Under-water structure repair
By
‘Wet welding’

By:
T.K.Purkayastha, SE (P)
IMR Section, ONGC, Mumbai.
INTRODUCTION:
IMR section under the Offshore Logistics Group of ONGC is carrying out the inspection, maintenance and repair of the sub-sea portion of the offshore structures. As on date, 192 no. of offshore platforms, 820 no. of risers, 5 no. of SPMs and approx. 3954 km. of sub-sea pipelines are being maintained by IMR group with the help of it’s fleet of 3 no. of MSVs (Multi Support Vessels) and 2 FFSVs. On regular basis IMR is undertaking the marine growth removal, operation and maintenance of SBM, fire fighting and rescue operation, pollution control, crane assistance and diving assistance to assets, rigs, etc.

All the offshore structures are periodically inspected and are re-certified by certification agency. The structures are inspected for any damage or anomaly, health of the cathodic protection system, all weld joints inspection and fatigue life weld inspection etc. and suitable remedial is adopted for enhancing the design life of the platform.

All the joints are under complex nature of loading and depending upon the various parameters after detailed structural analysis, some joints are identified as low fatigue joints. These joints require additional attention during the periodical inspection. Also, due to some external factors, like OSV collision, etc. some of the joints may fail. Different NDT techniques, viz, Magnetic particle inspection, A-scan, flooded member detection, ACFM technique etc. are done to see the condition of the joints.
BACK GROUND:
During periodical under water inspection by IMR section, 12 nos. of underwater weld cracks were found on structural member joints in 5 offshore jackets (IJ, EB, BA, HC & NP) at approx. 10M below the MSL. These cracks were found to be propagating during subsequent inspections. Detailed structural analysis was carried out by different agencies, viz, Structural Engineering Research Centre, Chennai; Engineers India Ltd, Delhi and ONGC’s inhouse Institute IEOT. It was recommended that the joints are to repaired by suitable method.

Although, different methods, like reinforcing the joints by grouted sleeves, hyperbaric welding, wet welding, etc. are available, after extensive deliberation with various reputed agencies from the industry, it was decided to undertake repair of the joints by wet-welding method. Accordingly, Global tender was invited and job was awarded in the year 2004 to M/s. Noordhoek, a Netherland based offshore construction company and job was executed in 2005.

SELECTION OF TYPE OF WELD:
Underwater welding is normally done by Hyperbaric welding (or Dry welding) and Wet welding. In wet welding the welding is performed underwater, directly exposed to the wet environment, whereas in dry welding, a dry chamber is created near the area to be welded and the welder does the job by staying inside the chamber.
A) **Hyperbaric welding (Dry welding):**

Hyperbaric welding is carried out in chamber sealed around the structure to be welded. The chamber is filled with a gas (commonly a mixture of Helium and Oxygen) at the prevailing pressure. The habitat is sealed onto the pipeline and filled with a breathable mixture of helium and oxygen, at or slightly above the ambient pressure at which the welding is to take place. *The method produces high-quality weld joints that meet X-ray and code requirements.* The gas tungsten arc welding process is employed for this process. The area under the floor of the Habitat is open to water. Thus the welding is done in the dry but at the hydrostatic pressure of the sea water surrounding the Habitat.

Limitations of **Dry Welding**

1) The habitat welding requires large quantity of complex equipment and much support equipment on the surface. The chamber is extremely complex.

2) Cost of habitat welding is extremely high and increases with depth. Work depth has an effect on habitat welding. At greater depths, higher voltages are required. The same chamber can not be used for different jobs.

3) For complex type of joints, designing a habitat is a big challenge.
Wet welding:

Wet Welding indicates that welding is performed underwater, directly exposed to the wet environment. A special electrode is used and welding is carried out manually just as one does in open air welding. The increased freedom of movement makes wet welding the most effective, efficient and economical method. Welding power supply is located on the surface with connection to the diver/welder via cables and hoses. In wet welding MMA (manual metal arc welding) is used. The power source should be a direct current machine rated at 300 or 400 amperes. Motor generator welding machines are most often used for underwater welding. The welding circuit must include a positive type of switch, usually a knife switch operated on the surface and commanded by the welder-diver. The welding power should be connected to the electrode holder only during welding. Direct current with electrode negative (straight polarity) is used.

Special welding electrode holders with extra insulation against the water are used. The underwater welding electrode holder utilizes a twist type head for gripping the electrode. The electrode types used conform to AWS E6013 classification. The electrodes must be waterproofed. All connections must be thoroughly insulated so that the water cannot come in contact with the metal parts.
**Advantages of Wet Welding:**

1) The versatility and low cost of wet welding makes this method highly desirable.

2) Other benefits include the speed with which the operation is carried out.

3) It is less expensive.

4) The welder can reach portions of offshore structures that could not be welded using other methods.

5) No enclosures are needed and no time is lost. Readily available standard welding machine and equipments are used. The equipment needed for mobilization of a wet welded job is minimal.

**Limitations:**

Although wet welding is widely used for underwater fabrication works, it suffers from the followings drawbacks:-

1) There is rapid quenching of the weld metal by the surrounding water. Although quenching increases the tensile strength of the weld, it decreases the ductility and impact strength of the weldment and increases porosity and hardness.

2) Hydrogen Embrittlement - Large amount of hydrogen is present in the weld region, resulting from the dissociation of the water vapor in the region. The H₂ dissolves in the Heat Affected Zone (HAZ) and the weld metal, which causes Embrittlement, cracks and microscopic fissures.

3) Another disadvantage is poor visibility when the welder some times is not able to weld properly.

4) With the increase of depth the complicacy multiplies and welding upto max. 400 ft of water depth is possible.

5) Welding near the surface is largely effected by the current and wave action.
6) Quality of weld may not always be possible to maintain in overhead position.

7) Wet welding repair is not recommended for pipe line repair job due to its poor strength in comparison to dry weld.

**WHY WET-WELDING WAS SELECTED:**

As some of the proposed joints were of complex nature comprising multiple members of different sizes the hyperbaric welding, which provides quality repair, could not be considered in view of requirement of specially designed & tailor made hyperbaric welding chambers for the specific weld joints. This would also require expertise for designing, construction and alignment of hyperbaric chambers and thus resulting in exorbitant escalation of time and expenditure.

Thus, the emerging underwater offshore structure repair technology, wet-welding repair was ultimately considered as optimum solution after extensive deliberation with various agencies and experts from the relevant field. This method was considered cost effective and less time consuming in comparison to Hyperbaric welding.

The global tender was floated in the year 2004, and job was awarded to M/s. Noordhoek Offshore B.V, a Netherlands based offshore construction company. M/s Engineers India Ltd, Delhi was engaged as the consultant of the project and the whole project was executed in the year 2005 under their supervision and in the presence of the certification agency M/s. Bureau Veritas (B.V).
STEPS FOLLOWED DURING THE PROJECT:

A) To see the carbon equivalent of the steel to see the weldability:

Chips of steel was collected from all the jackets by grinding from the nearby area of the joints proposed to be welded. The sample was then analysed in a laboratory to see the carbon equivalent ($Ec$) of the steel. It was required the see the weldability of the joints by wetwelding because the method is generally limited to low carbon equivalent steels, especially at greater depths, because of hydrogen-caused cracking. Further, it is required to decide the composition of the electrode for a specific job.

*Note:* The equivalent carbon content of a steel alloy refers to method of measuring the maximum hardness and the weldability of the alloy based on the chemical composition of the alloy. Higher concentrations of carbon and other alloying elements such as manganese, chromium, silicon, molybdenum, vanadium, copper, and nickel tend to increase the hardness and decrease the weldability of the material. A commonly used formula for calculating the equivalent carbon content is:

$$Ec = %C + [%Mn + %Si]/6 + [%Cr + %Mo + %V]/5 + [%Cu + %Ni]/15$$

B) Designing the electrode and qualification test of all the consumables:

The electrodes (Hydroweld 4.0mm) were designed and the welding procedure was finalised on the basis of the laboratory report of the steel. The electrode and procedure was qualified in the presence of a third party (Lloyd’s Register) in the testing facility of the vendor at Netherlands. Test coupons were welded by specialist diver welders inside a test tank and different NDT and physical tests (like, visual test, Radiographic examination, tensile test, guided bend test, impact test and microscopic examination) were carried out to see the quality of the weld. At the same time the divers were also qualified for actual execution of the job.

The weld test samples were prepared, welded and tested in accordance with the requirement of ‘**AWS D 3.6-93, Class B weld**’.
C) Designing the repair and execution of the project:

Detailed analysis was carried out for all the jackets to see the stress and load distribution pattern of each joint and on the basis of the ‘Fatigue analysis’ and ‘Local analysis’, different strengthening methods were designed for individual joint. These designs were approved by the consultant of the project, ie, M/s EIL. A Multipurpose Support Vessel (MSV) with diving facility was deployed for the purpose and 12 no. of joints in 5 offshore jackets were completed in 52 days.

Various strengthening methods adopted are:

a) Gouging out the cracked area and re-welding the V-groove:

b). Reinforcing the joint by welding scalloped sleeve.

(Joints repaired are MC15/MC33 & MC15/MC36c in NP jacket, MC15/MC37 in IJ)
c). Reinforcing the joints by welding doubler / scalloped plates:
(Joints repaired are NC11/MC22 in BA, NC19/MC28 & NC11/MC22 in EB, NC19/MC59, NC11/MC22a & NC19/MC28a in IJ)

d). Strengthening the joint by welding additional brace member:
(Joints repaired are MC59/MC77 & MC59/MC65 at HC platform)
e). Strengthening the joint by welding stiffener plates and gusset plates:

(Joint repaired MC59/MC75 in IJ platform)

D) Quality maintenance during the execution of the project:

In situ tests coupons were prepared by the divers at all the repair locations just before doing the welding and the samples were tested in the local laboratory at Mumbai to see the quality of the weld. Further, all the joints were inspected by MPI (Magnetic particle inspection – a NDT method) immediately after repair to see the presence of any defect.

CONCLUSION:

All the repair welds were inspected by MPI (NDT method) during November 2006 to March 2007 as per the contractual requirement, i.e. approximately after 18 months of repair and found satisfactory and without any anomaly. The reports were reviewed and certified by TPI.

The wet welding repair carried out for the first time to repair underwater structures in Indian offshore has been proved to be a very cost effective and reliable technology.
INVolVEMENT OF THIRD PARTY:

a) M/s. EIL, Delhi, was the consultant of the project and all the analysis reports and proposed weld design were reviewed and approved by them. Also, EIL representative was present onboard during the complete execution stage to ensure the quality of the job.

b) All the welding procedures, repair methodology and welding consumables were qualified by TPI (Lloyd’s Register).

c) All diver-welders, involved with the project, were qualified by the third party, after undergoing qualification test in the vendor’s testing facility at The Netherlands.

d) Re-certification agency, M/s .Bureau Veritas representative was present during the execution of the project and all the repairs, in-situ coupon tests, post repair MPI etc. were monitored and certified by them.

e) Post monsoon inspection reports were forwarded to B.V and duly certified by them.