

# WELD WELL

Quarterly newsletter of Weldwell Speciality Pvt. Ltd.

SERVICE TO THE WELDING COMMUNITY

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Tejas – India's first indigenous Light Combat Aircraft

## HIGHLIGHTS

- Dissimilar metals welding – use of nickel filler
- Understanding basics of welding symbols
- The Larsen-Miller Parameter- estimating remaining useful life of materials
- New TIG welding rod from Kobelco

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# SPECTRUM

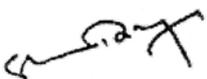


Dear Readers,

*The manufacturing sector in India is still not showing any steady growth. The fate of welding industry which is intimately linked to it is also not steady is though showing some improvements.*

*To derive maximum benefit from specific properties of materials in structures with tailored engineering properties and improving the ability to join dissimilar materials are enabling new approaches to light automotive structures, improving methods for energy production, and many other manufacturing and industrial uses. Dissimilar metal joining provides tremendous economic advantages too. All these aspects have been covered in the lead article. This also forces us to think about the remaining useful life of a material of construction under creep conditions. Since normal testing process is time consuming besides expensive the most common approach to find it out is to use Larson-Miller Parameter. Some simple elaboration has been made to this complex subject in the education section to that one can use it more frequently. Like other aspects of drafting, there's a set of symbols for welding to simplify the communication between designer and the welder. This language may seem a little strange at first, so it is best to learn it one symbol at a time. The symbols have been explained in the technical section. This will be covered in two parts. In the new product section the recently introduced GTAW (TIG) welding rod meeting AWS A5.18 ER70S-2 classification by Kobelco has been described. This GTAW welding rod is designed for welding mild steel and high tensile strength steel and suitable single-pass or root-pass welding of pipes in all positions. The review section covers how the defence section is opening up to private indigenous manufacturing units. A brief history of Indian defence manufacturing sector and some success stories have been narrated.*

*We hope you will enjoy reading this newsletter.*



*Dr. S. Bhattacharya*  
Editor

**Editorial Board:** P.S. Nagnathan, Ashok Rai and Kapil Girotra

### AWS Annual Lecture Series VIII

The IIW-India Foundation is planning to hold the next annual AWS Lecture Series VIII - 2017 on Heat Treatment of Welded Structures between 4<sup>th</sup> week of January and 1<sup>st</sup> week of February 2017.

The AWS Lecture Series started in the year 2005. Since then seven such annual lectures have been successfully conducted across India on various relevant subjects such as welding of stainless steels, low alloy steels, interpretation of ASME standards, welding of construction steels etc. The lecture will be held at seven branches. The AWS has nominated Mr. Christopher Bloch, an expert on heat treatment. He was one of the founding fathers of D10.10's revision. He holds a number of interesting patents. The speaker has designed the presentation meeting the interest of the Indian welding fraternity.

The key contents of the lecture are: Basics of Heat Treatment after welding such as Tempering, Solution Annealing, Normalising, Stabilization heat treatment and Stress Relief. It will also cover expectations, understanding code and some case studies. Heat Treatment before and during welding of commonly used metals and their alloys. It (heat treatment) will also cover that of clad vessel. Importance will be given to Metallurgical effects of PWHT, mechanical treatments after welding and modes and reason of failure. The expert will discuss how to apply Heat such as Gas, Electric or Induction and what care is required for the furnace and precautions for site jobs and localized heat treatment.

### National Welding Meet – 2016

The Indian Institute of Welding on occasion of its golden jubilee (50 Years) hosted National Welding Meet at Pune on 27<sup>th</sup> Aug. 2016. The theme of the meet 'Role of Welding in Make in India' was apt and in line with the mood of the industrial policy of Govt. of India. A large number of technical papers were presented by well-known authorities. The areas covered were defence, aerospace, special welding processes, special welding application, manufacturing of welding machine & consumables and some more. Few case studies were also presented. There was also a small exhibition during this show namely Weld India Expo 2016. A total of 18 stalls were there with welding products on display such as orbital welding systems, welding machines with modified arc characteristics to suite various applications etc.

About 200 delegates participated. The meet was a grand success.

# Welding Dissimilar Alloys Using Nickel Filler Metals

## IMPORTANCE TO INDUSTRY

Design engineers are increasingly faced with the need to join dissimilar materials as they are constantly seeking creative tailored engineering properties. Sometimes parts need contrasting properties. This leads to the necessity of joining dissimilar metals. Improving the ability to join dissimilar materials with contrasting engineered properties is enabling new approaches to light automotive structures, improving methods for energy production and many other manufacturing and industrial uses. Dissimilar metal joining provides tremendous economic advantages.

## DISSIMILAR METAL WELDS (DMW)

DMW or joints can be defined as those welds that are used to connect different metals together, where an object (such as a pipe) is subjected to multiple environments in one application. With DMW the properties of each section of the pipe can be optimized for its specific application.

Unlike similar metal fusion, a dissimilar joint consists of three alloys; two base metals and one diluted weld metal including filler metal in addition to two heat-affected zones. The bonding properties of the two metals being joined and the filler metal used for joining are to be considered. If there is a mutual solubility of two dissimilar metals, joints can be made easily. If little or no solubility exists between the two metals, the weld may not be successful. For fusion welding between dissimilar metals, it is important to investigate the phase diagram of the two metals involved. This gives rise to complex metallurgical considerations. Joining dissimilar materials is often more difficult. However, many dissimilar materials can be joined successfully with appropriate joining process and specialized procedures.

Experience with joining dissimilar materials indicates that no one process or set of parameters is best or fits all situations for all material combinations. Each process has advantages and limitations. A dissimilar material joint is best viewed as a special application with unique requirements every time.

Successful dissimilar metal joints can be made using

a variety of different metals and welding processes. Weldability is often a critical factor considered for the manufacture of fabricated products. This article is restricted to provide information where use of Nickel-based Filler Metals has been made to join dissimilar alloys.

## FACTORS AFFECTING DMW QUALITY

There are various factors which affect a successful DMW. Some of the most significant ones are discussed below.

### Chemical Composition

The success of a particular dissimilar joining operation depends largely on the final chemical composition of the weld deposit needed for the particular application and it (the weld deposit) should be at least as strong as the weaker of the two metals being joined i.e. with sufficient tensile strength and flexibility. This is to ensure that the joint will not fail in the weld.

### Dilution

The weld metal chemistry is controlled not only by that of the electrode or filler metal but also by the dilution from the two base materials. The selected welding product must be capable of accepting that dilution without forming a composition that is crack sensitive or has other undesirable characteristics. The effects of alloying with the dissimilar materials are too complex to permit prediction of results with certainty in all cases, however the dilution can be calculated and its effects ascertained, to aid selection of suitable electrode/filler metal.

### Thermal Expansion

Another factor involved in predicting successful life for dissimilar metal joints is the difference in thermal expansion coefficient of both the materials. If they differ significant, then the stress will set in during any changes in temperature of welded fabrication. Unequal expansion of joined members places stress on the joint area and can cause fatigue failure.

### Melting Point Difference

Differences in melting point between the two base

metals or between the weld metal and base metal can, during welding, result in rupture of the material having the lower melting point. The problem can often be eliminated by the application of a layer of weld metal on the low-melting-point base metal before the joint is welded. Nickel layer often serves to reduce the melting-point differential across the joint.

### Electrochemical Scale

The difference in the electrochemical scale of metals indicates their susceptibility to galvanic corrosion and is important to be considered depending on its application. If they are far apart on the scale, corrosion can be a serious problem at DMW.

### EVALUATING SUCCESSFUL WELD

A good estimate of the probability of success and improving the ability to join dissimilar materials with engineered properties can be made by the following:

#### Composition

The composition of the weld bead can be estimated using the compositions of the welding product and base metals. In a single bead, predicting weld metal contributed by each source is simple. In a multiple-pass weld, composition of each bead will be different. The root bead will be diluted equally by the two base metals. The subsequent beads may be diluted partially by a base metal and partially by a previous bead or entirely by previous beads. Composition of the weld metal, thus calculated, can be compared with known dilution limits, to determine whether it is crack sensitive or sound.

#### Amount of Dilution

The most important consideration, produced by a set of welding conditions can be determined by practically performing a chemical analysis on a sample bead. If analytical facilities are unavailable, dilution rate can be calculated from an area comparison on a joint cross section. In practice, dissimilar joints are often evaluated by using Dilution Rate based on known industry standard levels for various welding processes. A weld made without filler metal would have 100% dilution since the entire weld bead is supplied by the base metal.

SMAW in the flat position, the most widely used process for dissimilar joints, normally produces a dilution rate of 30%. GMAW has a wider variation about 10% to 50% in dilution, depending on type of metal transfer and torch manipulation. GTAW has the greatest variation in dilution.

### FILLER METAL SELECTION

Ni-based filler metals are popular choice to join dissimilar combinations such as pressure vessel steels to stainless steel and various Ni-based alloys. Proper selection of filler metals for these dissimilar combinations is essential and knowledge of metallurgical behaviour is required to prevent problems during fabrication or in service. In particular, the use of filler metals for cladding and for transition joints critical to the power industry. In certain situations, the only way to make a successful joint is the use of transition between two dissimilar metals. An example of this is the attempt to weld copper and steel. The two metals are not mutually compatible, hence not weldable. In such cases, using metallic nickel, in which both metals are weldable, as an interim joint is used to get a successful joint with satisfactory properties.

Several Special Metals Welding Products are commonly used for dissimilar joints. The Nickel-Chromium electrodes and filler metals such as Inco weld A; Inconel 112 and 182 electrodes and Filler Metals 82, 92 and 625 are particularly versatile materials for dissimilar welding. They can tolerate dilution from a variety of metals without becoming crack-sensitive. A matrix table of recommended welding consumables is available. (To obtain a free copy please contact Weldwell Speciality Pvt. Ltd. Email: [sales@weldwell.com](mailto:sales@weldwell.com))

In many cases, more than one welding product will satisfy the requirement of metallurgical compatibility. The selection would then be based on the strength required, service environment to be withstood or on cost of the welding product. If one of the base metals is of lower strength, a filler metal that has an expansion rate near that of the weaker base metal should be selected. When a suitable welding product for a dissimilar joint is not known, potential electrodes

and filler metals must be evaluated on the basis of their ability to accept dilution from the two base metals without forming a composition that is crack sensitive or that has other undesirable characteristics.

The elements normally of concern in considering dilution of nickel-alloy weld metals are copper, chromium, and iron. The weld metals can accept unlimited dilution by nickel.

### APPLICATIONS OF NICKEL-BASED FILLER METALS

Most nickel alloys have good weldability and can be joined successfully to a wide range of dissimilar alloys with appropriate joining process and specialized procedures.

There are a number of situations where dissimilar combinations of Ni-base alloys provide engineering advantages. In general these applications take advantage of several inherent properties of Ni-based alloy welding materials that make them ideal choices for specific types of applications. Each application in which the Ni-based welding material is used to weld other base metals usually takes advantage of the unique characteristics of the as-cast or as-deposited weld metal that allows it to provide equal to or better properties than that of the wrought base metal. Many of the nickel alloy filler metals have been used for making dissimilar metal joints with excellent results; dilution when welding joints between ferritic stainless and duplex steels being less important than when using a type 309 stainless steel filler.

Nickel also has a coefficient of thermal expansion between that of ferritic and austenitic steels and therefore suffers less from thermal fatigue when high temperature plant is subjected to thermal cycle. Inconel 625 has been a popular choice, the weld tensile strength matching or exceeding that of the parent metal. Ni-base filler metals (normally the solid –strengthened alloys) are used to weld overlay structural metals, such as Cr-Mo alloy steel water-wall tubing in power boilers.

Ni-base filler metals are used to join low-alloy steels to austenitic stainless steel in power plant applications requiring elevated temperature creep and thermal

fatigue resistance. When this combination is directly welded by austenitic stainless steel filler metals, the differences in coefficient of thermal expansion (CTE) leads to creep and fatigue failures in the HAZ of the carbon-steel after extended exposure to elevated temperatures. This will place the line of differential expansion along the weaker alloy on steel side. However, with Nickel- base filler metals this is not the case.

### CONCLUSION

\*Dissimilar welding of Nickel alloy to other alloys; dissimilar welding of Non-Nickel alloys and overlaying on non-nickel alloy are some of the major applications

\*Study of Dilution Rates - Predicting Weld Compositions - Dilution Limits - Thermal Expansion-Melting Points - Need for pre-heating one of the base metals - Post-weld heat treatment etc. are determining factors of successful welding quality.

\*Additions of Niobium or Titanium are added to specific filler metals, such as the popular Inconel 625, are used to help stabilize the welds and minimize the Carbide Precipitation influence

\*There are also metallurgical advantages realized by the use of Ni-based filler metals for dissimilar combination

\*In many cases, more than one welding product will satisfy the requirement of metallurgical compatibility. The selection will then be based on the strength required, service environment to be withstood, or on economics. The INCONEL nickel-chromium welding products are the most widely used materials for dissimilar welding

\*In certain cases, caution needs to be exercised when selecting a suitable filler. For example, Inconel 625 has been extensively used for welding dissimilar joints in austenitic and duplex steels. Use of this filler metal has resulted in the formation of niobium rich precipitates adjacent to the fusion line and has been discontinued. Inconel 686 or Inconel 622 filler metals has replaced Inconel 625 as the filler metal of choice.

## Larsen-Miller Parameter

### Introduction

Creep is a time temperature dependent failure of a material. It takes a long time to perform creep tests making the generation of design data expensive and the lead time between developing a new alloy and its exploitation excessive. The fact that there is an Arrhenius relation between creep rate and temperature has led to a number of time-temperature parameters to be developed which enable extrapolation and prediction of creep rates or creep rupture times to longer times than have been measured. They also enable rating comparisons to be made between different materials. It is important that no structural changes occur in the region of extrapolation, but since these would occur at shorter times for higher temperatures it is safer to predict below the temperature for which data is known than above. One of the parameter used is Larsen-Miller Parameter.

### Determination of Larsen-Miller Parameter

The elegant and quite successful Larsen-Miller (L-M) method of extrapolating stress rupture and creep results is based on the contention that the absolute temperature compensated time function should have a unique value for a given material depending only on the applied stress level. The L-M parameter converts time and temperature by the following equation:

$$P = 1.8T (C + \log t) \times 10^{-3}$$

where

P = Larsen - Miller parameter

T = temperature in °K

C = a constant

t = time to rupture in hours

The constant "C" depends on the metal and varies with stress. It is established by plotting a graph using all available data to correlate stress with temperature and rupture time. The constant may range from about 15 up to 45, but approximately 30 is a good average for the most metals. Many low alloy steels favoured for service at elevated temperature have a constant approximately 20. The factor of approximately 20 is applicable to C-Mn and low alloy steels; alternatively, a factor of 30 is sometimes applied in the case of higher alloy steels, e.g. 9%Cr steels. The relationship expressed by the Larsen-Miller parameter is that, at a given creep stress, a longer time at a lower temperature causes as much deformation as a shorter time at a higher temperature. Alternately, higher temperatures cause the same amount of creep at shorter time. This relationship holds true for such

rate processes as recovery, recrystallization, creep and stress rupture as well. Of course, if precipitation, aging or grain growth occurs, use of the parameter would not result in an accurate prediction. Where the conditions permit creep or stress rupture as a rate process, a few data points interpreted as Larsen-Miller parameters can be used to develop a master rupture graph at minimum cost and time. The Larsen-Miller parameter describes the equivalence of time at temperature for a steel under the thermally activated creep process of stress rupture. It permits the calculation of the equivalent times necessary for stress rupture to occur at different temperatures.

It is also possible to include heating and cooling by adding an additional time,  $\delta t$ , to the existing time factor in the above expression:

$$\delta t = \frac{T}{(2.3K (20 - \log K))}$$

K is the heating or cooling rate in Kelvin per hour.

The Larsen-Miller parameter has been modified for use on creep-resistant alloys with a high degree of dispersion strengthening, e.g. some nickel alloys and steels. Another modification of the Larsen-Miller parameter - the Manson-Haferd parameter - has proven to be more applicable to 9%Cr steels than the Larsen-Miller parameter :

$$P(\sigma) = \frac{\log t_r - 12.30}{T - 600}$$

P( $\sigma$ ) is the Mansen-Haferd parameter, and  $t_r$  is the rupture duration (in hours).

The Larsen-Miller parameter is similar to the Hollomon-Jaffe parameter, which deals with postweld heat treatment, but has different units.

The L-M parameter has found extensive application in designing power plant and other units which are likely to undergo long term exposure to higher temperatures.

### Conclusion

Use of Larsen-Miller parameter is a simple approach to determine and extrapolate stress rupture and creep results so that the life of a material subjected to application of prolonged heated condition such as in power plants can be estimated. The L-M parameter has been further modified to suit specific materials.

## Welding Symbols - The Basics\* - Part 1

Like other aspects of drafting, there's a set of symbols for welding to simplify the communication between designer and builder (i.e. the welder).

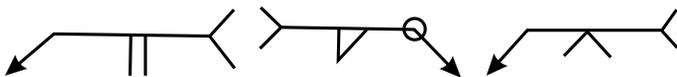
Like other aspects of drafting, there's a set of symbols for welding to simplify the communication between designer and builder (i.e. the welder). This language may seem a little strange at first, so it's best to learn it one symbol at a time.

Numerous weld symbols have been devised to represent all the different weld types used in the trade, as well as any joints that must be cut or bevelled during fit-up (Fig.1). Here are the most common ones which are used in weld symbols representation:

No.	Designation	Symbol
1	Butt weld between plates with raised edges	⌞
2	Square butt weld	⌚
3	Single-V butt weld	∇
4	Single bevel	∟
5	Single-V butt weld with broad root face	∪
6	Single-bevel butt weld with broad root face	∩
7	Single-U butt weld (parallel or sloping sides)	∩
8	Single-U butt weld	∩
9	Bead	⌒
10	Fillet	⌔
11	Plug or Slot	⌚

**Fig. 1:** Type of joints

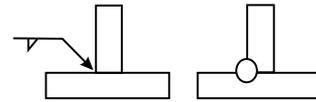
The figure 2 represents the core structure of every drafting specification for a weld to be performed. The welding symbol has an arrow, which points to the location on the drawing where a weld is required. The arrow is attached to a leader line that intersects with a horizontal reference line. Finally, there's a tail at the opposite end of the reference line that forks off in two directions. The tail is optional and needed only for special instructions.



**Fig. 2:** Core structure of drafting specification

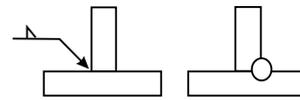
Dangling from the middle of the reference line, one will see a geometric shape or two parallel lines identifying what type of weld should be performed on the metal (Ref. Fig.1 above). This is called the weld symbol (not to be confused with the overall welding symbol). The three weld symbols you see in the drawings above represent a square, fillet and V-groove weld, respectively.

The weld symbol may also be placed above the reference line, rather than below it. This placement is important. When the weld symbol hangs below the reference line, it indicates that the weld must be performed on the "arrow side" of the joint. For example, in Fig. 3 a fillet weld is specified on the arrow side. One can see the actual weld in the second depiction.



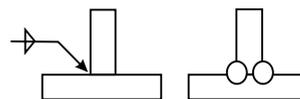
**Fig. 3:** Fillet weld specified on the arrow side

Now, if the weld symbol appears on top of the reference line, then the weld should be made on the opposite side of the joint where the arrow points (Fig.4). Here's how it will look:



**Fig. 4:** Weld on the opposite side of the joint

If the weld symbol appears on both sides of the reference line, as shown in Fig.5, it specifies that a weld must be performed on both sides of the joint.



**Fig.5:** Weld performed on both sides of the joint

....to be continued in the next edition

\*Based on an article by Rosemary Regello

## New Product

### TIG Welding Rod TG-S70S2 (AWS A5.18 ER70S-2) for Welding High Tensile Strength Steel

#### Introduction

Kobelco has introduced TG-S70S2 from its Thailand unit, a GTAW (TIG) welding rod meeting AWS A5.18 ER70S-2 classification. This GTAW welding rod is designed for mild steel and 490MPa high tensile strength steel and is suitable for single-pass or root-pass welding of pipes in all positions. TG-S70S2 is used in welding during boiler and pressure vessel fabrication, structural steel or general construction.

#### Chemical Composition Of Wire Rod

The chemical composition of wire rod is shown in Table 1.

#### Mechanical properties

The mechanical properties of the newly developed wire is shown in Table 2 whereas Table 3 shows the welding condition.

Grove configuration: Single V-groove (included angle

45°, 13mm plate of SM490A, root gap 6.5, back-up plate thickness 6.5) Unit: mm  
Pass sequence: 18 passes / 9 layers

**Table 3:** Welding condition

Wire rod size (mm)	2.4 x 1000
Welding polarity	DCEN
Welding current (A)	230
Arc voltage (V)	13
Weld position	Flat
Heat input (kJ/cm)	Avg.14.5
Shielding gas, flow rate	100%Ar, 15l/min
Preheat temperature (°C)	150 +15
Inter-pass temperature (°C)	150 +15
Dimension of base metal(mm)	260W x300L x13T

**Table 1:** Chemical composition of wire rod (wt%)

		C	Si	Mn	P	S	Cu*	Ni	Cr	Mo	V	Ti	Zr	Al
<b>TG-S70S2</b>		0.04	0.47	1.04	0.017	0.004	0.11	0.03	0.11	0.01	0.01	0.07	0.05	0.10
<b>AWS A5.18 ER70S-2</b>	Min	--	0.40	0.90	--	--	--	--	--	--	--	0.05	0.02	0.05
	Max	0.07	0.70	1.40	0.025	0.035	0.50	0.15	0.15	0.15	0.03	0.15	0.12	0.15
<b>KOBELCO Guarantee range</b>				Same as AWS A5.18 ER70S-2										

\* Including Cu plating

**Table 2:** Mechanical properties

	Tensile properties			Absorbed energy (J)					
	0.2%OS	TS	EI	vE - 46°C		vE - 30°C		vE - 20°C	
	(MPa)	(MPa)	(%)	Each.	Avg	Each	Avg.	Each	Avg.
As weld	572	638	29	189		226		280	
				150	122	215	255	256	262
				28		235		249	
PWHT 620°Cx8hr	532	616	32	200		243		248	
				197	188	192	206	217	233
				168		183		233	
AWS A5.18 ER70S-2	> 400	> 480	> 22	--	--	> 20	> 27	--	--
<b>KOBELCO Guarantee range</b>	Same as AWS A5.18 ER70S-2								

**Sulphide Stress Corrosion Cracking Test : NACE Standard TM0177**

Sulphide Stress Corrosion Cracking (SSSC) test was performed in accordance with NACE standard TM0177 Method B. Applied stress were 80~95% of actual yield stress of all welds metal. Table 4 shows welding condition and sampling of test specimen. Table 5 shows the test result. There is no failure during test for 720Hr. After the test (720Hr), surface of test specimens was observed. There was no crack observed.

**Table 4 :** Welding condition

Grove configuration: Single V-groove (included angle 45°), 15mm plate of SM490A, root gap 6.5, back-up plate thickness 6.5, Unit: mm  
Pass sequence: 18 passes / 9 layers

Wire rod size (mm)	2.4 x 1000
Welding polarity	DCEN
Welding current (A)	220
Arc voltage (V)	16
Weld position	Flat
Heat input (kJ/cm)	Avg.19
Shielding gas, flow rate	100%Ar, 20l/min
Preheat temperature (°C)	150 ±15
Inter-pass temperature (°C)	150 ±15
Dimension of base metal(mm)	280W ×250L ×15T

Size of test specimen: L 67.3mm × W 4.57mm × T 1.52mm

Number of test specimen: 3 pieces for each applied stress

**Table 5 :** Test result

No. of sample = 3 for each stress. Actual Y.S. = 554 MPa

Applied stress (MPa)		Result
0.80 × Actual Y.S.	443	No failure & No crack
0.85 × Actual Y.S.	471	No failure & No crack
0.90 × Actual Y.S.	499	No failure & No crack
0.95 × Actual Y.S.	526	No failure & No crack

**Hydrogen Induced Cracking test : NACE standard TM0284**

Hydrogen Induced Cracking test were performed in accordance with NACE standard TM0284 Test solution A.

Table 6 shows welding condition and sampling of test specimen.

Table 7 shows the test result.

After test (96Hr), surface of test specimens was observed. There was no crack observed.

Furthermore, cross-section of specimens (3 parts, per one specimen 1/4, 2/4 and 3/4 length) was observed. There was no crack.

**Table 6 :** Welding condition

Grove configuration: Single V-groove (included angle 45°), 15mm plate of SM490A, root gap 25, back-up plate thickness 6.5, Unit: mm

Pass sequence: 61 passes / 10 layers

Wire rod size (mm)	2.4 x 1000
Welding polarity	DCEN
Welding current (A)	220
Arc voltage (V)	16
Weld position	Flat
Heat input (kJ/cm)	Avg.19.1
Shielding gas, flow rate	100%Ar, 20l/min
Preheat temperature (°C)	150 ±15
Inter-pass temperature (°C)	150 ±15
Dimension of base metal(mm)	280W ×250L ×15T

Size of test specimen: L 100mm×W 20mm×T 13.4mm

Number of test specimen: 3pieces

**Table 7** Test result

Number of test specimen: 3pieces  
Result: No crack

**Conclusion**

TG-S70S2 (GTAW welding rod) satisfies AWS A5.18 ER70S-2 classification. TG-S70S2 satisfies NACE standards TM0177 and TM0284.

### Indigenous Production of Defence Equipments in India

The defence sector is increasingly scheduled to occupy bigger space in the country's long term strategic planning. The Indian government is very clear and focused in its vision for its defence sector indigenization.

#### A Brief About Indian Defence Sector

The history and development of Indian ordnance factories is directly linked with the British reign in India. The East India Company considered military hardware to be a vital element for securing their economic interest in India. In 1775 British authorities accepted the establishment of the Board of Ordnance at Fort William, Calcutta. This marked the official beginning of the Army Ordnance in India.

In 1787 a gunpowder factory was established at Ichapore and the site was later used as a rifle factory beginning in 1904. In 1801, Gun Carriage Agency (now known as Gun & Shell Factory, Cossipore) was established at Cossipore, Calcutta, and production began on 18 March 1802. This is the oldest ordnance factory in India still in existence.

#### Defence Equipment Production Firms In India

Defence spending in India has grown at about 17 percent in the past few years. It spends around \$24 billion a year and with this India has become forth largest arms importer in the world. Despite this huge market, the current policies and structure of the industry have constrained the domestic defence production. The public sector and domestic private sector players contribute only 20% and 5%, respectively.

Historically, India has always favoured the public sector over the private in the areas of defence production. India's first industrial-policy resolution in 1948 made it clear that a major portion of industrial capacity was to be reserved for the public sector including all arms production. When this document was revised in 1956, it placed the munitions, aircraft and shipbuilding industries in public sector under central Government control, preventing private sector production.

Now, the rush to participate in the manufacturing of defence equipment by the private sector is partly the result of Prime Minister Narendra Modi's emphasis on defence equipment as part of his Make in India campaign and the proactive stand taken by the defence ministry. According to the ministry of defence, the private sector now has the opportunity to pick up a 25% share of defence production which is estimated to grow to the order of \$620 billion by 2022. The ministry has already de-licensed 60-70% of the production.

There are already few big and established groups such as Tata group, Bharat Forge Ltd (BFL), Reliance Industries Ltd (RIL), Larsen and Toubro Ltd (L&T), Godrej Group and the Mahindra Group who are in defence equipment production.

Tata Advanced Systems Ltd (TAS) is working on projects, including missiles, radars, aerospace and unmanned aerial vehicles in partnership with Airbus. Himachal Futuristic Communications Ltd (HFCL) has also won government licences to design, develop and manufacture aircraft and unmanned aerial vehicles.

Bharat Forge Ltd. has tied up with Rafael Advanced Defence Systems Ltd. and Elbit Systems Ltd. of Israel and UK-based Rolls-Royce Corp. to make Spike anti-tank guided missiles for the Indian armed forces.

Mahindra Group has created two verticals under the defence divisions to focus on land defence and naval defence. Last year, the group opened a new underwater systems and naval applications manufacturing facility in Pune, which will produce torpedo launchers and radars.

Reliance Industries partnered with Boeing to build P8I naval reconnaissance aircraft for the Indian Navy.

Last year Hinduja Group partnered with Larsen & Toubro for the mounted guns artillery program of the Indian navy. In 2008, the group had set up Ashok Leyland Defence Systems, which manufactures

armoured vehicles for the armed forces.

Reliance Anil Dhirubhai Ambani Group, Hero Group and the Adani Defence Systems and Technologies Ltd. are the latest to enter the race. The Anil Ambani's Reliance Group announced its foray into the defence sector with its plans to set up a defence smart city to import components, systems and subsystems and later export finished products. The company has also set up a subsidiary, Reliance Defence and Aerospace, which will bid for 387 Army reconnaissance and surveillance helicopters and 100 Naval utility helicopters. After starting out as a manufacturer of bicycle components and becoming the world's largest two wheeler company, the Hero group is making big plans for the defence industry.

There are many more private sectors who contribute to defence production including some from Defence Public Sector Units.

### Development Centres

India is planning to set up 12 Development Centres with state of the art CAD/CAM facilities to boost R&D efforts in the ordnance factories which will prove to be a positive initiative. In real battle conditions more than esoteric high end technologies the day to day usable technology and product up-gradation helps the fighting forces more. The DPSUs have also embarked on intensification of their R&D effort – the initiatives taken by HAL (10 R&D Centres), BEL and BDL are particularly encouraging.

### A Success Story

#### Tejas inducted in IAF after 33 years

Tejas is the first advanced fly-by-wire (FBW) fighter aircraft designed and developed by the Aeronautical Development Agency (ADA) and produced by Hindustan Aeronautics Ltd (HAL).

Tejas is a fourth Plus generation aircraft with a glass cockpit and is equipped with state of the art satellite-aided Inertial Navigation System. It has a computer-based attack system and autopilot and can fire air-to-air missiles and drop precision-guided munitions

The first prototype of the light combat aircraft (LCA) Tejas' Naval version - LCANP1 completed its maiden

flight as the part of the carrier compatibility tests at the shore-based test facility in Goa. The Indian Air Force has inducted the first indigenous light combat aircraft (LCA) 'Tejas' into its No. 45 squadron, also called the 'Flying Daggers'.

Airframe of Tejas is made of indigenously developed metallic materials and processes like large size aluminium alloy forgings, control stretched extrusions, maraging steel and PH stainless steel. The construction also involved riveting / welding. The welding process was thermal assisted Friction Stir Welding. The machine was indigenously designed and developed by NMRL, Ambarnath and RV Machine Tools, Coimbatore. The salient features of the machine are – Load Capacity: 100 kN (z axis), 50 kN (Y & X axis). The X-axis travel is 1500 mm (weld length). The spindle speed is 100-3000 rpm. The heating was carried out by an induction Heater of 10 kW capacity. The tool holder was liquid cooled with temperature telemetry system. The machine established is capable of welding joint configurations like circumferential and longitudinal seam, T-, Lapp-, Fillet- and Butt joint. The alloy groups and thicknesses the machine can weld are Aluminium (2-50 mm), Magnesium (2-50 mm), Titanium (2-12 mm), and Steel (2-25 mm).

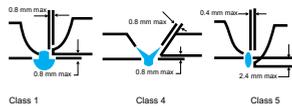
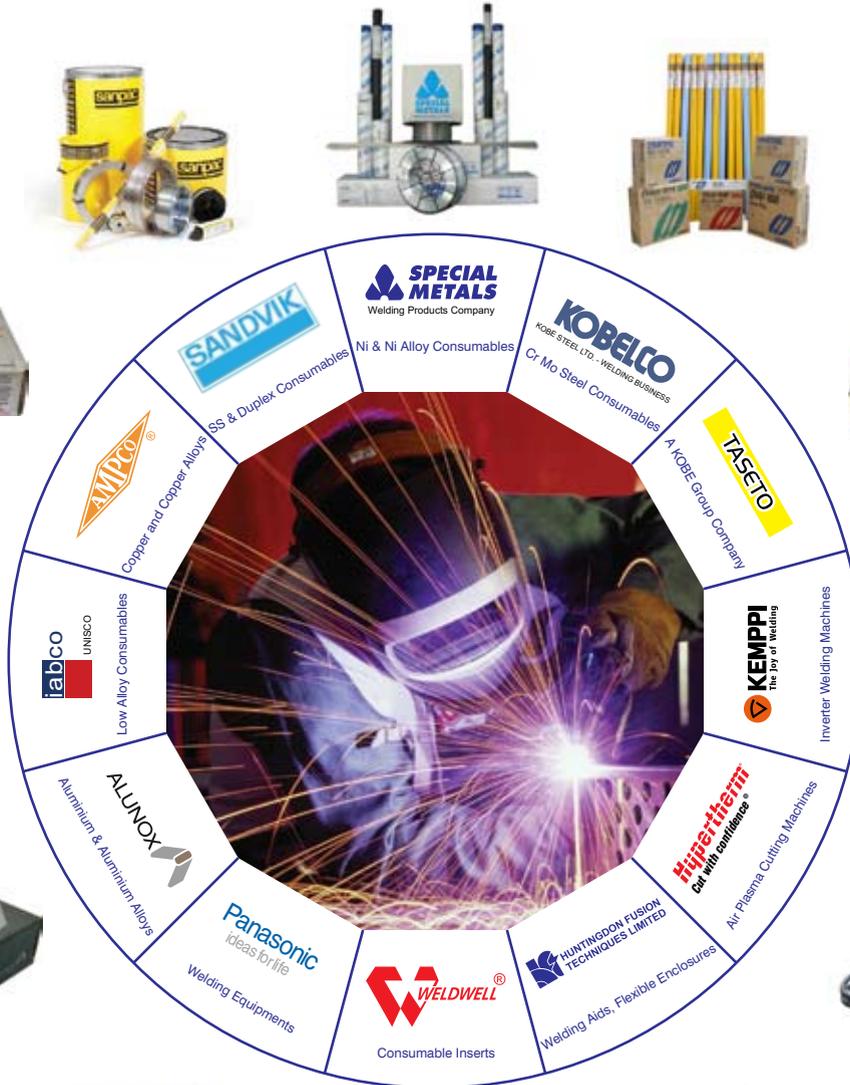
The inordinate delay in introducing the aircraft has though invited adverse comments from CAG but it must be appreciated that in the process India has developed not just the LCA (and built 16-17 flying prototypes) but also an aerospace ecosystem. That too for an amount, tiny compared to the billions that get sucked into developing fighters abroad. This is a laudable achievement which has made India proud and opens up avenues for development and growth of high quality welding infrastructure.



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