Impact and Measurement Techniques of Residual Stress in Welding of Bimetallic Material

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Abstract

Objectives: The welding techniques are being developed at a very fast pace with novel and efficient techniques coming up for unconventional cases such as dissimilar metal joints between plates of various types, which have various practical applications, like in nuclear power plants. **Methods/Statistical Analysis**: A few strategies and procedures have been proposed furthermore have been connected for measuring residual stress (σ_R) in a few metals. Some of such strategies are: stress relaxation procedures, X-Ray Diffraction methods, Techniques utilizing stress touchy properties and Cracking systems. In addition, endeavors have additionally been made to use ultrasonic and hardness strategies to decide remaining burdens in metals by measuring stress sensitivity properties. **Finding**: Failure investigations of many dissimilar joints and literature review have revealed that several failures of the dissimilar welded joints have taken place in the Heat Affected Zone [HAZ]. One of the major reasons for failure of dissimilar welded joints is the untreated left residual stresses. In the present paper a brief description of the ideology of bimetallic weld processes, their capabilities and restrictions, phenomenon and types of σ_R and their treatment techniques is presented. The overall impact of σ_R and their measurement techniques have also been discussed. **Application/Improvements**: There are numerous applications of dissimilar metal joints such as in automotive industry, power generation industry etc.

Keywords: Dissimilar Metals, Residual Stress (Σ_r), Measuring Techniques of Σ_r

1. Introduction

Quick advancement and change of welding strategies, driven by the requirement for minimal effort and weight sparing, there is a potential pattern to supplant bolts and clasp with welds in association of basic segments. The advantages of welding, in regard of joining process, incorporates high joint proficiency, basic set up, adaptability and low set up fabrication costs. Despite the fact that welding has numerous advantages, fusion welding can change the properties of the material and might lead to redirection, shrinkage and/or σ_R in the joint. The main use of post weld heat treatment is to assuage the residual stress generated because of welding.

The welding technique is utilized as a part of all commercial projects. The circumferential butt-weld is a very commonly used to join stainless steel pipes and very few passes are used in such welding cases. Severe case of heating and cooling occurs in such cases due to more than normal concentration of heat in welding areas for such cases. In the surrounding areas of σ_R the resulting stress may cause lot of damage to material, corrosion etc[1]. While designing to eliminate the possibility of occurrence of deformities residual stress must be taken into consideration along with deign loads [2]. To meet certain specific condition the σ_R are

to be reduced in the main weld areas. For multiple pass welding system the estimation of welding system depends on many variables and is very hard to determine as the range and types of stresses are numerous.

2. Technology of Bimetallic Welding

2.1 Bimetallic Weld

In the industry, distinctive parts work at different administration conditions and from now on legitimate materials are used for these fragments structures. The sections which work at high temperatures are of stainless steels and those working at minimum temperatures are made of ferrite steels. In this way, divergent joints are vital for associating the portions/structures made of different materials. For instance, one of kind metal joints between funnels of ferrite steels and austenitic stainless steels is used as a piece of steam generators. Exceptional metals joints are slanted to consistent failures 3 and these disappointments are primarily in view of the accompanying reasons: 1. Contrast in properties over the joint and coefficients of warm expansion [CTE] of two sorts of steels and the crawl at the interface 4, 2. Issues in general alloying of two various base metals 5, for instance, fragile stage development and weakening, 3. Development of carbon from ferrite steel into the stainless steel6, which incapacitates the HAZ in ferrite steel, 4. Specific oxidation on the interface 7, 5. Nearness of remaining anxieties in the weld joints, 6. Benefit states of various components8 et cetera.

Working learning with unique welding joints has moreover exhibited that a significant number of disappointments happened under the ordinary administration life9. An extensive part of the move joint disappointments in austenitic and ferrite steels joints happen in warmth impacted zone of the ferrite steel which is close to the weld interface there is a strong verification in power plants, that remaining anxiety is a critical explanation behind breakage in welds and HAZ areas in the midst of administration. These weld joints incorporate the use of a midway Inconel-82 buttering on the ferrite steel and stretch soothing warmth treatment [SRHT] at 998 K [725 8C] preceding the finish.

There are various procedures to evaluate the remaining anxiety scattering. Prior, welding remaining anxiety examination used simply test estimation schedules. These techniques can be parceled into two classes. One

is harming framework. For instance, gap penetrating and strain gage was utilized by String and Pukas 10 to quantify stresses. Another technique is non-ruinous. For instance, the remaining anxieties in a weld globule were measured by Chandra 11 and Brand 12 utilizing X-Beam Diffraction [XRD] systems.

2.2 ΣR

The stresses which remain in a body after it has been manufactured and processed, without external powers or thermal gradients are known as residual stresses[13]. The heat regions appear to form groups in nearby regions of weld line due to fluctuating thermal cycles. It causes non uniformity of material resulting in irregular plastic deformation and σ_R which are generally ductile in nature[14]. While surveying the danger for development of deformities, for example, surface imperfections in layouts of pipe networks, σ_R are more important as compared to stress brought on by configuration loads[15]. In addition, with a specific end goal to avert between granular stress erosion splitting and to meet certain specific condition the σ_R are to be reduced in the main weld areas. For multiple pass welding system the estimation of welding system depends on many variables and is very hard to determine as the range and types of stresses are numerous.

It is therefore in the case of multi-pass welding that it becomes very difficult to predict formation and determination of the σ_R[16]. Residual stress, which shows up amid various phases of the manufacturing procedure of basic components or their working, might apply an extensively negative impact on both the structures static quality and weakness life-time.

2.3 Types of σ_R

σ_R can be classified by the scale in two categories, over which they self-equilibrate, or as indicated by the system by which they are measured[17]. They can be characterized as large scale or small scale stress which can be available in a part at one time. Full scale σ_R, which are regularly eluded to as Type 1 σ_R, shift inside of the body of the part over an extent much bigger than the grain size. Type 2 or 3 miniaturized scale σ_R comes about because of contrasts inside of the microstructure of a material. Type 2 σ_R are smaller scale σ_R which focus on the work at the grain-size level. Further, Type 3 is created at the nuclear level[18].

Smaller scale residual stress regularly comes out because of the vicinity of various stages or particles present

in a material. These stresses can change sign and/or size over separations equivalent to the grain size of the material under examination. In nutshell, σ_R can be classified as:

- Type 1 - which allude to full scale residual stress that is created in the body of a segment on a scale, which is bigger than the grain size of the material.
- Type 2 - These are small scale σ_R that varies in the size of an individual grain. These stresses might be relied upon to prevail as single-stage materials in view of anisotropy in regard of the conduct of every grain.
- Type 3 - These stresses might be generated in multi-phase materials due to the distinctive properties of the diverse stages that are miniaturized scale residual stresses, which exist inside a grain, basically due to consequence of the vicinity of disengagements and also other crystalline imperfections.
- Types 2 and 3 are generally gathered altogether as smaller scale stresses. When the results from different techniques are compared, sampling volume and resolution of each measurement method should be kept in focus in relation to the type of σ_R being measured, especially when the Type II and type III micro σ_R are of interest.

2.4 Origins

σ_R develop during most manufacturing processes also including material disfigurement, heat treatment, machining or handling operations that lead to the change in the shape or properties of a material. These emerge from various sources and can also be present in the natural crude material, presented amid manufacturing or can also emerge from the service loading.

The origins of residual stress in a particular component can be classified as:

- Mechanical
- Thermal
- Chemical

2.4.1 Mechanically Generated ΣR

Mechanically created σ_R is mainly the outcome of production procedures which deliver non-uniform plastic distortion. These stresses might grow normally amid handling or treatment, or might be acquainted intentionally with add to a specific stress profile in a part. Cases of operations that deliver undesirable surface ductile stresses

or σ_R inclinations are pole or wire drawing, welding, turning and grinding [ordinary or rough circumstances]. Compressive residual stress generally prompts execution advantages and can be presented by shot penning, autofrottage of weight vessels, toughening of glass or cold extension of gaps.

2.4.2 Thermally Generated ΣR

On a macroscopic level, the thermally created σ_R is frequently the result of non-uniform heating or cooling operations. Combined with the material requirement in the majority of an expansive segment this can prompt serious thermal inclinations and the improvement of huge internal stresses. A case is the extinguishing of steel or aluminum compounds, which prompts surface compressive hassles, balanced by tensile stresses in the real part of the segment.

2.4.3 Chemically Generated σ_R

The synthetically produced σ_R can erupt because of changes in volume connected with chemical reactions, precipitation and stage change. Concoction surface medicines and coatings can provoke the era of significant σ_R slopes in the surface layers of the section. Nitridine generates compressive stress (σ_c) in the dissemination area on account of extension of the cross section and also precipitation of nitrides and carburizing lead to a comparative impact.

2.4.4 Effect of σ_R

σ_R adversely affect the behavior of the structure. High tensile σ_R in areas close to the welding region produce rough surface rupture. A significant detrimental effect of this σ_R is the inter-angular stress corrosion cracking in austenitic stainless steel. Also, in addition such stresses appear to accelerate all forms of corrosion. The buckling strength may be reduced by compressive σ_R and initial distortion. The effect of σ_R in ductile materials fracture is negligible[19] but is quite dominant when superimposed with other type of stresses the material may experience.

2.5 Prime Causes of Formation of Residual Stresses

- Material of electrode and material to be welded.
- Type of weld i.e. its shape and dimensions.
- The ratio of weld metal and main material weight.

- Type of joint and method used in making weld [e.g. tacking, back-step sequence, etc.].
- Heat input into the weldment i.e. on flame size in oxyacetylene welding; and current, electrode size and welding.
- Speed in arc welding.
- Type of structure and neighboring joints.
- Expansion and contraction [free or constrained component].
- Rate of cooling.
- Stresses already present in the weld metal[20].

2.6 Methods of Relieving or Controlling Welding σ_R

σ_R are virtually elastic deformations which possess some potential energy accumulated in a body. The main feature of residual stress relieving is that they can be avoided only through metal plastic deformation, where, how and when to develop deformation are important points of the problem. The choice of residual stress relieving method greatly depends on the kind of σ_R and its negative effect on the weld structure. Reducing welding σ_R consists, of the following possibilities:

- Decreasing the level of residual stresses, in particular the maximum tensile stress level
- Decreasing the zones with high residual stresses
- Decreasing the degree of multi-axiality of residual tensile stresses

To achieve these aims the following methods are employed:

- Design consideration
- Material consideration
- Heat treatment
  - Mechanical stress relieving process
  - Shot penning
- Hammer penning
- Vibration stress relief
- Explosive treatment.

2.7 Residual Stress Measuring Techniques

Several methods are tried and tested also have been utilized for determining the σ_R in metals.

- Stress relaxation techniques,
- X-Ray Diffraction methods.

- Techniques utilizing stress sensitive properties.
- Cracking methods.

Elastic strain release is measured to determine the residual stress in Stress relaxation technique. This happens when due to the cutting of specimen into two parts the σ_R are relaxed, or a piece can also be removed from specimen. Strain discharged amid push unwinding can be resolved utilizing a matrix framework, weak coatings or photograph flexible coatings or electrical or mechanical strain gages.

3. Conclusion

In the current research paper detail study the impact of σ_R on bimetallic weld were discussed the σ_R are of great importance while calculating the overall strength of the weld. These effects on the mechanical properties of the weld should be taken care to avoid cracks and other defects. Various residual σ_R measurement techniques were discussed in this paper.

4. References

1. Deng D, Luo Y, Serizawa H, Shibahara M, Murakawa H. numerical simulation of residual stress and deformation considering phase transformation effects (mechanics, strength and structural design). Transactions of Joining and Welding Research Institute. 2003 Dec; 32(2): 325–33.
2. Radaj D. Welding ΣR and Distortion Calculation and Measurement. Elsevier Science and Technology; 2003.
3. Davis SR. Hard facing, weld cladding and dissimilar metal joining. ASM International. 1993:789–829.
4. Klueh RL, King JF, Griffith JL. A simple test for dissimilar-metal welds. Welding Journal. 1983 Jun:1-6.
5. Emerson RW, Hutchinson WR. Welded joints between dissimilar metals in high temperature service. Welding Journal. 1952; 31(3):127s–41s.
6. Lundin CD. Dissimilar metal welds-transition joints literature review. Welding Research Supplement. 1982 Feb:1–15.
7. Singh Raman RK. Role of microstructural degradation in the heat affected zone of 2.25 Cr-lMo steel weldments and sub scale features during steam oxidation and their role in weld failures. Metallurgical Material Transaction. 1998 Feb; 29A(2):577–86.
8. Bruscato R. Temper embrittlement and creep embrittlement of 2.25 Cr-Imo shielded metal arcs weld deposits. Welding Journal.1970 Apr:1–9.

9.   Eckel JF. Diffusion across dissimilar metal joints. Welding Journal. 1964; 43(4):170s–8s.

10. Pang CS, Pukas MW, Park JH. Investigation of welding residual stress of high tensile steel by finite element method and experiment. Korean Society of Mechanical Engineers International Journal. 1999 Dec; 13(12):879–85.

11. Chandra D. A numerical thermo-mechanical model for the welding and subsequent loading of a fabricated structure. Computer Structure.1973 Sep; 3(5):1145–74.

12. Brand B. Determination of residual stress in submerged arc multi-pass welds by means of numerical simulation and comparison with experimental measurements. Welding World. 1994 Jan; 33:152–9.

13. Katsareas DE. Residual stress prediction in dissimilar metal weld pipe joints using the finite element method. Materials Science Forum. 2005 Jul; 490-491:53–61.

14. Murugan S, Rai SK, Kumar PV, Jayakumar T, Raj B, Bose MSC. Temperature distribution and residual stress due to multi-pass welding in type 304 stainless steel and low carbon steel weld pads. International Journal of Pressure Vessel and Piping. 2001 Apr; 78(4):307–17.

15. Brickstad B, Josefson BL. A parametric study of σR in multi-pass butt-welded stainless steel pipes. International Journal of Pressure Vessel and Piping. 1998 Jan; 75(1):11–25.

16. Dang D, Kazumurukawa H. Numerical simulation of temperature field and residual stress in multi-pass welds in stainless steel pipe and comparison with experimental measurement. Computational Materials Science. 2006 Sep; 37(3):269–77.

17. Bose MSC, Raj B. Residual stress analysis in weldments. Theoretical Approach Indian Welding Journal. 1996; 29(4):7–23.

18. Masubuchi K, Hopkins DW. Analysis of welded structure. Elsevier; 1980.

19. Kobayashi A. Experimental Mechanics. 2nd Rev ed. New York: VCH Publishers; 1990.

20. Lobanov L, Pivtorak V, Savitsky V, Tkachuk G. Determination of residual stress in structural elements using electron speckle interferometry method. 13th International Conference on Fracture China; 2013 Jun. p. 1–9.

21. Moore AJ, Tyrer JR. Two-dimensional strain measurement with ESP. Optical Laser Engineering. 1996 May; 24 (5–6):381–402.