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A Review Paper on Reduction Mechanism of Porosity in Welding Process

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Abstract: The porosity is a defect in a weld, which results in weakening the strength of the joint and corrode the metal parts by depositing impurities like moisture and atmospheric contaminant. This defect is caused due to disturbance of external impurities like oxygen, nitrogen, hydrogen, etc., in the molten weld pool. In fact, most of the industrial and manufacturing companies play a key role in finish products. Besides, there is substantial use of welding in building construction and therefore the quality of welding effects the strength of welded structures. In general, the entire product quality depends on the weld quality, irrespective of the type of weld being used. The many researchers have examined the different mechanisms to reduce the porosity such as adjusting the pulse frequency, a set of arc current, depth of penetration, proper application of welding parameters, enough duration to solidification process, etc. This review paper will disseminate the preventive measures to reduce the porosity as a collective idea in a small amount to count for big volume.
Keywords: porosity, impurities, contaminant, depositing and penetration.

I. Introduction

The welding defects are caused due to improper use of welding parameters in the filler metal and parent metal. This defect has the potential to be dangerous resulting in failing of joint, not able to withstand the required load and poorly finished products. Welding is a metal joining process wherein the metals are joined together by melting the base metals and filler metal, infusion of the molten metals and solidification. In the welding process, it involves large amounts of heat energy that effects the welded area to molten metal. It is used in producing a designed product in industrial and manufacturing companies, as reasons every individual technical must know the importance of defects otherwise it leads to products residual stresses, ultimately weaken the links in the welds, etc. In this paper, section II contains a literature review, followed by a section III review analysis, IV conclusion, and finally reference in section V.

II. Literature Review

(HAYASHI Tomotaka et.al. 2002)[1] 'Reduction mechanism of porosity in Tandem Twin-Sport Laser Welding of Stainless Steel' the authors study on the formation of porosity in leaser weld bread penetration caused by the low and high power co_2 laser welding utilizing a single spot and tandem twin-spot beam strike on the thick plates of Type 304 steel. It determines the feasibility of porosity prevention and establishing the optimum conditions in a single spot and tandem twin-sport welding. Initially, porosity formation tendency was inspected in the partial penetration weld in a single-spot co_2 of the laser beam at low speed followed by tandem twin-spot laser beam welding. It used micro-focused X-ray transmission in-situ observation system with a high-speed video camera for the result. At the end, it found many pores near the bottom parts of the weld beads without and with the assist of gas at the low exceeding 10 and 15Kw, but in twin-sport laser beam the numbers of pores were found to be drastically reduced. It also observed similar results in the high power laser welding in a single spot beam as well as twin-spot welding respectively.

(KATAYAMA Seiji et.al. 2006)[2] 'Physical Phenomena and Porosity Prevention Mechanism in Laser-Arc Hybrid Welding' this experiment is to determine a porosity preventive mechanism using Hybrid welding of stainless steels with the heat sources of YAG laser and TIG respectively. In their experiment, it was observed that the defect in the weld was due to welding conditions, penetration depth, geometry, and porosity formation with the X-ray transmission real-time. It was also found generating of bubbles and porosity formation tendency depended upon the welding parameters. In the hybrid welding at 100A, the porosity increased in comparison with that in the laser welding. Especially at 200 A, the top diameter of the keyhole inlet was slightly wider and the surface of the molten pool was concave due to the strong gas stream stress or arc pressure, only a few bubbles were generated in the molten pool, resulting in a reduction of porosity. It was confirmed in both laser and hybrid welding of steel the penetration and geometry of weld bead depended on the volume of oxygen in the ambient atmosphere.

(Jun Zhou and Hai-Lung Tsai, 2007)[3] 'Porosity Formation and Prevention in Pulsed Laser Welding'the formation of porosity was studied. The porosity was regularly observed in solidified form; it uses mathematical models for systematically investigating the transport phenomena leading to the formation of porosity and to reduce porosity formation in laser welding. It expresses mainly two competing factors: the solidification rate of the molten metal and backfilling speed of the molten metal during the keyhole collapse process. This formed when the solidification rate of the molten metal exceeds the backfilling speed of liquid metal during the keyhole collapse and solidification processes. The formation of porosity is witnessed to be strongly related with the depth-to-width aspect ratio of a keyhole; larger the ratio, easier porosity will be formed, and the larger the size of a void. Besides, it also proposed to control the laser pulse profile to prevent porosity in laser welding. It concludes that porosity in laser pulse shape is controlled due to the delaying of the solidification process, allowing the liquid metal in a weld pool to easy flow downward to fill up the keyhole.

(Mamoru Nishihara et. al. 2011)[4] 'Some Factors Affecting Porosity of Inert-Gas Arc Welded Ti Metals'. This experiment was to determine the factors that effects the porosity usinga joint in pure Titanium with blowholes both TIG andMIG inert-gas shield welding process by X-ray examination. The tendency of "blowhole development" was done in butt joints of 5 mm thick commercial pure Ti plate as a specimen. In this process, it involved conditions like shielding inert-gas as pure, welding geometry, welding current, welding speed, feeding rate of filler wire and appearance of filler wire as factors. It was observed that:

i. In MIGwelding process, it was less susceptible toblowhole, and more suitable than TIG welding to obtain better welds.
ii. Welding under atmosphere containing nitrogen, oxygen, and hydrogen are more susceptible toblowhole than under pure Argon atmosphere.
iii. Cleanliness of the work and smooth surface of filler, and wire were necessary factors to obtain sound welds.
iv. Quality of welds depended on suitable ranges of current and welding speed.

(Chen Gao and GAO Ziying 2013)[5] 'EFFECT OF WELDING PROCESSING PARAMETERS ON POROSITY FORMATION OF MILD STEEL TREATED BY CO2 LASER DEEP PENETRATION WELDING'. Porosity is caused due to minimal welding penetration in low carbon steel, which affects the quality. In this experiment, mild steel was taken as a specimen for the high-quality requirement of welding using high power co_2 laser generator. It uses a cutting cross section of weld seam to analyze the numbers of porosity and to observe the morphology and its porosity location in the weld. Finally, it was observed that:

i. It leads the porosity in unstable of a keyhole in the process of co_2 laser penetration in low carbon steel.
ii. The porosity is formed due to the speed of bubble escaping from a weld pool is lower than the speed of melting metal solidifying.
iii. While increasing the shield gas flow, the porosity number presents a curve of increase at first and then decreases.
iv. The porosity decreases as deeper the penetration of welding and increases as the laser a beam inclination angle of 22.5º respectively.

(Ramanjeet Singh et al., 2014) [6] 'A Review of Porosity Formation and Recommendations on the Avoidance of Porosity in TIG Welding of Steels'. The objective of this review report was to investigate the causes of welds porosity defect and suggested preventive measures to minimize the weld defects. In this paper, it examined the porosity could adversely affect in mechanical properties and performance of a service. Finally, to avoid porosity in TIG welding can be summarized as follows;

i. Check the leakage in torch connections and gas hoses.
ii. Proper cleaning of the joint and filler wire to avoid moisture, grease, etc.
iii. Clean with a wire brush in the joint areas.
iv. Adequate shielding gas coverage of the weld pool must be provided.
v. Adequate gas flow rates should be maintained.
vi. Proper selection of welding parameters

(Yimin YUAN et.al. 2015)[7] 'Relationship between penetration and porosity in horizontal fillet welding by a new process "hybrid tandem MAG welding process"'. In this, it discussed on a formation of porosity in the primer painted on the surface of steel plates to prevent from rust, but, when welding on primer-coated plates, the arc heat decomposes and vaporize the coating. Then it generates the gas during the solidification process leading to porosity defects like blowholes and pits. In order to overcome a porosity in primer-coated steel plate the following remedial measures are effective:

i. Increase the depth of penetration.
ii. Decreasing the non-penetrated joint root length.
iii. Reduce the leading electrode torch angle.
iv. Combination of high-current and low-voltage welding to create the buried arc to realize the above measures.

(J. WANG et.al 2015)[8] **'**MECHANISMS OF THE POROSITY FORMATION DURING THE FIBER LASER LAP WELDING OF ALUMINIUM ALLOY' this is the biggest challenge in the joining of aluminum alloys as forming a porosity and it deteriorates mechanical properties. The experimentinvolves lap welding on an aluminum alloy 5754 metal sheets with a thickness of 2 mm. It used X-ray inspections to observe the welding quality and at the end the laser-welding parameters have great effects. The way to control a porosity is solidification duration of the molten pool; if the duration of the molten pool is large enough, maximum bubbles can escape from a molten pool and less porosity will be obtained.

(Paul Kah et.al. 2015)[9]**'**Investigation of weld defects in friction-stir welding and fusion welding of aluminum alloys' it determines the welding defect based on address arising from different agencies to emphasize on energy saving and ecologically sustainable products and moreover to provide innovative solutions in environmental issue. In addition, it can meet industries requirement for greater productivity and minimize the operational costs. It was analyzed that the relationship between friction-stir welding process parameters and weld defects. In was concluded that the defect was due to metallurgical aspects that influence weld metal microstructure and arc weld of aluminum alloys respectively.

(Blecher, J. J. et.al. 2016)[10] **'**Porosity in thick section alloy 690 welds - Experiments, modeling, mechanism, and remedy' it is to examine a porosity using laser and hybrid laser-arc welding for thick section welding of nickel-based alloys in construction and repair of nuclear power plant components. Unfortunately, its impact on the fusion zone geometry and defect levels in Alloy 690 could not be understood, even then, the series of laser and hybrid laser-gas metal arc welds were used with varying laser powers and welding speeds. Finally, internal macro-porosity was detected by x-ray computed tomography, porosity levels attributed to keyhole, instability, and collapse remained high in the laser welds in all power levels. In the other hand hybrids, laser-arc welds inhibited the formation of porosity at laser powers in excess of 4 kW. Moreover, it also determines the geometry of the fusion zone and the filler metal mixing region in the weld pool using three-dimensional heat transfer and fluid flow model. In result, it found, the porosity in Alloy 690 hybrid welds will be eliminated only if the laser heat input and arc conditions are properly selected. Further at the lower laser powers with a combination of high-speed filler metal to prevent bubbles escaping from small pool size.

(Junhao Sun et.at. 2017) [11]'The characteristics and reduction of porosity in high-power laser welds of thick AISI 304 plate'. This experiment was to determine the reduction of porosity in the 304 stainless steel laser welds, a laser power of 10kW with different welding speeds and shielding gases. The record was examined with the help of a high-speed video camera. The suppression of the porosity was made in N2 rather than Ar or He shielding gases. It was observed that the porosity was produced only at the root and less than 0.02 mm^3. In addition, the solubility of N2 in the liquid melt pool also contribute to the reduction or elimination of the porosity in the 304-L laser welds. Severe porosity was formed in the laser welds when Ar and He was used as a shielding gas during high-power laser welding of AISI 304L.

(Guoxiang Xu et al. 2019)[12]**'**Influence of Arc Power on Keyhole-Induced Porosity in Laser + GMAW Hybrid Welding of Aluminum Alloy' A three-dimensional numerical model was applied to simulate heat transfer and fluid flow phenomena in fiber laser + gas metal arc welding (GMAW) hybrid welding of an aluminum alloy to investigate induce of porosity. It incorporates three-phase coupling and to depict the keyhole dynamic behavior, but found to be keyhole-induced porosity. It also examined the calculation and percent porosity of weld bead in different conditions using X-ray non-destructive testing (NDT). This compute result was based on the agreement with the experimental data. Result, in hybrid welding, with an increase of arc power, the keyhole-induced porosity, besides the solidification rate of the molten pool. A relatively steady anti-clockwise vortex caused by arc forces tends to force a bubble to float upward at the high-temperature region close to the welding heat source, which benefits in the escape of gas bubble from the melt pool. However, another hand increase of arc power, the anti-clockwise region was strengthened; result in a risk of a gas bubble for capture by the liquid/solid interface underneath the keyhole tip, which result in lower the weld percent porosity.

III. Review Analysis

This review analysis is based on the solution referred from the authors to enrich in welding quality. It discusses the technique to ensure quality in weld such as penetration of weld, the geometry of weld bead, metallurgical aspect, a setting of suitable current and welding speed. In addition, it depends on other factors like a short period of solidification cause trapping of air in the molten pool leads to porosity in weld joint and vice versa.

IV. Conclusion

The formation of porosity is observed in relation to the depth-to-width aspect ratio of the keyhole; larger the ratio, the easier porosity formed, and the larger the size of the voids. It was also learned that the porosity is due to the speed of bubble escaping from the weld pool is lower than the speed of melt metal solidifying. The significant key to measuring the control of porosity is large enough solidification duration of the molten pool, in which the bubbles can escape freely from the molten pool and less remain as porosity. The othercauses are due to improper application of welding parameters, leading electrode torch angle, non-penetrate joint root length and impurities involve in the welding process.

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