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Study and establishment of skill assessment parameters for weld gouging operators

Kumar Sawrav[1*], Rupam Bhattacharjee[2], Sovan Lal Das[2]

[1*]Department of Mechanical Engineering, Indian Institute of Technology Kharagpur, Kharagpur, West Bengal, India, Pin 721302

[2] Representative experts of the fabrication industry

***Corresponding Author**
E-mail address: kumarsawrav@gmail.com

Abstract

Carbon arc-air gouging is a standard technology for repairing defects in welded structures. The skill of weld gouging operators is equally important, as the skill of welders involved in welding and weld rectification is essential. The skill of gouging operators is considered necessary considering their capability to identify defects during gouging, optimized gouging to avoid joint damage of puncher, process safety etc. but no established documentation or standards are available which will give guidelines to fabricators to judge the skill of gouging operators through proper skill assessment and certification. This work presents detailed guidelines for skill assessment and certification of gouging operators for fabricators to refer. Parameters consisting of safety, pre-operational check, technique, defect identification & post-gouging operation checks have been considered for gouging. The skill assessment process involves observation, asking questions & physical sample testing and scoring of individual points of the questioner, which is multiplying factor of weightage & score obtained. Weightage needs to be adjusted by individual fabricators considering their criticality of operation. A standardized matrix has been established.

Keywords: Gouging; skill; skill assessment; certification; welding; repair.

1. Introduction

Carbon arc-air gouging is a common technology when repairing defects in welded structures. This technique is often applied in repeated cycles, even on the same joint location. Due to the multiple heat input by Gouging and subsequent re-welding, the residual stresses are strongly influenced. This can become crucial when microstructure and mechanical properties are adversely affected by multiple weld reparations. Knowledge about the relationship between Gouging and residual stresses is scarce but important when high-strength steels, sensitive to residual stresses, are processed [1]. During the fabrication of steel components, non-destructive testing for quality control is frequently applied. Emerging failures are often treated locally by repair welding. In this case, multiple repair cycles may be required to eradicate the failure. Standards do not limit the number of such repair cycles. Therefore, how the number of repair cycles influences the mechanical properties and residual stresses is unknown. These stresses become important when high-strength steels are applied, which are more sensitive to residual stresses due to their limited ductility. For the removal of weld defects, carbon arc-air gouging is a commonly used method during fabrication. The advantage is the excellent failure-finding ability due to the good accessibility, even on the edges of a component. Carbon arc-air gouging uses a copper-covered graphite electrode. Typical diameters are 6, 8 or even 10 mm. A positive polarity is used for the electrode when gouging steel. The specific current load reaches from 10.5 A/mm² for a 6 mm diameter electrode to 7.5 A/mm² for a 10 mm diameter electrode. The molten material is blown out of the weld by an air stream. The gouging depth is controlled by the angle of approach, which is usually between 30° and 45° [2-3]. Similar behaviour may be expected from slit welds used to evaluate welds' cold cracking behaviour. The notch created by Gouging is comparable to the slit used in specific tests [4-8]. Published data reveals that the residual stresses in such tests are influenced by slit characteristics, i.e., length [4-5] and position in the sample [9-10], and the stiffness

(restraint intensity) of the test pieces [6]. Nevertheless, the number of Gouging and respective repair welding cycles has not been investigated yet. While plasma gouging is not a new concept, little has been presented on subjects such as terminology, how the gouge is produced, and the relationships between process parameters. Seeks to present this information to help aid in the gouging process design [7]. Welding came into its own in the 1930s leading up to World War 2. Born out of a need to fuel the war effort, firms that supplied equipment rich in welded features needed more efficient manufacturing methods. During this era, welding processes and engineering saw significant levels of evolution. As specifications drove engineers to design better products, more strength and durability in welded joints were required. By necessity, innovation in welding followed suit. By applying engineering principles and experimental techniques, technologists learned more about materials, interactions, and processes. Previously a collection of tools and techniques driven by tribal knowledge, welding evolved quickly from a trade to a science. Though much more sophisticated than earlier, welding still required preparation and repair. The need to gouge away material was identified to address this process step. Early methods consisted of mechanical means of removing the material (i.e., grinding and chipping). Carbon arc gouging was then developed by Myron Stepath in the 1940s using the welder itself and a carbon electrode to melt metal. Over time this became the default method to gouge [7]. Air carbon arc gouging is a relatively inexpensive process for removing or cutting metal more rapidly than grinding, flame gouging, or chipping. An arc is established between a carbon-graphite electrode and the workpiece, and the metal by the arc is blown away by a high-velocity air jet directed at the arc. The process can be used in several applications, including cutting or trimming parts to size, removing excess metal, and cutting bevels for weld preparation. Unlike oxyfuel gas cutting, the new process can be used for most metals of engineering importance, including those that produce high-melting refractory lags [11]. Tests have been carried out on the Arc Air Gouging Process to assess the effectiveness of exhaust ventilation systems and protective equipment against fume and noise. The measures are described in some detail. The results show that adequate protection can be achieved by using an exhaust booth with a face velocity of 300 lpm. Investigation into the efficiency of an air-fed welding visor showed that it reduced exposure to particulate fume by about 80 per cent and could thus find use in workshops and semi-confined spaces (coupled with local exhaust ventilation). Measurements of the noise generated confirmed the existence of a serious hazard to hearing, but the use of certain ear defenders can provide the necessary protection [12]. During the Gouging, the process measured the concentration of the microparticles with Micro Dust 880mm detector. The results obtained after the gouging operation were analysed with a scanning electron microscope to characterize the grooves' surfaces. To characterize the gouged surfaces, we used a scanning electronic microscope type Vega Tescan LMH II equipped with a dispersive X-ray analysis system [13].

Overall literature study clearly stated the need and technology of air arc gouging operations, its application and versatility. Still, the skill of the gouging operators has yet to be considered for assessment or recording in the case of the fabrication industry. This field has the potential to be studied to create and established guidelines for skill assessment and certification of gouging operators.

This work presents detailed guidelines for skill assessment and certification of gouging operators for fabricators to refer. Parameters consisting of safety, pre-operational check, technique, defect identification & post-gouging operation checks have been considered for gouging. The skill assessment process involves observation, asking questions & physical sample testing and scoring of individual points of the questioner, which is multiplying factor of weightage & score obtained. Weightage needs to be adjusted by individual fabricators considering their criticality of operation.

2. Methodology

Scheduled stages were followed to define the criteria of judgement required for skill assessment and certification of gouging inspectors. Multiple work sites have been selected to visit and take interviews of production managers, quality engineers, production planning engineers, expert welders, and gouging operators to identify necessary skill sets required to assess the essential skill set of a gouging inspector. The following sequence was followed to complete the process.

Step 1: Selection of sites involved in fabrication work

Step 2: Interview production managers, quality engineers, production planning engineers, expert welders, and gouging operators

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Step 3: Identification of '**Category**' of skill sets

Step 4: Identification of '**Judgement criteria'** of skill sets

Step 5: Defining '**Marks set'**

Step 6: Defining **'Testing method'**

Step 7: Defining '**Weightage**'

Step 8: 'Standardization of **Matrix** based on Step 3 to Step 7'

Step 9: Defining guidelines for **'Level of Qualification'**

2.1 Step 1: Selection of sites involved in fabrication work

Local sites were surveyed to identify the type of operation being conducted for fabrication. Primary sites were selected practically deployed mild steel and another structural steel welding, subjected to a non-destructive testing methodology called ultrasonic testing and rectification of defects recorded in ultrasonic testing. Rectification of job categorically done using Air arc gouging operation.

Ultrasonic testing utilizes ultrasound waves to locate defects [14] in weld joints having defects inside the mass or closer to the weld surface. The few defects often found in welds are porosity, cracks, slag inclusion, lack of fusion, penetration, root concavity, HAZ cracks and much more [15]. Ultrasonic testing was done with probe specification of 22.5°, 70 MHz, and the inspectors were qualified to meet the guidelines of ASNT SNT-TC-1A, Level II [14]. The defect noted in ultrasonic testing was assessed against the specification for its acceptance/rejection. Rejected jobs were given for rework using air arc gouging operation. Details of the process are explained in Fig. 1.

Gouging is a method to melt or fuse metals in a narrow groove. Air Carbon Arc (ACA) Gouging or cutting occurs when the intense heat of the arc between the carbon electrode and the workpiece melts part of the workpiece. Simultaneously, the air quickly passes through the arc to blow the molten material away. The Indian shipping industry uses air-carbon arc gouging techniques for various aspects. Gouging electrodes are made of mixing carbon/graphite with a binder, baking, and then coating with a controlled thickness of copper. The air carbon arc process is flexible, efficient, and cost-effective on practically any metal; carbon steel, stainless steel, and other ferrous alloys; grey, malleable, and ductile cast iron; aluminium; nickel; copper alloys and other nonferrous metals. Single-phase machines with low open circuit voltage may not work for air carbon arc gouging (CAC-A). However, any three-phase welding power source of sufficient capacity may be used for air carbon arc gouging. The arc voltage used in air carbon arc gouging and cutting ranges from a low of 35 to a high of 56 volts; thus, the open-circuit voltage should be at least 60 volts and 100 psi at the torch; higher pressures may be used, but they don't remove metal more efficiently. Use 60 psi (413.7 kPa) with the light-duty at least 3/8" (6.4 mm). Gouging electrodes are made of mixing carbon/graphite with a binder, baking, and then coating with a controlled thickness of copper. Carbons are available in three types: Pointed, Jointed, and Flat. Pointed Carbon is the standard all-purpose gouging electrode. The controlled copper coating improves electrical conductivity, providing more efficient, cooler operation and helping maintain electrode diameter at the point of the arc. Joined carbons have the added benefit of working without stub loss, with each rod having a female socket and matching male tang. They can be used with semi and fully automatic torches. Flat carbons are specially designed for close tolerance metal removal and producing a rectangular groove. The air carbon-arc process does not require oxidation to maintain the cut, so it can gouge or cut metals that the OFC process cannot. Common metals (e.g., carbon steel, stainless steel, many copper alloys and cast irons) can be cut using the air carbon-arc process. The metal removal rate depends on the melting rate and the air jet's efficiency in removing molten metal. In the process, the air must lift the molten metal clear of the arc before the metal solidifies air carbon-arc gouging found many uses for the process in metal fabrication and casting finishing, chemical and petroleum technology, construction, mining, general repair, and maintenance. The air carbon-arc process is flexible, efficient, and cost-effective on any metal [16]. Details of the air arc gouging process are explained in Fig. 2.

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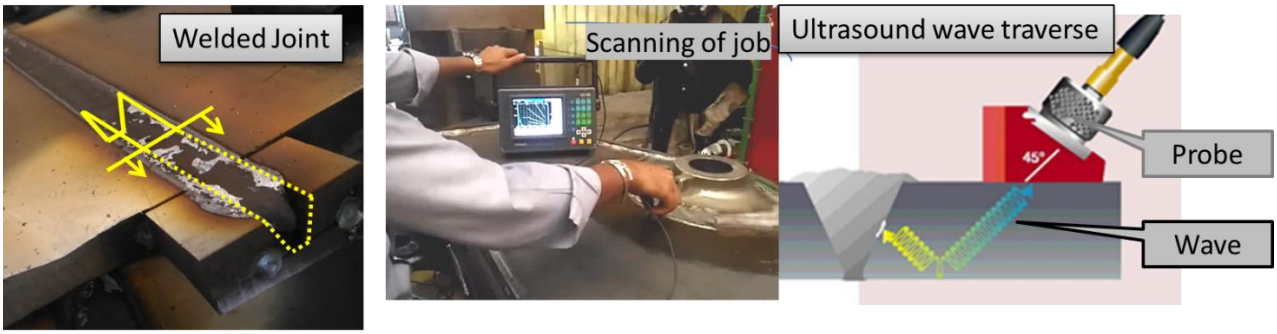

Fig. 1. Details of the ultrasonic testing process explained

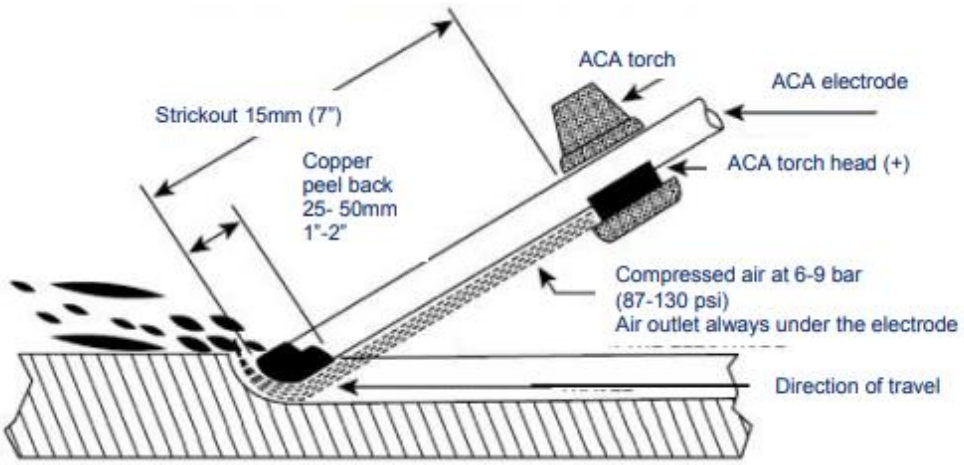

Fig. 2. Details of the air arc gouging process explained

2.2 Step 2: Interview production managers, quality engineers, production planning engineers, expert welders, and gouging operators.

Multiple production managers, quality engineers, production planning engineers, expert welders and gouging operators at various sites were interviewed to finalize the critical details listed in Steps 3 to 7.

2.3 Step 3: Identification of '<u>Category</u>' of skill sets

The following skill sets were finalized based on interviews defined in Step 2.

- **i.** Safety
- **ii.** Pre-operational checks on air-carbon arc gouging equipment
- **iii.** Gouge workpieces- Technique
- **iv.** Defect identification and action after Gouging
- **v.** Post-gouging cleaning and joint preparation

2.4 Step 4: Identification of '<u>Judgement criteria'</u> of skill sets

The following list of 'Judgement criteria' has been finalized against each 'Category' of skill as stated in Table 1.

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Table 1. Assigned category and judgement criteria for skill

Sl no.	Category	Judgement Criteria
1	**Safety**	Knowledge of standard PPE (personal protective equipment) for Shopfloor and adherence (Safety Helmet, Strap, goggles, Safety shoes)
		Knowledge of mandatory PPE, specifically for gouging operation
		Understanding of Machine related Safety Aspects (Welding machine, grinding machine, gouging machine, cutting etc.)
2	**Pre-operational checks on air-carbon arc gouging equipment**	Current voltage required for gouging, gouging direction and air pressure required, the importance of Gouging holder insulation cover
		Knowledge of current and voltage required for gouging
		Ability to hold and handle torch and rod properly at a proper angle
3	**Gouge workpieces-Technique**	Self-positioning with respect to job orientation, joint orientation
		Gouging depth and width ratio(1:1) followed
		Stub length of gouging rod
		Knowledge of depth of gouge for individual Joint
		Fusion check for Butt Joint (parting line knowledge)
		Gouging is done as per joint requirements and ensures defects are removed by gouging.
		Knowledge of gouging at the joint start and end point
		Foreign material generated during gouging is removed securely.
4	**Defect identification and action after Gouging**	Weather able to judge defects after gouging
		Ability to check and identify fusion lines
		Knowledge of fundamental defects observed after gouging
		Ability to identify defects in lug extension welding
5	**Post-gouging cleaning and joint preparation**	Knowledge of cleaning and preparing joints after gouging is complete.
		Sensitive towards the effect of improper cleaning on the final weld joint

2.5 Step 5: Defining '<u>Marks set'</u>, <u>Step 6:</u>'<u>Testing method' & Step 7</u>'<u>Weightage</u>'

Each Judgement Criterion has been assigned with a maximum of one (1) mark each for applicable sections for skill assessment. The total mark assigned was 20, as stated in Table 2. The final score against each judgement criteria needs to be assigned as Zero **(0)** if it is judged as the operator 'cannot do the specific task or **(1)** can do the specific task, or **(X)** not applicable as per details mentioned in Table 3.

For each Judgement Criterion, a 'Testing method' has been assigned. The testing method is a guideline on how to judge the skill; it has been categorized as Observe (**O),** Test **(T),** or Ask **(A),** as stated in Table 2. 'Observe' means actual skill needs to be checked while the gouging operator carries out the actual operation. 'Test' means specific general knowledge written test and 'Ask' means interview of the gouging operator. The weightage section is user-defined and needs to be decided based on an understanding of the fabricator, considering the criticality of the specific judgement criteria related to their operation or application. Sample weightage has been

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assigned in Table 2. This assigned weightage can also be referred to as a standardized value, as it has been derived after site surveys.

Table 2. Standardized matrix of the category assigned with judgement criteria, marks assigned, testing method and weightage.

Sl no.	Category	Judgement Criteria	Marks obtained (X)	Testing method	Weightage (Y)	Section Total (X)*(Y)
1	**Safety**	Knowledge of standard PPE for Shopfloor and adherence (Safety Helmet, Strap, goggles, Safety shoes)	1	A	1	
		Knowledge of mandatory PPE, specifically for gouging operation	1	A/O	2	
		Understanding of Machine related Safety Aspects (Welding machine, grinding machine, gouging machine, cutting etc.)	1	O	1	
2	**Pre-operational checks on air-carbon arc gouging equipment**	Current voltage required for Gouging, Gouging direction and air pressure required, the importance of Gouging holder insulation cover	1	T	2	
		Knowledge of Current and voltage required for Gouging	1	A	2	
		Ability to hold and handle torch and rod properly at the proper angle	1	T	1	
3	**Gouge workpieces-Technique**	Self-positioning with respect to job orientation, joint orientation	1	T	1	
		Gouging depth and width ratio(1:1) followed	1	T	3	
		Stub length of gouging rod	1	A	1	
		Knowledge of depth of gouge for individual Joint	1	A	3	
		Fusion check for Butt Joint (parting line knowledge)	1	O	5	
		Gouging is done as per joint requirements and ensures defects are removed by Gouging	1	T	4	
		Knowledge of Gouging at the joint start and end point	1	T	2	
		Foreign material generated during Gouging is removed securely.	1	T	2	
4	**Defect identification**	Weather able to judge defects after Gouging	1	O	4	

	and action after Gouging	Ability to check and identify fusion lines	1	A/T	5	
		Knowledge of primary defects observed after Gouging	1	A	3	
		Ability to identify defects in lug extension welding	1	O	3	
5	**Post-gouging cleaning and joint preparation**	Knowledge of cleaning and preparing joints after Gouging is complete	1	O	3	
		Sensitive towards the effect of improper cleaning on the final weld joint	1	O	2	
Total			**(T1)** =20		**(T**2) =50	**(T3)**

Table 3. Score assignment rule

1	Can do
0	Cannot do
x	Not relevant

2.6 Step 9: Defining guidelines for 'Level of Qualification'

For deciding the final skill score of the gouging operator, marks assignment needs to be done in column 'X'; marks are obtained from Table 2. **Section Total {(X)*(Y)}** against each judgement criteria to be calculated and put against respective judgement criteria. Summation 'T3' is to be calculated as Total as specified in Table T2.

Percentage total to be calculated as 'T3' divided by 'T2'. This percentage score is the actual skill score for the gouging operator. In the case of Not relevant point, as mentioned in Table 3, respective weightage and scoring are to be ignored while calculating 'T2', 'T3' and Percentage score.

The certification of the gouging operator is to be decided based on his achieved score and by refereeing guidelines mentioned in Table 4.

Table 4. Guidelines for Deciding Skill level certification

Level of Qualification	Marks Scored	Course of Action
Not Suitable for Gouging Operation	< 70	Don't deploy on gouging operation Retraining and on job training for complete modules required
Basic Qualification Level	71 to 85	Free to deploy on all areas, but under scheduled audit and supervision
Advanced Qualification Level	86-100	Free to deploy on all areas and can be deployed as supervisor to not suitable & basic skill gouging operator

3. Result and discussion

BPVC Section IX-Welding, Brazing, and Fusing Qualifications- 2021 [17]: This Section contains rules relating to the qualification of welding, brazing, and fusing procedures as required by other BPVC Sections for component manufacture. It also covers rules relating to the qualification and requalification of welders, brazers, and welding, brazing and fusing machine operators so that they may perform welding, brazing, or plastic fusing as required by other BPVC Sections in the manufacture of components. Welding, brazing, and fusing data cover

essential and nonessential variables specific to the joining process used. But this detailed standard didn't specify the skill assessment and qualification of gouging operators.

As explained in section 2, the detailed methodology can be adopted for skill assessment and certification of gouging operators. This gives a standardized matrix as specified in Table 2, which can be filled as per the guidelines stated in **Step 3 to Step 7**, referring to Table 4, and the final score can be judged. Once the percentage score is obtained, the decision for deployment, training etc., can be taken, referring to Table 4. This methodology being a standardized sequence is ready to refer to guidelines for the fabricator and can be used as it is or with updates with respect to their application for recruitment, skill assessment and deciding training needs of gouging operator.

4. Conclusion

Considering the skill of weld gouging operators an essential trait for proper defect removal in weld rectification procedure involved in welding, the skill of gouging operators considering his capability to identify defects during gouging, optimized gouging to avoid joint damage of puncher, process safety etc., established documentation has been made, which will give guidelines to fabricators to judge the skill of gouging operators through proper skill assessment and certification.

i. This work presents detailed guidelines for skill assessment and certification of gouging operators for fabricators to refer.
ii. Parameters consisting of safety, pre-operational check, technique, defect identification & post-gouging operation checks have been considered for gouging.
iii. The skill assessment process involves observation, asking questions & physical sample testing and scoring of individual points of the questioner, which is multiplying factor of weightage & score obtained.
iv. Weightage needs to be adjusted by individual fabricators considering their criticality of operation.
v. Once the percentage score is obtained, the decision for deployment, training etc., can be taken.

References

[1] Arne Kromm et al. Influence of Weld Repair by Gouging on the Residual Stresses in High Strength Steels. Materials Research Proceedings 2 (2016) 169-174 DOI:http://dx.doi.org/10.21741/9781945291173-29.

[2] V.S. Miltyutin, the effect of arc-air cutting on the quality of metal, Welding Production 26 (1979) 44-46.

[3] Doshchechkina et al., Changes in the Structure of the surface zone in the air-cutting of metals, Welding Production 27 (1980) 40-42.

[4] K. Satoh, Y. Ueda, H. Kihara, Recent Trend of Researches on Restrain Stresses and Strains for Weld Cracking, Transactions of JWRI (1972) 53-68.

[5] K. Satoh, An Analytical Approach to the Problem of Restraint Intensity in Slit Weld. Transactions of JWRI (1972) 69-76.

[6] C. Schwenk, T. Kannengiesser, M. Rethmeier, Restraint Conditions and Welding Residual Stresses in Self-Restrained Cold Cracking Test, in S.A. David, T. DebRoy, J.N. DuPont, T. Koseki, H.B. Smartt (Eds.), Trends in Welding Research. Proceedings of the 8th International Conference, 2009, pp. 766-773.

[7] Cliff Darrow, The Fundamentals of Gouging with Plasma. doi: 10.17729/ebis.2017.3/8.

[8] Y. Ueda, K. Fukuda, I. Nishimura, H. Iiyama, N. Chiba, Cracking in welded corner joints. Metal Construction and British Welding Journal 1 (1984) 30-34.

[9] R.D. Stout, R. Vasudevan, W. Pense, A Field Weldability Test for Pipeline Steels, Welding Journal 55 (1976) 89-94.

[10] R. Vasudevan, R.D. Stout, W. Pense, A Field Weldability Test for Pipeline Steels - Part II, Welding Journal 59 (1980) 76-84.

[11] PANTER, D, American Welding Society. http://worldcat.org/issn/00432296

[12] T. P. Surgeon-Commander, Arc Air Gouging: The Hazards and Their Control. Occupational Medicine, Volume 23, Issue 4, 1973, Pages 114–119, https://doi.org/10.1093/occmed/23.4.114

[13] Barna Fazakas et al., Characterization of the Surfaces Obtained by Gouging. Materials Science Forum (Volume 907). DOI: https://doi.org/10.4028/www.scientific.net/MSF.907.220

[14] Atomic, I.; Agency, E. Non-Destructive Testing : A Guidebook for Industrial Management and Quality Control Personnel Non-Destructive Testing : A Guidebook for Industrial Management. 1999, No. 9, 129–130.

[15] Baughurst, L. Welding Defects, Causes & Correction; 2011.

[16] Anoop G Das et al. Comparative Study of Air Carbon Arc Gouging Process on Sae 316 Stainless Steel, IRJET, Volume: 02 Issue: 02 | May 2015.

[17] BPVC Section IX-Welding, Brazing, and Fusing Qualifications BPVC-IX - 2021