Underwater Welding - Its Mechanism, Challenges, Risks and Recent Advancements

ORCID : A. K. VAISH : https://orcid.org/0000-0002-0282-0534
ORCID : S. D. KAHAR : https://orcid.org/0000-0002-1920-1051
ORCID : Dr. B. J. CHAUHAN : https://orcid.org/0009-0004-7363-3770
ORCID : K. M. BHAISAHEB : https://orcid.org/0009-0009-3724-9903
ORCID : ANKIT BHOJANI : https://orcid.org/0000-0002-6760-2781

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[1]A. K. Vaish, [2]Ritesh Patel*, [3]J. Krishnan*, [4]B. J. Chauhan, [5]S. D. Kahar, [6]K. M. Bhaisaheb & [7]Ankit Bhojani
Department of Metallurgical and Materials Engineering
The M. S. University of Baroda, Vadodara - 390001
*Larsen and Toubro Ltd., Hazira, Gujrat
Email : [1]vaishakvnml@gmail.com;[2]ritesh.patel@larsentoubro.com; [3]j.krishnan23@gmail.com; [4]bjchauhan13@gmail.com; [5]kahar_sunil@yahoo.co.in; [6]kaizar_999@yahoo.co.in; [7]theankitbhojani@gmail.com

Abstract

Underwater welding involves a high degree of technical complexity. It is basically applied in ship building and maintenance, waterway structures, submarines, subsea pipelines, offshore oil rigs and nuclear reactors etc. High quality standards are required for underwater welding systems and personnel. Underwater welding profession is attracting much more than other professions since it is more challenging and highly paid. In view of this fact, an attempt has been made to briefly discuss its mechanism, challenges, risks and recent advancements.

Keywords: Underwater welding, Mechanism, Challenges, Risks, Advancements

1.0 INTRODUCTION

Welding is different from brazing or soldering in which the base metal is not melted. During welding two or more parts are fused by means of heat, pressure or both and a join is formed after cooling. In fact welding is joining of two objects together using heat and filler material. The filler is heated to melt and pool between the two parts to form a strong joint/weld. Thus welding is a fabrication process performed at both inland and offland. Arc welding with consumable metal electrodes was introduced by Nikolay Slavyanov in 1888 [1], whereas Soviet Engineer Konstantin Khrenov invented underwater welding in 1932 [1] to weld fully or partially submerged marine structures. It involves welding at high pressures and is also known as hyperbaric welding. In 1936 crews performed underwater welding to lift an enormous ship called Boris out of the Black Sea [2] and in 1940 an underwater welding program was led by Cyril Jensen [1] in the US Navy to repair bridges, dams, pipelines, oil rigs, and other marine infrastructure.

1.1 Need for underwater welding

Since it is not possible to take out the structure from the water and perform its maintenance, it becomes essential to adopt underwater welding for the repair and maintenance of such structures. Underwater welding is required for underwater construction and repair of ships and pipelines. Further due to frequent storms and unexpected collisions, the parts of offshore structures are damaged, underwater welding is required for the repair and maintenance of such offshore structures. Underwater welders are in great need repair and maintain all marine structures. It is also being used in nuclear power stations, canals and rivers etc

Underwater welding processes are also being applied almost in all manufacturing industries as well as for fabrication of structures [3]. Presently important applications of underwater welding are (i) offshore construction for tapping sea nodules (ii) temporary repair work caused by ship's collisions or unexpected accidents and (iii) construction of large ships beyond the capacity of existing docks. Further underwater welding is playing key role in the instalment of large number of offshore structures including oil drilling rigs, pipelines and platforms.

1.2 Underwater welding process

Underwater welding process is classified as (i) wet underwater welding and (ii) dry underwater welding. Further wet underwater welding is classified into three types and dry underwater welding into six types [4] as shown in **Figure 1**. In wet underwater welding process, the welding is performed freely under water in wet environment, whereas in dry underwater welding a dry chamber is created and welding is performed inside the dry chamber in dry environment. A typical view of underwater welding is depicted in **Figure 2** [5]. Thus in view of the significant importance of underwater welding, an attempt has been made to briefly discuss its mechanism, challenges, risks and recent advancements.

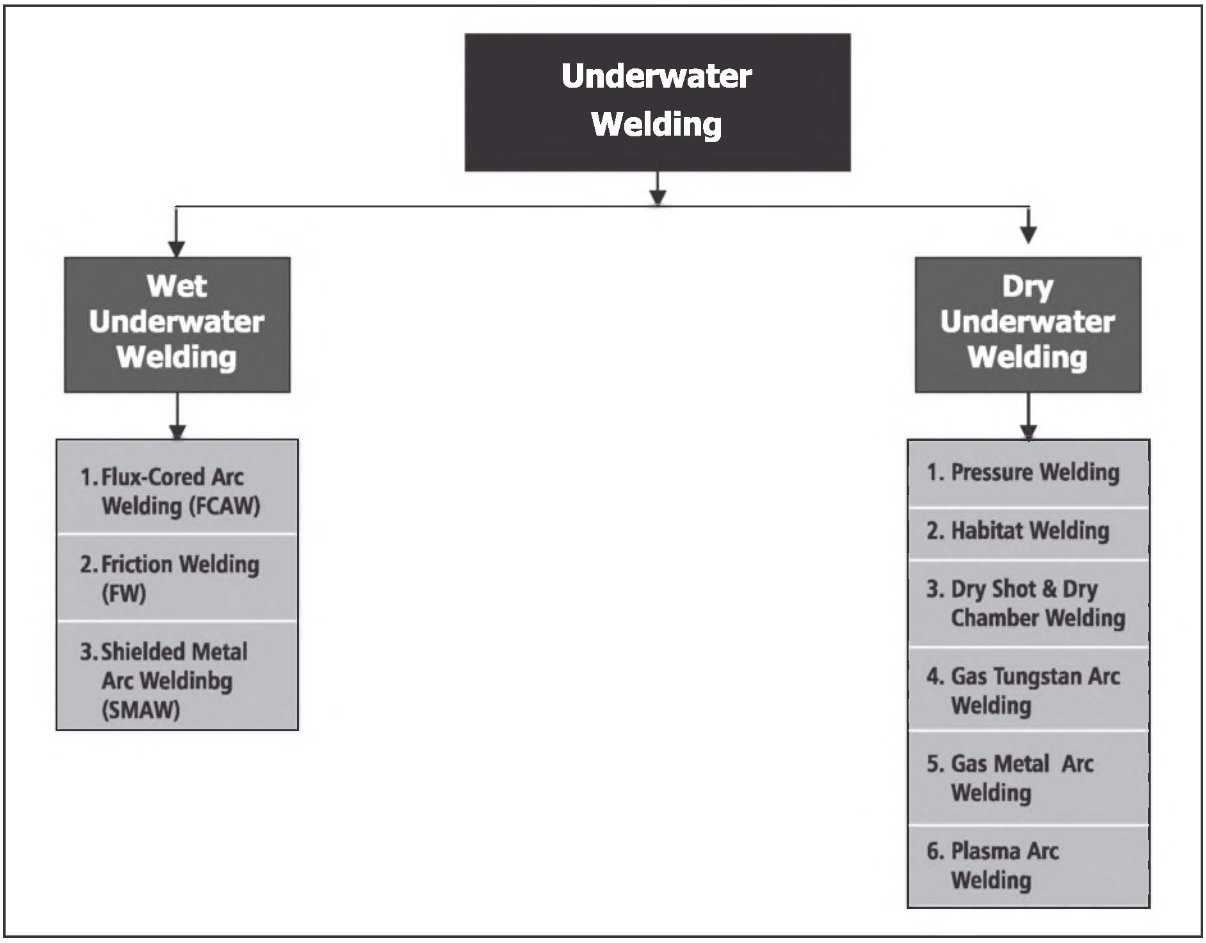

Fig. 1 : Types of underwater welding

2.0 MECHANISM OF UNDERWATER WELDING

In order to understand the mechanism of underwater welding one has to understand the process of evolution of oxygen, bubbling phenomenon, cooling of weld, flow of electric current and control mechanism etc.

2.1 Science and technology of welding

Welding continued to evolve to its modern day form by involving the scientific principles from physics, chemistry, mechanics, electronics and materials. It is essential to understand the materials and their properties. Generally the parent material is heated to a high temperature, it melts and combines with other materials forming a strong weld joint after cooling. Some methods of welding make use of heat to melt two pieces of metal together by adding a "filler metal" into the joint which acts as a binding agent, some rely on pressure which binds metals together while others make use of both heat and pressure. Welding has now advanced significantly to become more accurate, fast and effective. The methods of welding are constantly being developed with new research in the nuclear, space, transportation and ship building industries.

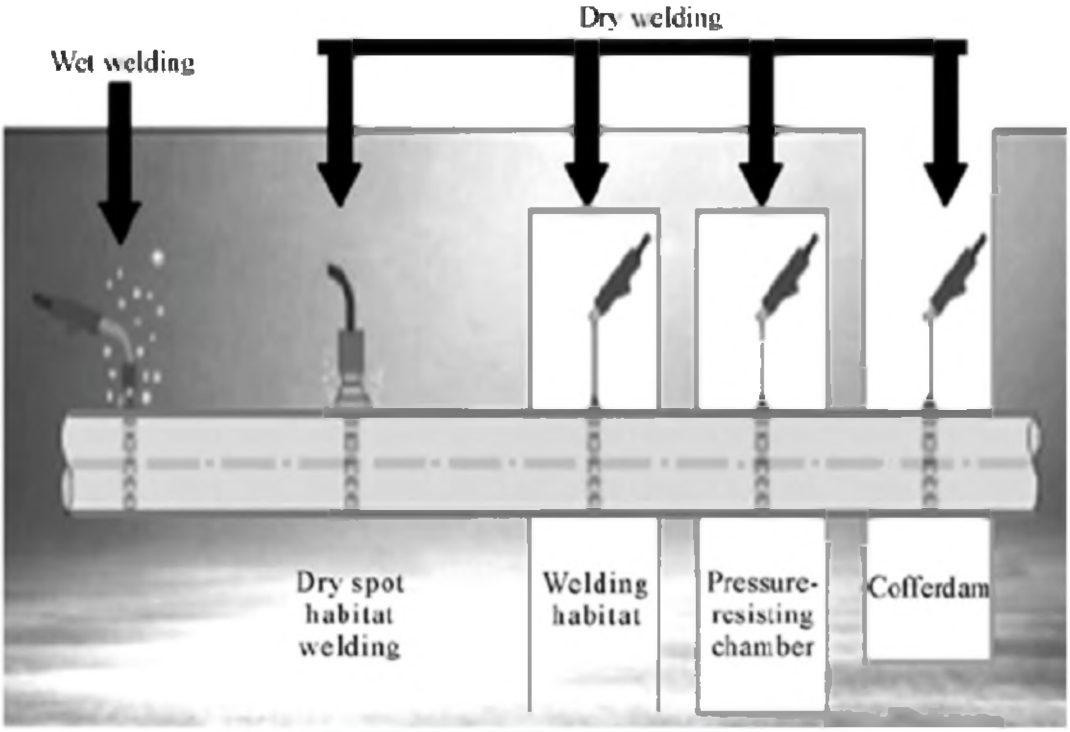

Fig. 2 : Underwater welding

Fig. 3 : Wet underwater welding [6]

2.2 Insight of wet underwater welding

Among three varieties of wet underwater welding, Shielded Metal Arc Welding (SMAW) is cost effective. In this method an electric arc is produced between the electrode and the infrastructure metals and welding is carried out using manual metal arc electrodes having a waterproof coating over the flux coating. The thick layer of gaseous bubbles is created by the flux of the electrode. It covers the weld and shield the electricity from water, corrosive gases and other oxidizing compounds. Direct current is used with a positive ground which protects the divers/welders from electrocution. In Flux-Cored Arc Welding (FCAW), welders use a spool to provide continuous filler metal whereas in Friction Welding (FC) welders face together metal using high friction and heat without material melting. The wet underwater welding is depicted in **Figure 3** [6] and **Figure 4** [7]. Welders can easily reach the portions of offshore structures. During wet welding the weld metal is rapidly quenched, as a result tensile strength is increased, decreasing the ductility and impact strength of the weldment and increasing its porosity and hardness.

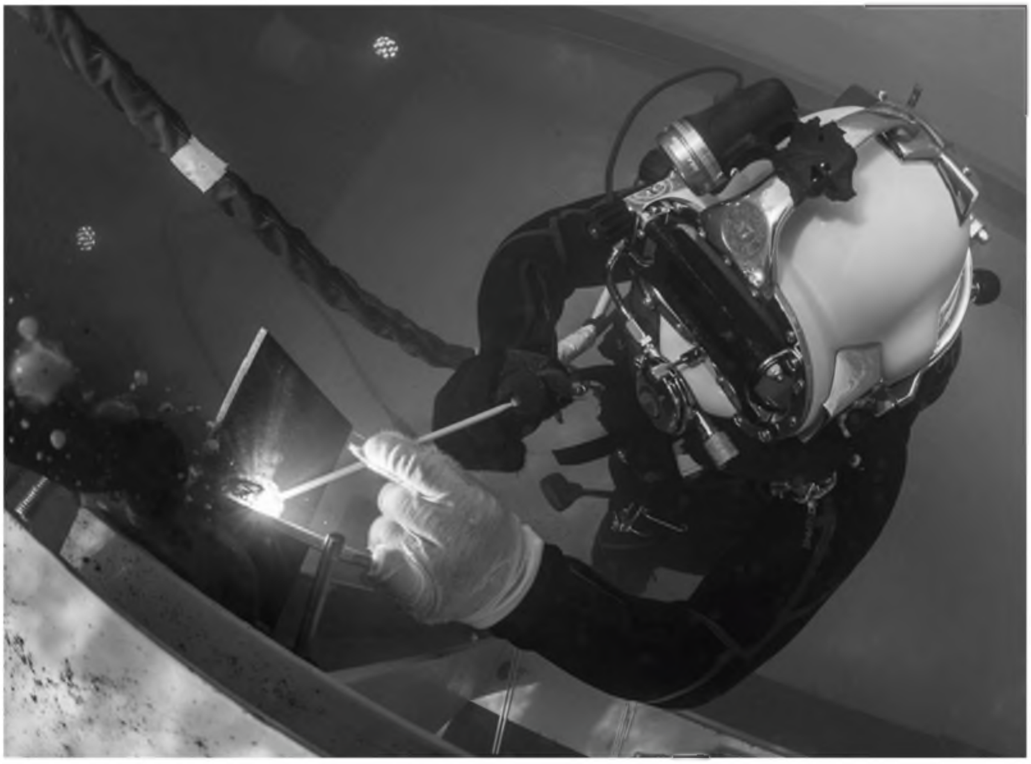

Fig. 4 : Wet underwater welding [7]

2.3 Insight of dry underwater welding

In dry underwater welding the structure to be welded is sealed in a chamber which is filled with the mixture of gases namely helium and oxygen or argon as shown in **Figure 5** [6]. This mixture of gases forces the water outside of the hyperbaric sphere and allows a dry environment to perform welding. In dry underwater welding the welding is performed in a dry chamber at the prevailing pressure. The chamber is immune to ocean currents and marine animals. It has its own environmental control room and can produce quality welds. The welding is done at the hydrostatic pressure of sea water. During dry underwater welding there is no water to quench the weld and hydrogen level is much lower than wet welds. Compared to wet underwater welding high quality welds are produced by dry underwater welding. In dry hyperbaric welding, welding is performed at raised pressure in a chamber filled with gaseous mixture. The structure to be welded is sealed in this chamber. Thus in dry underwater welding water is not present and hydrogen level is much low. As a result the quality of weld is good and it is possible to perform NDT of weldment in order to judge its quality. It has been observed that the arc constricts at greater depths, therefore the build- up of pockets of gas should be avoided during welding in order to avoid the explosion. Depending upon the need and requirement, different type of dry underwater welding is adopted.

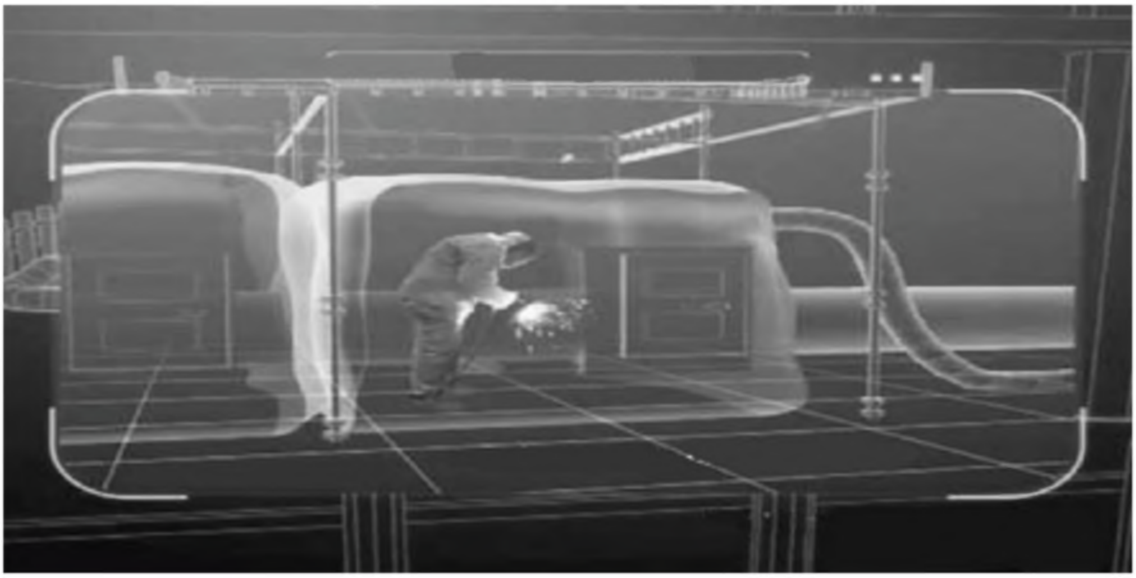

Fig. 5 : Dry welding in an enclosed area [7]

3.0 CHALLENGES INVOLVED IN UNDERWATER WELDING

- The greatest challenge to become an expert underwater welder is to pass a course at a commercial diving school. He has to learn perfectly the diving skills along with safety and emergency procedures apart from welding skills. He has to be a certified welder and acquire high quality standard for underwater welds.
- In fact underwater welding requires a great amount of skill with a high degree of technical complexity. The profession of underwater welding continues to demand higher quality standards for underwater welds and more certification of underwater welding systems and personnel.
- Wet welders face steaming, arc constriction, and electrode diameter. During wet underwater welding the welds are exposed to surrounding water and their strength is affected by the deposition rate and bubbling.
- The development of a special technology of welding at low temperatures is an urgent scientific and technical challenge aimed at solving the problems of increasing the validity and safety of equipment and structures operated under conditions of North and Arctic.

4.0 RISKS INVOLVED IN UNDERWATER WELDING

- ✦ The underwater welders may face long term health issues and fatalities. The underwater welders are likely to face exposure to intense ultraviolet radiation which may lead to temporary blindness and extreme discomforts. They may face the damage of their ears, lungs and nose since they spend a lot of time in high pressure waters. Large pressure in underwater welding threatens the entire body of the welder. Due to large bubbles created by the weld and dark atmosphere, the welders may not be able to see clearly.
- ✦ There is great risk of the attack of marine wildlife such as shanks and other potentially dead creatures on the underwater welders. The deeper they go and the longer they stay down, their life span may decrease substantially.
- ✦ Electrocution is the biggest threat to underwater welders and gas pockets created by the formation of hydrogen and oxygen pose a huge risk to underwater welders [8].
- ✦ Drowning - A failure of any part of an underwater welders SCUBA gear could lead to drowning [8].

5.0 RECENT ADVANCEMENTS IN UNDERWATER WELDING

- ■ The knowledge of metal composition and its strength have improved the welding parameters namely hold time and squeeze time.
- ■ Further considerable advancements have taken place in welding technology due to improvements in welding equipment and use of robots. Robotic welding is preferred in all such manufacturing industries which make use of repetitive welding processes.
- ■ Tele operated electric robot arm welding systems have been developed for nuclear industries. These days robot based welding processes are replacing human welders in intricate situations.

- The automation of welding process for pipe structures have gained significant momentum to improve the productivity and accuracy in the areas involving marine applications. Several new welding technologies namely electron beam welding, friction stir welding, laser beam welding, computerized and robotic welding are recent developments.

6.0 CONCLUSIONS

(i) Utilization of welding processes is booming to its full potential day by day with increasing marine and offshore applications.

(ii) Oil and gas industries require marine transportation and industrial application in water as well as above the sea. This process of extraction will continue for about next 100 years.

(iii) The need of the hour is to come up with a solution of advanced welding process which can be suitable under water for simple, quick and high quality weld.

(iv) The automation in welding process for pipe structures have improved the productivity and accuracy in marine applications.

(v) As underwater welders work hundreds of feet beneath the surface and face pressure changes, they may suffer from decompression sickness and arterial gas embolism.

(vi) Wet welding usually costs less than dry welding, but it is more dangerous. Wet welders perform underwater welds the same way they would on dry land.

(vii) During last 50 years new welding technologies have been introduced from electron beam, friction, plasma arc and friction stir welding, to explosion, laser beam, computerized and robotic welding.

(viii) Robots may not be able to completely replace welders in near future even in intricate situations.

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