Testing Measurement and Control of Welds—a view point

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1. INTRODUCTION

Welding is an important means to fabricate structures and components from a wide spectrum of materials, of varied complexity and thickness ranges. Welds can be made with properties appropriate for service conditions. The requisite quality can be achieved based on adequate and appropriate testing, measurement and control of welds.

It is to be realised that no weld is completely perfect. Welds are small castings except that weld metal often cools much more rapidly. Microstructural variations due to heat input and thermal stresses may lead to cracking. Depending on the welding process employed, the possibility of entrapment of gases or foreign materials within the welds also exists. The defects or imperfections depend on the welding process, welding conditions, qualification level of welder, etc. Thus Quality Assurance in welded components is a specialised area meriting R&D efforts of basic and applied nature. Defects beyond permissible levels can be the cause of premature failure of the weld in service. Hence, the need for appropriate and adequate testing, measurement and control of welds becomes essential and crucial.

2. SCOPE OF THE TERMS - TESTING, MEASUREMENT AND CONTROL

The term 'testing' covers all tests on welded joints which determine the fitness of the joint for the intended application. These tests include non-destructive, destructive and metallography. The criteria for acceptance in terms of these tests are determined by various codes of practice, experience and specific structural analysis for newer materials and/or service conditions not covered in the codes.

The term 'measurement' covers such aspects as measurements on fit-up, root-gap, angle of the edge, reinforcements, penetration, distortion during welding etc. These are essentially specified by the designers.

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The term 'control' covers such aspects as control of chemical composition of the base metals and electrodes, control of current and voltage, control of moisture in the electrodes, control of rate of heat input, composition of cover gas, etc. The purpose of the control operation is to obtain a weld with desirable mechanical, metallurgical and integrity characteristics as indicated under the conditions of the code of practice specified or requirement tb meet desired properties in a given material weldment.

3. IMPORTANCE OF TESTING, MEASUREMENT AND CONTROL (TMC)

Although significant progress has taken place in understanding of various welding methods and processes, materials behaviour, response to welding processes, etc., it cannot be predicted theoretically with certainty that a weld will not have any harmful defect and will not pose any problem during service. TMC of welds are three facets of the approach that comes under the purview of quality control of welds and are considered essential to obtain appropriate welds where defects are allowed to be present, but only those which are innocuous as decided by either standard codes or by fracture mechanics considerations. The latter is more commonly known as fitness of purpose approach.

It is important to realise that though the primary purpose of TMC of welds is quality assurance, it generates very useful information towards evolving of better procedures, understanding of welding processes, generating base line data for inservice inspection and upgrading the welding science and technology.

4. WELDING PROCESS

It is convenient to classify the welding processes in two major categories in context of the topic of this paper.

Pressure Welding Processes

In this, externally applied forces play an important role in the bonding operation, consummated at room or elevated temperature.

Fusion Welding Processes

In this, the joining operation involves melting and epitaxial solidification, and any external forces applied to the system play no active role in producing coalescence.

5. CLASSIFICATION OF WELD DEFECTS

The defects that are encountered during a welding process can be classified into four main categories.

Defects Involving Inadequate Bonding

Interference weakning in pressure welds
Incomplete penetration welds

Foreign Inclusions

Oxides films in fusion welds
Slag inclusions
Delamination
Tungsten inclusions in Gas Tungsten Arc Welds.

Geometric Defects

Undercutting
Excessive reinforcement

Metallurgical Defects

Defects related to microsegregation

Hot cracking and microfissures
Cold cracking and delayed cracking
Stress-relief cracking
Strain-age cracking
Gas porosity

Problems arising from metallurgical phenomena

Embrittlement
Structural notches in pressure and fusion welds.

6.0 EVALUATION OF A WELD

The only sure method of evaluating a weld is to test it exactly as per service conditions and whether it performs satisfactorily during its intended life time. Even though service testing may be the ideal method of weld evaluation, economical and time limitations often preclude this. Therefore, accelerated performance or proof tests together with numerous destructive tests on weld pads and non-destructive tests on weld pads and components are currently employed to predict the performance of a given weld.

7. DESTRUCTIVE TESTS

Destructive tests like longitudinal and transverse tensile tests, nick-break tests, root, face and side bend tests, nil ductility transition temperature tests (NDTT), drop weight tests, macro-etch and metallographic examination and chemical analysis on welds have been well established for evaluating the weldments. The specimens used for the above tests are usually rather small and may or may not be representative of actual production weld in question. Samples for examination may be specially prepared test pads which are prepared by the same welding methods as the production weld or they may be samples trepanned from an actual production weld. Direct information is obtained concerning the actual properties of the weld such as strength and ductility. However, disadvantages of destructive tests are that they are slow and costly and give information about the weld samples only. Destructive tests by themselves are not sufficient to properly evaluate present day welds in critical components,

8. NON-DESTRUCTIVE TEST METHODS

Non-destructive test methods are required to obtain the necessary information for evaluating welds which are to be placed in service. The primary advantage of the NDT methods is that the product can be examined without destroying its usefulness. These can be rapidly applied to 100% of the welds being produced.

Quality characteristics of welds such as cracks, inclusions (metallic and non-metallic), porosity, lack of penetration, lack of fusion, lack of bond, undercut, alloy identification, alloy composition etc. can be evaluated by NDT methods. Present range of NDT techniques and evolved capabilities of NDT techniques promise evaluation of weld joints for the most stringent service conditions. However, proper choice of materials, welding processes, etc. is a necessity to do cost effective and reliable NDE. Choice of the technique or complement techniques should be carefully selected to ensure structural integrity during designed life of weld.

9. MEASUREMENT AND CONTROL OF WELDS

To achieve quality weldments, adequate measurement and control of welds during fabrication is essential and an important requirement.

During welding of a material, heating and cooling induces thermal stresses in the weld metal and base metal regions near the weld. The strains produced during heating may be accompanied by plastic upsetting. The strains due to stresses can also combine and cause distortion. Presently, there is no welding process that completely eliminates distortion. However, the extents of distortion varied considerably depending on welding process and welding parameters. The factors during the welding process that contribute to the distortion include welding sequence, heat input, degree of restraint, joint details, material thickness and the preheat inter-pass temperature, etc. Although the distortion in welding is inevitable, welding process can be suitably chosen and welding parameters are optimised so as to minimise the distortion to acceptable levels. To this effect, measurement and control of welds play an important role. Measurement and control of welds also ensure achieving the desired geometrical tolerances and quality levels.

10. CONCLUSIONS

The basic need for Testing, Measurement and Control of Welds and the significance of the destructive and non-destructive tests employed to achieve the above requirement has been emphasized.

To promote better understanding and importance of Testing, Measurement and Control of Welds, this is the first one of a series of articles intended to be published in the Indian Welding Journal.

WELDING INDUSTRY BUYERS GUIDE

NAME OF COMPANY	WELDING CONSUMABLES																			WELDING EQUIPMENT							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	1	2	3	4	5	6	7	8
ADVANI OERLIKON LTD	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●		●	●		●	●		●	●
ARIM METAL INDS PVT LTD														●													
ASIATIC OXYGEN LTD	●																			●		●					
D & H SECHERON LTD	●			●	●	●	●	●	●	●	●	●	●	●				●									
EWAC ALLOYS LTD			●														●	●	●			●					
GENERAL ELECTRODES & EOPT LTD				●	●	●	●	●	●	●	●																
INDIAN OXYGEN LTD	●	●	●	●	●	●	●	●		●	●	●		●	●	●		●		●	●	●		●	●	●	●
INDUSTRIAL GASES LTD	●		●	●		●	●	●	●	●	●	●	●		●					●	●	●		●			
KARNATAKA WELDING PRODUCTS LTD												●									●					●	
KIRLOSKAR ELECTRIC CO LTD																				●	●		●	●		●	
KOBE STEELS PVT LTD				●	●	●	●	●	●	●	●																
MODI ARC ELECTRODES CO				●	●	●	●	●		●	●	●															
PEICO ELECTRONICS & ELECTRICALS LTD				●	●	●	●	●	●	●	●	●		●						●	●						
ROCKWELD ELECTRODES INDIA LTD				●	●	●	●	●		●																	
SOUTHERN ELECTRODES LTD				●	●	●	●	●	●	●	●																
WELDCRAFT PVT LTD			●	●	●	●	●	●	●	●	●			●				●									
WELDING RODS MFG CO				●		●		●			●																

WELDING CONSUMABLES

1. Gas Welding Filler Materials
2. Brazing & Soldering Alloys
3. Fluxes for Brazing, Soldering & Welding
4. Mild Steel Electrodes for General Fabrication
5. Cellulosic Electrodes
6. Hydrogen Controlled Electrodes
7. Iron Powder Electrodes
8. Stainless Steel Electrodes
9. High Nickel Alloy Electrodes
10. Hardfacing Electrodes & Powder
11. Electrodes for Welding of Cast Iron
12. TIG/MIG/SAW Filler Materials for C–Mn Steels
13. TIG/MIG/SAW Filler Materials for Low Alloy Steels
14. TIG/MIG/SAW Filler Materials for Stainless Steels
15. TIG/MIG/SAW Filler Materials for Aluminium
16. Gas Mixtures for TIG/MIG Welding
17. Flux Cored Wires for Welding & Surfacing
18. Low Heat Input Welding Alloys for Maintenance Welding
19. Metal Powder Alloys for Surfacing

WELDING EQUIPMENT

1. Arc Welding Equipment
2. TIG/MIG/SAW/Plasma Cutting Equipment
3. Gas Welding Equipment
4. Welding Generators
5. Welding Fixtures & Positioners
6. Large Cutting Machines
7. Special Purpose Custom Built Welding Equipment & Systems
8. Drying Ovens and other Accessories for Welding