and flux cored wires are manufactured.

Solid wires

There are about 10 or more companies who manufacture carbon steel solid Wires. The consumption of the solid wires is about 5000 tonnes/year. Solid wires for welding C-Mn steels are freely available in the country and some manufacturers have also set up high speed continuous drawing and copper coating plants. Availability of low alloy steel wires are limited (Ref.7). ER 70S-2, ER 70S-6 type filler wires are being manufactured in India.

It is predicted that by 1995, the demand for solid wires would be around 7500 T per annum & by turn of century, 9000T per annum assuming a simple 5% growth rate (Fig. 8).

Flux Cored Wires

The present demand for FCAW wires is around 2000 T/annum. There are about 5 companies who manufacture flux cored wires for joining and hard-facing purpose in India. The popularity of flux cored wires over solid wires is due to more consistent X-ray quality of weld, better bead finish, reduced weld spatter and over all better welder appeal. The consumable manufacturers have the advantage that the flux cored wire can be tailor made to match any base material composition. This is achieved by adjusting the flux constituents. Wire can be produced in small volumes without dependence on steel maker and the rolling mill. The present capacity of flux cored wire is 400 T/year for joining processes and 800 tonnes / year for hard facing applications.

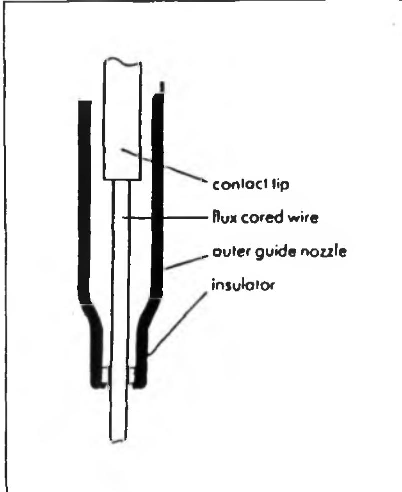


Fig 7 Wire extension support (self shielded FCAW)

About 400 - 500 tonnes are still being imported for joining processes. The demand for these wires by 1995 is 2000 Tonnes and by the end of century, it would be 3000-4000 T per annum assuming 10% growth rate (Fig. 9).

Wire winding techniques

As regards winding, layer winding is adopted by a number of suppliers of wires. Layer winding is preferred as it offers trouble free, smooth, wire feeding. Most of the suppliers supply wires in card board spools, while imported wires are normally wound on plastic or metal basket type spools. In Japan, some developments were taking place in winding of spools. One manufacturer is using 'Ayamaki' type (Fig. 10) wound spools which are stated to help in improvement in feeding and also reduction of operator fatigue with improved electrical conductivity (Ref 8)

The Spools normally available from the suppliers are 300 mm dia size and the weight of the spool is around 12.5 Kg. Since the CO_2 welding presently is employed in the semi-automatic mode, there is a great demand for this size of the spools. However, if the industries go in for mechanised CO_2 welding then there will be a need for large size spools of 200 Kg, with self dispensing arrangement.

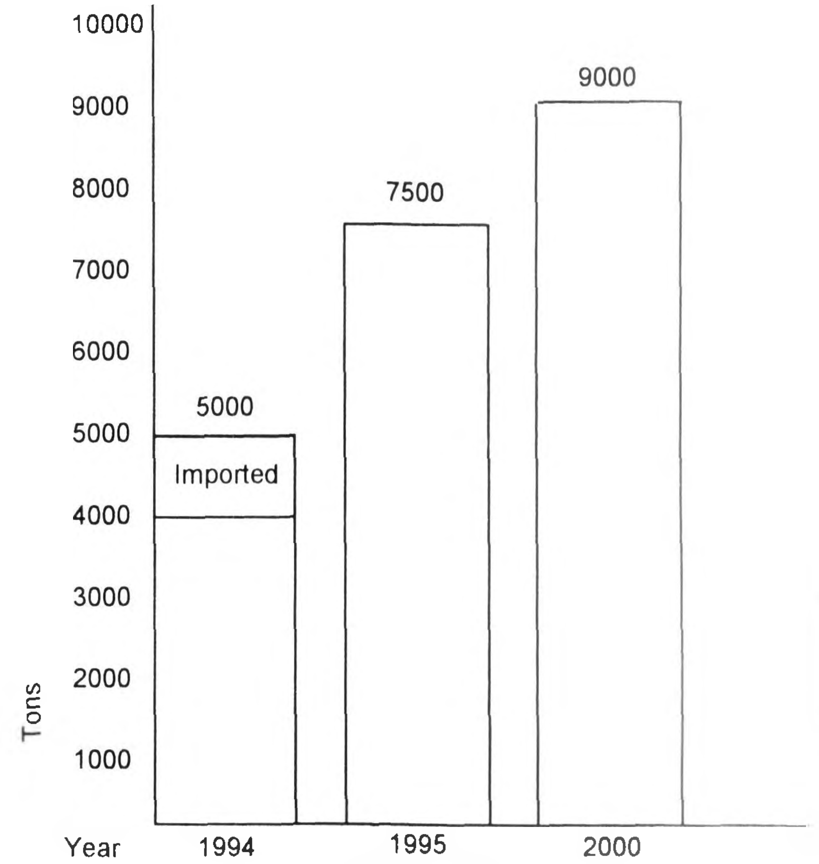


Fig 8 : Solid Wires

Shielding Gases

In GMAW, the process component which is often given the least consideration is the shielding gas. The correct choice of shield gas is dependent upon both material and process factors. The influence that the shielding gas has upon the different areas of the GMAW is shown Fig. 11. In GMAW, irrespective of the material being welded the cost of shielding gas is unlikely to represent more than 10% of the total cost of producing a weld (Fig.12).

What is often not understood is the rationale behind choosing certain combinations of gases and their effect on productivity cost and quality. Quality of the weld can be evaluated in ralation to its mechanical properties, sensitivity to properties of the weldment. The various gases that can be used for GMAW are Ar, He, CO_2, and mixtures of Ar He, CO_2, H_2, O_2. The various application of these gases are given in Table No. 4

A lot of development has been taken place in the types of mixture gases. These offer better properties compared to single gases. Latest development in the shielding gas mixtures is the use of Ar/Co$_2$/He/O_2, mixture for carbon and low alloy steel. This resulted in a new process called TIME process

(TIME process - Transfer Ionized Molten Energy process).

The process produces welds that are very clean with reduced S & P level and enhanced weldment toughness. The details are given in Table 5 (Ref 9).

Status of Shielding Gases in India

The consumption of shielding gases like Ar, CO_2, mixture of these two is about 4 to 5 lakh Cu.M. of Ar and 4000 to 5000 tonnes of CO_2. Previously there has been shortage of high purity Ar and Ar based gas mixtures. But the position has now imporved. Quality of CO_2 needs to be improved.

CO_2 gas in India is produced in two ways. In one technique, charcoal is burnt in a furnace, CO_2, gas from the products of combustion is separated in absorber. The separated CO_2 is cooled and liquified at a temp of +3 to +7C. Others Technique utilises CO_2 generated as a by product in petroleum refining operation. Gas is available in 9 Kg 22 Kg and 27 Kg weight cylinders. Gas supplied is reported to comply with IS 307 Gr.I specification requirements (purity 99.7% min) even though batch test certificates are not supplied as a routine.

Area of Application

Automobile sector

Use a smaller diameter solid/cored wires for body, frames etc. is made on a large scale in this rapidly growing sector of industry (Ref 10)

Cargo containers

Stringent dimensional tolerances have favoured use of CO_2 welding process over SMAW as the former leads to reduced distortion (Ref.11)

Structural and pressure parts in tyre curing equipments

It is reported that as the process is found economical and technically suitable. Out of the total 12 T weld metal deposited, 10 T is deposited with automatic FCAW process (Ref. 12)

Boiler manufacturer

Use of CO_2 solid/flux cored wires is reported for fillet, butt,groove plus fillet type of joints resulting in net gain of 18 to 20% over SMAW (Ref. 13)

Earth moving equipment fabrication

Hydraulic excavators are being successfully fabricated using GMAW process (Ref.14)

Heavy Electrical Machinery

A successful switch over from SMAW to CO_2, welding using solid wires has been reported for welding of ribbed shafts of A.C. motor Ref 15).

Industrial Machinery

In fabrication of cranes and other material handling equipments, safe vaults, rubber industry machinery, cement industry machinery for repairs of blow holes in castings and for hard facing applications, extensive use of CO_2 welding with FCAW is reported (Ref. 16)

Constraints on CO_2 welding consumables

Importance of CO_2 welding process is generally recognised by Indian Industry. Share of the process is increasing. However, the share of the

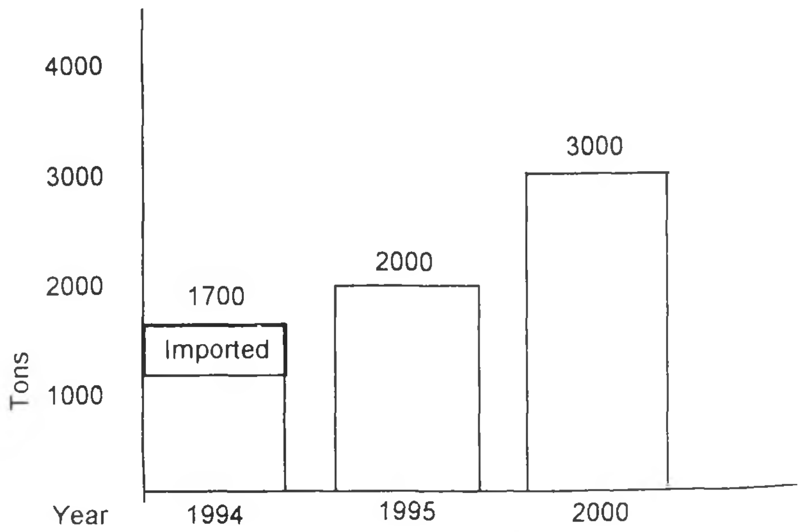


Fig 9 : Flux Cored Wires

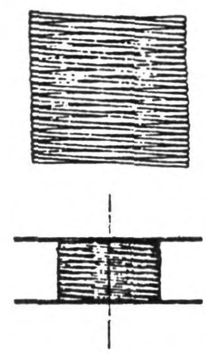


Fig 10 "AYAMAKI" Winding Unique to kobe steel

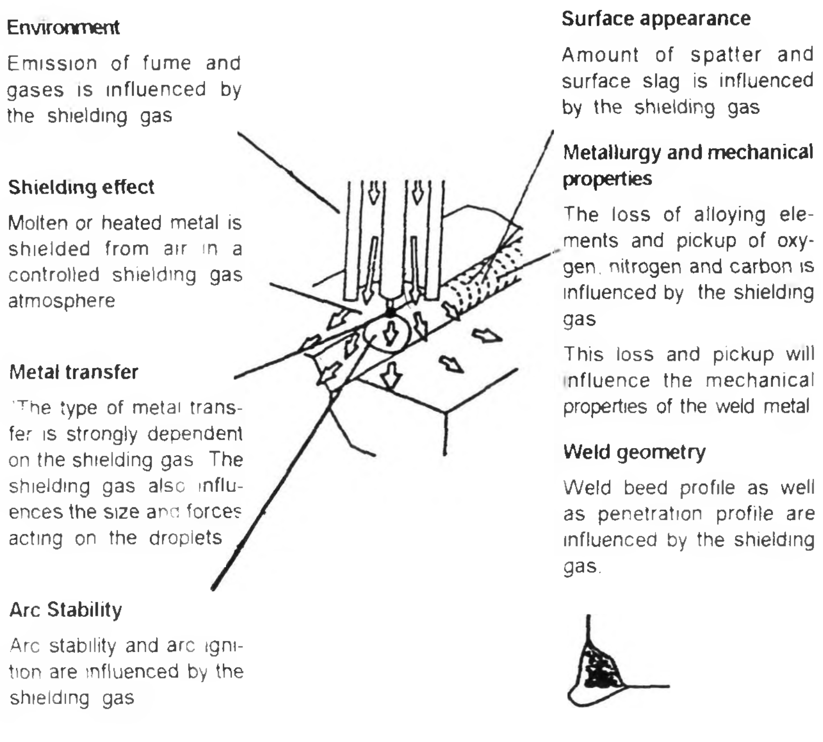


Fig 11 : The influence of shielding gas upon gas shielded arc welding. Shielding gas choice also effects the welding speed, the total welding cost and degree of user friendliness

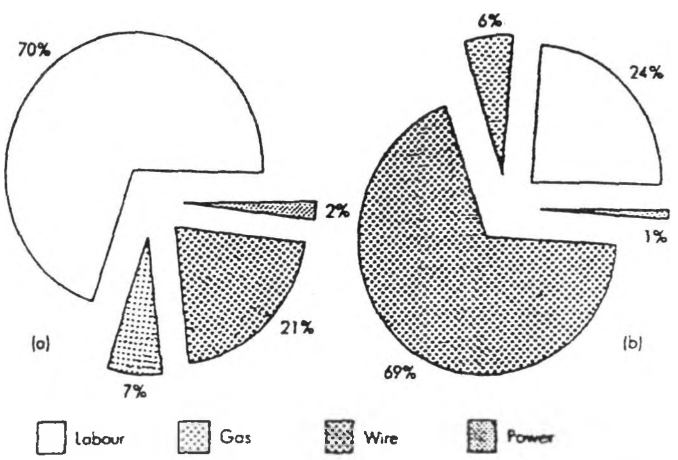


Fig 12 : Cost comparison of process components per meter of weld, (a) mild steel, (b) stainless steel

process has not reached to its estimated level due to various constraints on consumables as listed below

Cost of filler wire

It is presumed that CO_2 welding process does not provide much benefit to fabricators over MMAW due to much higher cost of filler wire than that for stick electrode. From Fig. 13, it can seen that though filler wire costs higher than the electrode, the over all cost of the process is much lower. What is costly is capital plant, man power and overheads needed for production process. If one of these resources is optimised the relatively small additional cost of consumable is quickly recovered.

Quality of filler wires

Quality of Indian wires for solid as well as flux cored wire are adequate in most of the available varieties. Though the chemical composition and mechanical properties can be met in some of the varieties, still there is room for improvement to match the imported varieties in the finish, spooling and packaging. Due to non availability of raw materials, many grades of wires are not being manufactured. Self-shielded cored wires are available for hardfacing purpose. However, for fabrication they are still to be developed. Approximately, 10% of constituents in the core such as high grade fluorospar, chromium powder etc. are being imported by wire manufacturers. Low carbon strips or tubes (which is basic raw material) or required specifications are not available.

Non-availability of smaller dia wires

Some sizes of filler wires (0.8mm, 0.9mm & 1.0mm dia) are not available. This is possible due to low

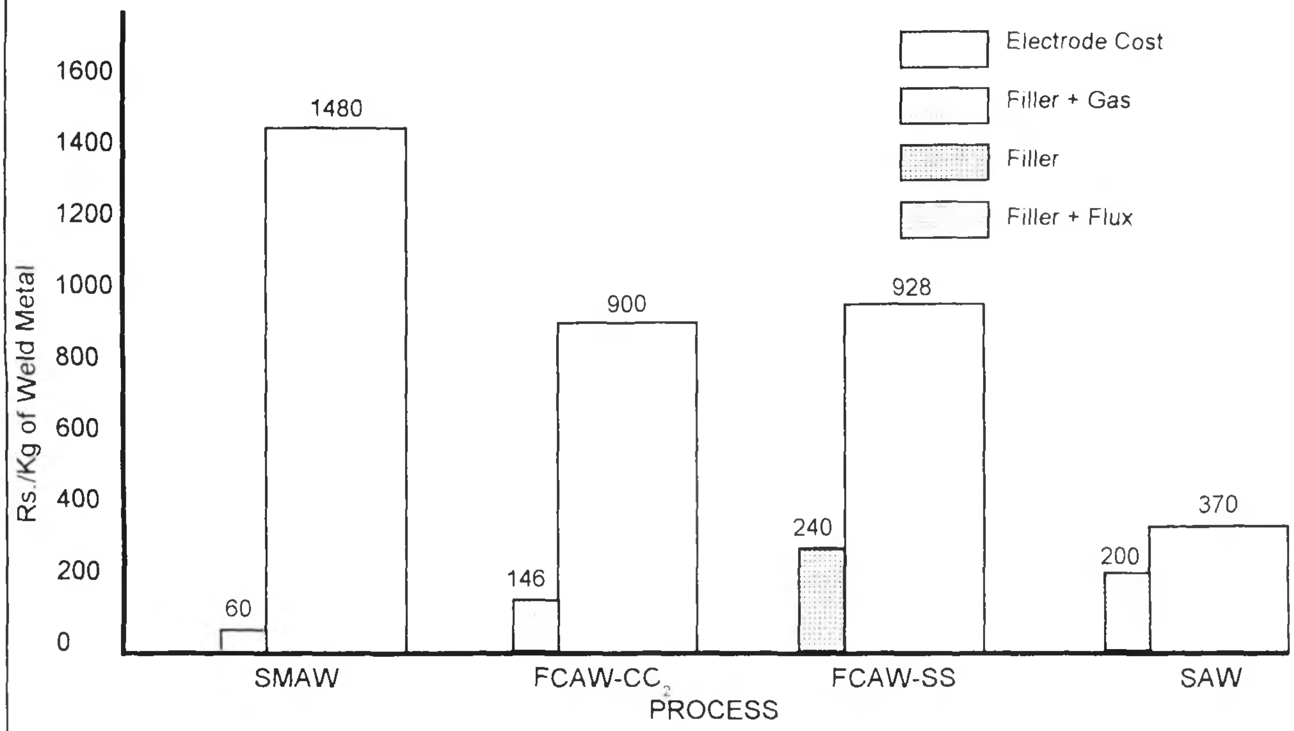


Fig 13 : Weld metal cost comparison chart

demand, which does not make it economically viable.

Copper coating

Most of the Indian solid wires need an improvement on the control of copper coating. The wires get rusted quickly and some times too thick or too low copper coating leads to many problems during welding operation due to improper wire feeding.

Wire cast & helix

This is an important factor relating to wire feeding. The poor cast, and helix leads to arc wandering problem during welding. This will be a serious problem in mechanised welding. Very few Indian wires meet these requirements.

Spatter with solid wires

Spatter levels are slightly higher with solid wires compared to coated electrodes. However, gas shielded flux cored wires have been developed to reduce spatter level to much lower values.

Control of fumes

The concern about the welder's environment has resulted in efforts to minimize smoke and fume generation with all welding process, the fume levels by various welding processes are given in Table No 6 and Fig. 14 (Ref. 17 & 18). Adequate Ventilation needs to be used to overcome ill effects of fumes. However, some developments have been carried out to reduce fume levels with flux cored wires (Table No 7) (Ref. 19).

Constraints on shielding gases

Irregular supply and / or non-availability of gas mixtures for various applications slows down the growth of this process. There is no standard facility available for instant checking the quality of the CO_2 or mixed gases. Inconsistent gas quality and or gas mixtures often lead to questionable weld. This retards the growth of CO_2 welding process.

CONCLUSIONS

Indian Industry has accepted CO_2 welding process as a productive manufacturing tool. Due to various constraints on consumables as mentioned, the growth rate may be hampered if adequate attention is not made. Hence a lot of development is required to be carried out on the consumables front and to push the share of the process to a level where Indian industries can compete with the global leaders. We have no choice but to strive for overcoming teething problems and push forward to survive.

ACKNOWLEDGEMENTS

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TABLE 1 : HOW AWS Classifies SOLID WIRE

MILD STEEL SOLID ELECTRODE CLASSIFICATION GMAW, GTAW & PAW

ER 70 S - 4

- **ER** — Electrode or Rod
- **70** — Tensile KSI
- **S** — Solid
- **4** — Chemical Composition & Shielding Gas

LOW ALLOY (solid) ELECTRODE CLASSIFICATION GMAW, GTAW & PAW

ER 80 S-NI3

- **ER** — Electrode or Rod
- **80** — Tensile KSI
- **S** — Solid
- **NI3** — Chemical Composition & Shielding Gas

Shield Gasses

2	Co_2A-O, A-CO_2	4	Co_2	6	Co_2A-O
3	Co_2A-O,A-Co_2	5	Co_2	7	Co_2A-O,A-Co_2

TABLE 2 : AWS CLASSIFICATION OF FLUX CORED WIRES

The system of classification is as follows :

E X X T X XX

- **E** — Electrode
- **X** — Tensile strength
- **X** — Welding Position
- **T** — Tubular
- **X** — Performance and formulation type plus gas shielding requirements
- **XX** — Special alloy designation

Minimum tensile strength in 10,000 PSI Unit, normally :

6	-	60,000 PSI
7	-	70,000 PSI
8	-	80,000 PSI, but alloy grades
11	-	110,000 PSI, upto 12-1200,000 PSI.

Welding Position 0 = Flat and HV 1 = All position

Performance and formulation details

Digit	Gas	Details
EXXT-1	CO_2	Rutile type, smooth running, general purpose electrode
EXXT-2	CO_2	As T-1 but high Mn/Si ratio for single pass HV fillets
EXXT-3	none	Self Shielded, thin material, spray transfer
EXXT-4	none	Self shielded low penetration, general purpose, HV or IG, Globular
EXXT-5	CO_2	Basic type, high toughness, hydrogen controlled, globular transfer
EXXT-6	none	Self Shielded, deep penetration, good mechanical properties
EXXT-7	none	Self Shielded, high deposition rate
EXXT-8	none	Self Shielded, positional and improved toughness
EXXT-10	none	Self Shieled high speed, single pass
EXXT-11	none	Self Shielded, general purpose
EXX-G & T-GS	As required	Special grades, eg. metal cored

TABLE 3 PROPERTIES OF SOLID / CORED WIRES WITH VARIOUS GASES
(CO_2 as Reference)

Properties	Solid Wire		Cored Wire							
			Rutile horizontal		Rutile vertical		Metal powder	Basic		
	Co_2	Ar+20Co_2	Co_2	Ar+20Co_2	Co_2	Ar+20Co_2	Ar+20Co_2	Co_2	Ar+20Co_2	No Shield Gas
Spatter	0	+	+	++	+	++	++	0	+	-
Pores	0	-	0	-	0	-	0	+	+	-
Lack of fusion	0	-	++	+	++	+	0	+	+	+
Penetration	0	-	++	+	++	+	0	++	+	+
Toughness	0	+	-	+	+	++	0	++	++	-
Weldibility	0	+	++	+	+	++	++	-	+	+

Ratings :-

BETTER	WORSE	EQUAL
+	-	0
++		

TABLE 7 FUME LEVELS BY MODIFIED CORED WIRE

	Earlier E71T-1	**Modified E71T-1**
Fume, lm/min	1 01	0 73
% weight of electrode converted to fume	1 33	0 93

(1 2 mm 0, welded at 230A/26V, CO_2 gas)

TABLE 5 : TIME PROCESS - GAS COMPOSITION

AY	**He**	**Co_2**	**O_2**
65%	26%	8%	0 5%

TABLE 4 : Gas mixtures available and their applications

GAS	APPLICATIONS	FEATURES
Argon	GTAW All metals. GMAW Spray/Pluse aluminium, nickel, copper alloys	Stable arc performance. Poor wetting charecterstics in GMAW Effcient shielding. Low cost
Helium	GTAW. All metals especially copper & aluiminium GMAW. High current spray aluminium	High heat input increased arc voltage
Argon+25 to 80% He	GTAW aluminium, copper stainless steel. GMAW aluminium & copper	Compromise between pure Argon & pure He. Lower He contents normally used for GTAW
Argon+0.5 to 15% H_2	GTAW austenitic stainless steel, some copper nickel aloys	Improved heat input, edge wetting and weld bead profile
Co2	GMAW plain carbon and low alloy steels	Low cost gas. Good fusion charecterstics/shielding efficiency but stability and spatter levels poor Normally used for dip transfer only
Argon+1 to 7% CO_2 +up to 3% CO_2	GMAW plain carbon and low alloy steels. Spray transfer	Low heat input, stable arc. Finger penetration. Spray transfer and dip on thin sections. Low CO_2 levels may be used on stainless steels but carbon pickup may be a problem
Argon+8 to 15% CO_2 up to 3% O_2	GMAW plain carbon and low alloy steels. General purpose	Good arc stability for dip+spray pluse and FCAW. Satisfactory fusion & bead profile.
Argon+16 to 25% CO_2	GMAW plain carbon and low alloy steels. Dip Transfer/FCAW	Improved fusion characteristics for Dip.
Argon+1 to 8% O_2	GMAW. Dip and spray & & pulse plain carbon and stainless steel	Low O_2 mixtures suitable for spray and pulse but surface oxidation and poor weld profile often occur with stainless steel. No carbon pickup.
Helium+10 to 20% Argon+Oxygen+CO_2	GMAW dip transfer stainless steel	Good fusion characteristics, high short circuit frequency not suitable for spray/pulse transfer
Argon+30 to 40%He +CO_2+O_2	GMAW dip spray and pulse welding of stainless steels	Improved performance in spray on pulse transfer. Good bead profile. Restrict CO_2 level for minimum Carbon pickup.
Argon+30 to 40%He +up to 1%O_2	GMAW dip, spray and pulse welding of stainless steels	General purpose mixture with low surface oxidation and carbon pickup (It has been reported that these low oxygen mixtures may promote improved fusion and excellent weld integrity for thick aluminium alloys)

TABLE 6 FUME GENERATION RATES OF COMMON WELDING ELECTRODES				
Electrode Class	Type	Current range Amps	Fume generation rate g/min	g. fumes./kg Weld metal
E6013	Covered	145-160	0 31-0 58	14.16-25 75
E7018	Covered	170-180	0.57-0.60	20 35-21.83
E316-16	Covered	145-160	0.21-0 31	6.56-11.92
ER316LT-3	Cored	440-445	1 64	9.11
ER 316	Solid	165-175	0 04	0.58
E70T-1	Cored	435-485	0 96-2 27	6 65-17 51
E70T-5	Solid	425-450	2 26-3 25	17.87-23.63
ER70S-3	Solid	260-290[1]	0 41-0 46	4.97-5.68
ER70S-3	Solid	190-205[2]	0 20-0 26	4.11-4.91

1) Argon + 2% O_2 and Argon + 2% O_2 - Spray transfer
2) Argon + 25% CO_2 - Short circulating transfer
(Note Fe - denoted iron powder MMA electrodes)