IJEAST

INTERNATIONAL JOURNAL
OF ENGINEERING APPLIED SCIENCE
AND TECHNOLOGY

VOLUME : 6 ISSUE : 6 Print / Issue Publication Date: 10-Jan-2022

ISSN : 2455-2143

DOI : 10.33564/IJEAST.2021.v06i06.045

Indexed In

WWW.IJEAST.COM

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International Journal of Engineering Applied Sciences and Technology, 2021
Vol. 6, Issue 6, ISSN No. 2455-2143, Pages 304-310
Published Online October 2021 in IJEAST (http://www.ijeast.com)

REVIEW OF UNDERWATER WELDING PROCESS UNDER MECHANICAL VIBRATION FOR ENHANCE PROPERTIES OF WELDING JOINT

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Abstract— **In present work arc welding technology, by applying mechanical vibrations during the welding in arc in underwater welding process. Studies have showing that welding of metals along with mechanical vibrations result in uniform and finer grain structures. Metallographic studies conducted show that weld metals under vibratory condition infatuated comparatively finer microstructure and high hardness, due to the finer microstructure. The concept of welding in underwater yields the attraction of much naval construction because it is useful in repairing of collided ships and damaged ones. Interest of underwater welding of this steel grade is connected with necessity of preparing welding repair technologies for subsea pipelines widely used in offshore oil and gas industry.**

Keywords— **Vibration, underwater welding, Welding quality, heat input**

I. INTRODUCTION

In manufacturing industries, welding is widely used for metal joining and cutting process. Metal arc welding is the most flexible fusion welding and also one of the most widely used welding process in world. The welding joints prepared by arc welding process generally offers good yield strength and hardness mechanical properties. Welding technology updating become day by day in the field of underwater welding. The growth of welding practice was Forge welding, in this process by using hammering action the joining process was carried out. This singularity consumes a long safety equipment time and needs skilled labours. The developmental works were started in the year 1900. There are many varieties of welding done in the land like 1. Metal Inert Gas (MIG) 2. Gas Metal Arc Welding (GMAW) 3. Tungsten Inert Gas (TIG) 4. Gas Tungsten Arc Welding (GTAW) 5. Shielded Metal Arc Welding (SMAW) 6. Flux-Cored Arc Welding (FCAW) 7. Atomic Hydrogen Welding (AHW), etc. But all these types of welding would be useful on land. But taking the case of welding a leaking pipeline or sinking ship, it is not possible to weld them by taking them to the shore. The emergence of underwater welding makes fabrication process easier under underwater. The level is above atmospheric pressure which is used in Underwater welding. The origin of Underwater hyperbaric welding dates back to the 19th century when Kon stantin Khrenov invented a way to join metals underwater in the year 1894. Khrenov pursued his education in electric welding, engineering, and mathematics and he taught and researched in Saint Petersburg State Electro Technical University (ETU). Khrenov suggested underwater weld for faster vessel repairs. To avoid the porosity in the welds, burst out and untamed was very difficult while wet welds lie in the sporadic outflow of gas bubbles from the point of contact with the arc and metal. Stable powder source and waterproof coating upon the electrodes may be the best practice for underwater welding. The development of underwater welding experimental works in the labs and followed by the fieldwork in the Black Sea was successful in the year 1932. Dry and Wet underwater welding are the two major categories of underwater welding. The outer structure being welded is covered with a gas mixture which is at the existing pressure of the chamber in the dry underwater welding process. The structure is placed around the product to be welded. The covered area will be filled with gas. The process of dry underwater welding will begin inside the chamber. The final product produced by this method is very accurate. In the atmospheric water pressure, the weld is exposed to water in the wet welding process. There is no physical barrier between water and welding arc in the wet welding process due to the usage of a special waterproof electrode. Today high strength structural steels are increasingly used in underwater-operated constructions. Particular interest is observed in the duplex, ferritic-austenitic stainless steels, which are used for structural components of offshore constructions as well as for pipelines for oil and ocean water transportation. These steels apart high strength show good corrosion resistance and resistance to cracking caused by the interaction of stress and the presence of hydrogen, which source is the acidic environment of liquid hydrocarbons. Despite the wide applications of duplex steels there is still little understanding of the effect of welding in the water environment on the structure and properties of welded joints. In a dry hyperbaric welding, a direct effect of water on the weld is considerably reduced compared to the wet welding, but there is a detrimental effect of increased pressure on the stability of arc. High pressure reduces arc length, which makes it necessary to increase welding voltage.

II. LITERATURE REVIEW

[1] According to Jerzy Labanowski , Dariusz Fydrych, Grzegorz Rogalski, Krzysztof Samson they experiment in duplex stainless steel work was conducted to assess the weldability of duplex stainless steel at underwater conditions. Interest of underwater welding of this steel grade is connected with necessity of preparing welding repair technologies for subsea pipelines widely used in offshore oil and gas industry. The GMA local cavity welding method was used in the investigations. Welded beads were performed underwater at 0.5 m depth and in the air. Investigations have shown that the duplex stainless steels can be successfully welded in water environment without fear of undesirable structural changes, but this assumption concerns only welding processes performed on low depths where pressure factor can be omitted. Usefulness of the local cavity method was also confirmed for underwater welding. In all welds very narrow heat affected zones were recorded with width ranged from 0.2 to 0.6 mm. Increasing the welding heat input up to1,8 kJ/mm, only slightly increased the width of the HAZ. − HAZ hardness in welds made under water and in air were similar and take the value between the hardness of the base metal and weld metal. This indicates that there were no secondary phases precipitation processes during welding thermal cycle.

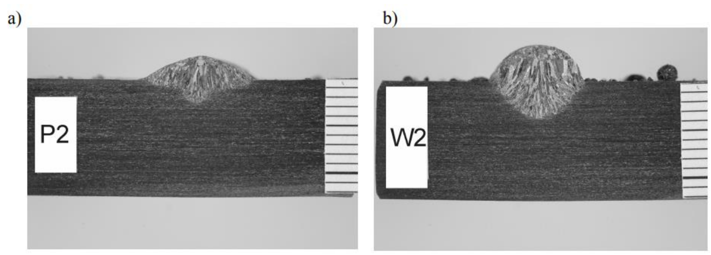

Fig. 1. Welded beads performed in the air (a) and underwater (b) with heat input 1.2 kJ/mm[1]

[2] **Acoording to Jianfeng Wang, Qingjie Sun, Shun Zhang, Chengjin Wang, Laijun Wu, Jicai Feng,** To evaluate the effectiveness of arc bubble, the influences of controllable arc bubble on the process stability and microstructural evolution of welded joint under different welding conditions were investigated UWW > MC-UWW > onshore welding. A more stable wet welding process can be realized by controlling the arc bubble detachment, which provides a new orientation for wet welding technique application. In conclusion, mechanical constraint may have a dual function in UWW based on the controlling of arc bubble. On the one hand, welding arc can burn steadily in the larger bubble space and hence weld surface formation is improved. On the other hand, the reduce in surface heat loss can cause the increase in the effective heat input for the weld metal and even HAZ. Thus, the observed improvement in the effective heat input will reduce the effect of rapid cooling which is beneficial towards the microstructure 23 properties of the joint in MC-UWW. This can be verified by investigating the microstructural evolution in MC-UWW.

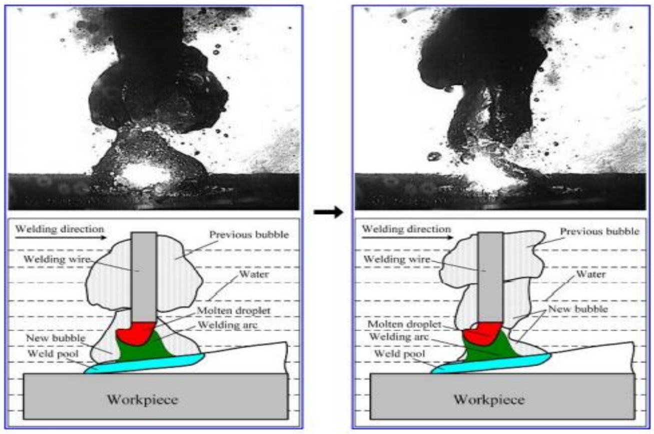

Fig 2 Simplified combination process of previous floating bubble and newly formed bubble.[2]

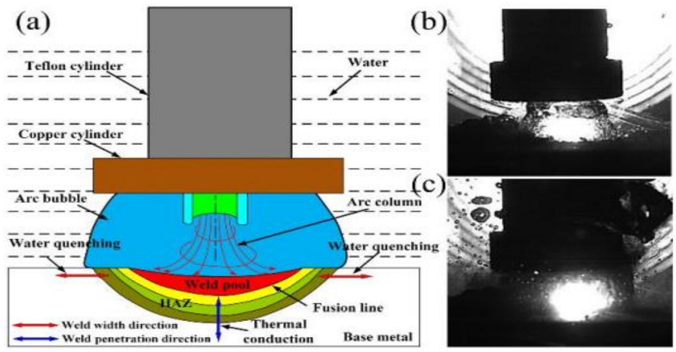

Fig 3 Simplified arc bubble during the mechanical constraint assisted underwater wet welding [2]

[3] **According to HongLiang Li , Duo Liua, YaoTian Yanb, Ning Guoa,, YiBo Liua,, JiCai Fenga,** Real-time electric signal data, microstructure characteristics and mechanical properties at six different heat inputs (16 kJ/cm ∼39 kJ/cm) in underwater wet flux-cored arc welding (FCAW) of E40 steel were investigated. The electric signal results showed that the arc stability would deteriorate at high heat input because of the formation of spatters. The heat input changed the chemical composition of weld metal. With increase in the heat input, the ultimate tensile strength and impact toughness of weld metal increased due to solid solution strengthening of alloying elements.

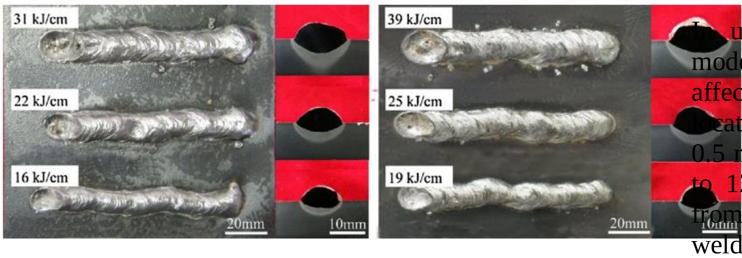

Fig 4 weld bead appearances and cross sections of the weld joints at different heat inputs.[3]

[4] **Acoording to Ning Guoa, Yunlong Fu, Yongpeng Wang , Yongpeng Du, Jicai Fenga, Zongquan Deng;** Metal transfer process in underwater flux-cored welding are investigated by X-ray transmission method for welding velocity from 0.5 mm/s to 9.5 mm/s. The metal transfer mode of underwater flux-cored wire welding is the mixed transfer mode mainly composed of four fundamentaltransfer modes i.e. wide-angle globular repelled transfer mode, small-angle globular repelled transfer mode, surface tension transfer mode and short-circuit transfer mode. The welding appearance and cross-sectional macrostructure of weld specimens at different welding velocities are also investigated. When the welding velocity increases from 0.5 mm/s to 3.5 mm/s, the weld width decreases from 20 mm to 12 mm and the weld penetration increases rapidly from 0.8 m to 3.7 mm, completely different from in-air welding.

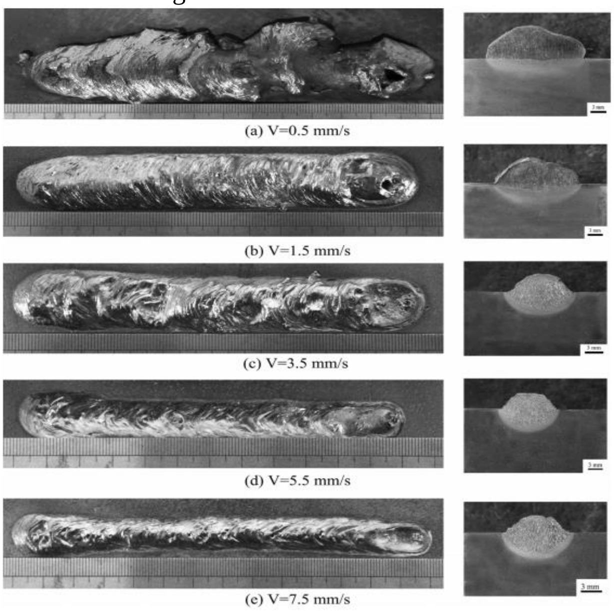

Fig 5 Weld appearance and cross section at different welding velocities: (a) V= 0.5 mm/s, (b) V= 1.5 mm/s, (c) V= 3.5 mm/s, (d) V= 5.5 mm/s, (e) V= 7.5 mm/s.[4]

In underwater flux-cored wire wet welding, four transfer modes are observed . The welding appearance is significantly affected by the variation in metal transfer mode and the impact location of droplets. As the welding velocity increases from 0.5 mm/s to 3.5 mm/s, the weld width decreases from 20 mm to 12 mm, whereas the weld penetration increases rapidly from 0.8 mm to 3.7 mm, considerably different with in-air welding.

[5**] P. SĘDEK; VIBRATION TREATMENT** At present the Institute of Welding has the type SW02A vibrator available. This is a new generation of installation with an automatic control system, a new drive system and vibrator . The driven a.c. unit (high current frequency converter) gives a high accuracy setting of the resonance frequency. In the automatic control system the amplitude measuring unit together with a sensor is a feedback module. Vibration stabilization is a low energy consuming process and finds increasingly wide application. The implementation of vibration stabilization in more than 30 enterprises in Poland proves that this method of treatment is an interesting technological process and attracts the attention of the industry.

[6] **S. Godwin Barnabas ,, S. Rajakarunakaran , G. Satish Pandian , A. Muhamed Ismail Buhari , V. Muralidharan**; under water welding has its wider application in many major fields. The concept of welding in underwater yields the attraction of much naval construction because it is useful in repairing of collided ships and damaged ones. In this paper the classifications of underwater welding and some of its characteristics such as arc bubble formation, arc stability, arc atmosphere and the relation between the arc bubble and arc length and relation between bubble rise and arc temperature have been discussed. significant industrial effort has to be taken to progress process performance and manage strategies for the diverse underwater welding processes in various fields like reducing the rate of quenching of the welded area, automation of the process to reduce the risk of divers and trying to implement advanced welding techniques used in the land be made use underwater which would contribute to achieve a greater milestone.

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Fig 6- Comparison of different underwater process with future scope and parameters

	TITLE	AUTHOR	PROCESS	METHOD /PARAMETER	OUTCOME	SUGGEST FUCTURE WORK
1	Improvement of mechanical properties of ferritic stainless steel weld metal by ultrasonic vibration	Takehiko Watanabe, Masataka Shiroki, Atsushi Yanagisawa, Tomohiro Sasaki	The material used- 1 mm thick SUS444 .	In this experimet filler metal was ultrasonically mechanically vibrated through a guide tube attached on the tip of an ultrasonically vibrating hornTIG.	The ultrasonically vibrating filler metal could effectively transmit ultrasonic vibration to the weld molten weldment pool through a guide tube attached on the tip of an ultrasonically vibrating horn. The ultrasonic vibration encouraged	On this paper try to impliment the welding under ultrasonics condition in underwater through some poratable vibration device with sutable frequency . Also we make new mechanisum of vibration and ultrasonic vibration apply for benefit of this principla to improving welding quality .
2	Effect of ultrasonic vibration on microstructural evolution	Jianfeng Wanga,b, Qingjie Suna,b, Laijun	This research introduced a fusion method for refining weld quality by using overlaid ultrasonic vibration on workpiece directly in underwater flux cored	FCAW E40 steel plate with 8 mm-thick dominantly involes of polygonal ferrite and pearlite. Commercial CHT81Ni2 type self-shielded	FCAW with using ultrasonic vibration is employed to produce sound weld for microalloyed E40 steel in	However, little information is available in literature on the use of ultrasonic vibration to refine the microstructure of weld metal in underwater welding so some
3	Effects of welding velocity on metal transfer mode and weld morphology in underwater flux-cored wire welding	Ning Guoa, Yunlong Fu, Yongpeng Wang , Yongpeng Du, Jicai Fenga, Zongquan Deng	In this paper welding velocity on metal transfer mode and its effected mechanism in underwater wire wet welding at different arc lengthsare search. The weld morphology including weld appearance and cross-sectional macrostructure of weld specimens at different welding velocities are analyzed.	Chemical Composition of Q235-mild steel -welding consumable was TiO2-CaF2-CaO-SiO2 slag sys tem self-shielded flux-cored wire with a diameter of 1.6 mm.	In underwater flux-cored wire wet welding, 4 metal transfer modes are observed wide-angle globular repelled transfer mode, small-angle globular repelled transfer mode, surface ten sion transfer mode and explosive short-circuit transfer mode.	According to this paper The welding appearance and cross-sectional macrostructure of weld specimens at different welding velocities are also investigated. so some fucture work is to be their in filed of penetration of weld ment , this penetration will be impreving with different mechanical vibration appling and check whats are improvment in different condition .
4	Porosity variation along multipass underwater wet welds and its influence on mechanical properties	Ezequiel Caires Pereira Pessoa , Alexandre Queiroz Bracarense , Eduardo Maluf Zica , Stephen	The objective of this work is to evaluate the influence of porosity variation on multipass V-groove weld metal properties. Commercial covered electrodes E6013 and E702and three different steels A-36, A-572 and API 5L grade B were used to perform the wet welds at 50 and 100 meter depth. A pressurized chamber with 20 atmospheres capacity was used to simulate the depth with fresh water. A	Three different steel plates, 12.7 mm thick ASTM A-36 steel with 220 MPa specified minimum yield strength (SMYS) and 400 MPa specified minimum tensile strength (SMTS), 12.7 mm thick A-572 grade 50 steel with 345 MPA SMYS and 450 MPA SMTS and 18.0 mm thick API L grade B steel	Porosity of welding were reduced along the weld length in multipass wet weldsTensile strength and ductility of multipass wet welds were influenced by the porosity variation.The use of gravity feeding system produced E6013welds that met the macroetch	In pipie and plate or suface welding during underwater welding there is different phenomena is their , some time heavy part to be repait in underwater and some times pipe and vessles also need to repair , so at that time proper welding must be their and frequncly weldwe do multipass on plate so according to depth of water their is different bubble formation and pressue

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5	Vibration assisted welding processes and their influence on quality of welds	M. J. Jose1,2, S. S. Kumar1 and A. Sharma	Vibration assisted welding (VAW) has emerged as a successful replacement for heat treatments and post-weld vibration treatments of arc welds to reduce residual stresses and distortions and thus to improve its mechanical properties	The different ways in which the vi bration is being applied are listed below: (i) vibration of workpiece during welding (ii) weld pool oscillation (iii) molten droplet oscillation (iv) oscillation of welding arc (v) vibration of electrode.	The common outcome of vibration during welding, irrespective of which element of the welding system is vibrated, is the grain refinement of the weld metal. Vi bration of workpiece has emerged as a competent process capable to replace post-weld vibration and heat treatments in terms of its advantages of less total energy input,	Future directions Such hybrid systems can be tried, in particular underwater pipe and plate joing in single and multipass welding also , to eliminate residual stresses after welding which has a prominent role in the quality of welds. The cas cading effect of two or more Vivration assistWelding processes may be explored to reach at a point where the residual stress is the absolute minimum.
6	Effect of cooling rate on microstructur e, inclusions and mechanical properties of weld metal in simulated local dry underwater welding	Xinjie Di , Shixin Ji , Fangjie Cheng , Dongpo Wang , Jun Cao	The chemical compositions and mechanical properties of the used E550 steel and deposited metal of E71T-1C-J flux-cored wire .. A dry area (500 × 300 mm) was surrounded by baffles for welding. During A shielding gas of pure CO_2 with the gas flow rate 15–20 L/min was used.	The mechanical properties tests were performed according to the AWS D3.6-2010A standers. Vickers hardness measurements were made across the weld metal and were performed at 10 kg loading for 15 s. Charpy V-notch impact test of weld metal (10.0 × 10.0 × 55.0 mm) was tested at −20 °C. The location of test specimens in test plates and dimension of all weld metal tensile specimens are shown in Fig. 5. The fracture surfaces were observed by SEM	Acicular ferrite nucleation inclusions are mainly composite oxide of Ti and Mn with a little of Al and Si oxide and Mn-sulfide. Also, there is a distinct Mn-depletion zone in the rapid cooling rate (with heat input of 10.0 kJ/cm and water-cooling), while there is no Mn-depletion zone in the slow cooling rate (with heat input of 30.0 kJ/cm and air cooling). This is due to the Mn diffusion and homogenization increased at a decreased cooling	sometines rapid cooling is not favable in welding to porosity and residual stress generation , overcome to this phenomena we can used proper vibration woth mechanical horn for overcome to bubble formation si welding is smooth and final grain structure is arrived .
7	Characterization of the underwater welding arc bubble through a visual sensing method	Jianfeng Wang , Qingjie Sun , Shun Zhang , Chengjin Wang Laijun Wu , Jicai Feng	To investigate the relationship between the arc bubble and process stability in different welding conditions, the high-speed video camera system and welding electrical signal acquisition system are established successfully .The high-speed video camera system consisted of a Olympus i-SPEED 3 high-speed camera used for capturing the images of arc bubble with a sampling frequency of 2000 fps (frames per second), and a background light source. In order to record good contrast images of arc bubble, a dysprosium lamp backlighted shadowgraphic method was used to provide background light. The welding current and arc voltage waveforms could be acquired by the Hall sensor during the wet welding process. On this basis, the data acquisition card and computer could process the welding electrical signal and store the instantaneous datas of welding current and arc voltage, which	In order to analyze the effect of the welding condition, preliminary investigations of weld formation and microstructural evolution were carried out.	(1) The adverse effect of surrounding water with its higher heat conduction is not negligible compared to onshore welding, and mechanical constraint assisted in UWW is realized and effective in resisting the arc bubble detachment and keeping the larger arc bubble attached to the weld pool surface for providing better protective effect of welding region. (2) With welding current and arc voltage waveforms, the dynamic behavior of arc bubble appears as a new variable which clearly affects the arc characteristic under different welding conditions. 31	In fucture for this mechanical we have to experiment with arc vibration method or electrod vibration method .
8	Application of ultrasonic vibrations in welding and metal processing: A status review	S. Kumar, C.S. Wu, G.K. Padhy, W. Ding	application in metal joining and processing including its limitations, future prospects and assessments. Allied welding and metal processing technologies employing ultrasonic vibrations either as the primary source to accomplish the intended operation or as an assistant source to improve the operation effi ciency and product quality are classified and discussed. The detailed state-of the art, experimentation and progresses of the ultrasonic vibrations and its applications in the	(GTAW), also known as tungsten inert gas (TIG) welding is an arc welding process that uses a non consumable tungsten electrode to form the welds. Inert gases such as argon or helium are supplied into the weld zone in the form of shielding gases to protect the weld area from atmosphere con taminations. GTAW proved to be a low	depicted that ultrasonic vibrations do play a substantial role in the welding and metal processing. There is tremendous scope for application of ultrasonic vibrations for estab lishing cost effective manufacturing solutions for relatively tough and ductile metals such as titanium, nickel-alloys. It is	According to this ultrasonic method is very usefull in welding application ; this fundametal is used in underwater welding process with maje new small mechanisum of ultrasonic vibration mechanisum for welding in wet condition .

9	Underwater arc welding of higher strength low-alloy steels	S.Yu. Maksimov	This level of impact toughness indicates the presence of zones of failure – brittle martensitic structures, microcracks, and so on – formed while welding.The trajectory of crack propagation corresponds to the weakest areas of the HAZ.	The investigations were carried out on industrial and experimental high-alloy welding wires made of alloys based on Fe–Mn, Fe–Mn–Cr, Fe–Cr–Ni and Fe–Cr–Ni–Mn. The values of Nieq and Creq change in the range 18–56 and 2–25%, respectively. Separation cracks were found in some cases in these interlayers. The width of the interlayer decreases with an increase in the austenitic ratio but hot cracks appear in the upper sections of the multipass welded joints	The experimental results show that the combined alloying with nickel and chromium has a positive effect on the mechanical properties of the weld metal. The tensile diagram of a cylindrical specimen, produced from a metal deposited on a plate (Figure 5), is characterized by a long region of uniform elongation with parabolic hardening. This is characteristic of FCC metals and indicates the absence of 'dangerous' macrodefects reducing the plasticity of the weld metal.This confirms the	According to this for high alloy steel we can medified electrod specification releted to weld metal and also apply proper welding method to improve weldability .
10	Multiscale 3D characterization of discontinuities in underwater wet welds	L.F. Silva , V.R. dos Santos , S. Paciornik J.C.E. Mertens , Nikhilesh Chawla	in this paperThe relevant objectswere rendered in 3D, confirming the expected size and orientation characteristics. Whenever possible, results from different scales and techniques were compared.	The welding for this work was done at the welding laboratory of the Universidade Federal de Minas Gerais (UFMG) using a LINCON ELETRIC, POWER WAVE 450 as the electronic source. Rutile coated electrodes with a low carbon steel wire core possessing a diameter of 3.25 mm and a length of 35 mm were used under different conditions. For shal low	A multiscale, multi technique method for 3D analysis of microscopic discontinuities in wet underwater welds was developed and evaluated. Lab scale X-ray MicroCT was sensitive to detect pores and cracks, and their main geometrical features were measured after suitable image processing steps. No attempt wasmade at observing the same	In multiscale 3d modeling there is lot of information we an get about the microstructure of welding joint , in underwater welding joint there is lots of possibility ti arrive cracks in multipass and reparing under sea while welding , so with improving this phenomena we can anaysys of different welding techniques like vibration and mechanial constrain method to avoid bubble foemation , aslo we can apply suitable welding

By this work some findings has been highlighted they are the development of underwater welding in last 25 years has been discussed. The microstructure arrangement in terms of strength has been identified by the coatings with ferro-manganese, addition of titanium and boron to the electrode. Some of the critical issues in watery environment and some of the current trends in underwater welding is discussed. Series of weld strengths by varying the aluminium are characterized by the usage of energy dispersive X-ray analysis and electron diffraction. Other studies are also carried out such as impact, toughness, charpy notch location and path of fracture propagation for grade 91 steel welds. From this work the concept of improving the weld strength in underwater welding is carried out using different methods and materials.

III. CONCLUSION AND FUTURE SCOPE OF UNDERWATER WELDING PROCESS.

The dynamic behaviours of evolution under different welding conditions are investigated and compared by different parameter method. Main conclusions as well as future scope can be derived as follows:

1. This paper tries to implement the welding under ultrasonics condition in underwater through some portable vibration device with suitable frequency. Also, we make new mechanism of vibration and ultrasonic vibration apply for benefit of this principal to improving welding quality.
2. little information is available in literature on the use of ultrasonic vibration to refine
the microstructure of weld metal in underwater welding so some research work will do that in this area for biter quality and authentic method will implement.
3. The welding appearance and cross-sectional macrostructure of weld specimens at different welding velocities are also investigated.so some future work is to be there in field of penetration of weldment, this penetration will be improving with different mechanical vibration applying and check what's are improvement in different condition.
4. In pipe and plate or surface welding during underwater welding there is different phenomena is there, sometime heavy part to be repair in underwater and sometimes pipe and vessels also need to repair, so at that time proper welding must be there and frequency welded do multiphases on plate so according to depth of water there is different bubble formation and pressure condition is there, according to this improve method by applying vibration to suitable part and then weld.
5. Sometimes rapid cooling is not Favable in welding to porosity and residual stress generation, overcome to this phenomenon we can used proper vibration worth mechanical horn for overcome to bubble formation is welding is smooth and final grain structure is arrived.
6. In multiscale 3d modeling there is lot of information we can get about the microstructure of welding joint, in underwater welding joint there is lots of possibility arrive cracks in multipass and repairing under sea while welding , so with improving this phenomena we can analysis of different welding techniques like vibration and mechanical constrain method to avoid bubble formation , also we can apply suitable welding electrode .

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