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Large-Diameter Offshore Pipelines in the Persian Gulf

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Quality Assurance

Off the south coast of Iran since August 2008 large-diameter pipelines made of PE 100 (outer diameter 1600 mm, SDR 26) have been welded together by butt fusion in order to take sea water from the Persian Gulf to be used as process cooling water and for desalination. At the instigation of the Iranian customer and long-term project partner P.E.S. from Tehran, in the run-up to the project SKZ trained and certified the PE-welders and the welding supervisors in accordance with DVGW GW 330 [1] and GW 331 [2]. It is the task of SKZ to inspect the quality assurance chain starting from the processed raw material via the pipe up to the execution of the welded joints on site.

Fig. 1: Map with marking of the building site in Assaluyeh on the Persian Gulf (source: Google Maps)

Project Description

A large-diameter PE pipe project is being implemented in the South Pars Gas Field off the south coast of Iran in the Persian Gulf. SKZ acts as a contractor in charge of quality assurance of the raw material applied, the pipes and the welded joints. This article presents the tasks of SKZ as well as the experience made so far within the scope of this large-scale project.

With the help of large-dimension pipelines made of PE 100, dimensioned 1600 x 61.2 mm (SDR 26), it is planned to take sea water from the Persian Gulf close to the Iranian city of Assaluyeh. Due to the very shallow gradient of the seabed it is necessary that the pipes run approx. 2 km into the sea so that there is sufficient depth for the suction of the water. The supply capacity of the system is planned to be 40,000 m^3 seawater/h. The seawater sucked in will be supplied to the local chemical industry as process cooling water or to a seawater desalination plant.

For this purpose, six PE pipelines, each approx. 2.5 km long, are to be produced. The pipelines are joined by heated tool butt welding technology. Approx. 500 m of these PE pipelines are laid on land, the remaining pipelines (2000 m) are laid in the sea. **Picture 1** shows where the building site is located on the Persian Gulf.

With around 75 million inhabitants and an area of approx. 1.6 million km^2, Iran ranks among the 20 most populous and largest states worldwide. In the south and southwest, Iran has an approx. 2000 km long coast bordering the Gulf of Oman and the Persian Gulf. The most important industrial sectors are the petroleum and natural gas industry.

Production and Transport of the Large-Dimension Pipelines Made of PE 100

The PE 100 pipes are produced by the Iranian company P.E.S. Co. in Saveh, approx. 100 km to the southwest of Tehran. This production plant is situated about 1300 km north of the

Fig. 2: Lorry loaded with large-dimension PE pipes, prior to departure to the building site in Assaluyeh

Fig. 3: Production plant in Saveh with extrusion line for large-dimension PE pipes

building site on the Persian Gulf. Due to the inadequately developed infrastructure in the south of Iran, the transport of the pipe sections can only be effected by means of lorries.

Picture 2 shows two lorries loaded with 12 m long pipe sections. In view of the large pipe diameter, only 2 pipe sections can be supplied during each transport. Thus, for the overall project about 625 lorry drives from Saveh to Assaluyeh over a distance of 1300 km (one-way) are necessary, resulting in a total distance of about 1,625,000 km (!).

For the production of PE pipes of this dimension it is necessary to use a PE pipe material which features a so-called low-sagging behaviour. After the extrusion up to the cooling of the pipes, materials with this property show only a very low sagging due to the force of gravity. The wall thickness fluctuations going hand in hand with the sagging of the material are therefore minor. As PE 100 pipe material HE 3490 LS (black) of company Borouge is used.

Picture 3 shows the production hall with extrusion line and **picture 4** the storage of the 12 m long pipe sections in the yard. Both the testing laboratory of the pipe producer and the test control units being used within the scope of the internal quality control of the raw material and the pipe quality, comply with the latest state of the art. The staff members are well trained for their respective activities; they readily accept recommendations or suggestions for improvement, partly implementing them in no time at all (**picture 5**). Often they showed noticeable technical skills when it came to improvising for finding a short-term solution.

Fig. 4: Storage of the large-dimension PE pipes on the grounds of the production plant

Training of the Welders

Training and examining of the welding staff and welding supervisors are crucial for the success or failure of such a project, thus constituting a significant component. It is of major importance that not only high-quality pipes are used but also that these pipes are joined by state-of-the-art technology, i.e. by heated tool butt welding.

Prior to the welding tasks on site, the welders had been trained and certified by SKZ staff according to the DVGW rules and standards GW 330. The field welding is to be performed exclusively by certified welders with valid welding certificates. Furthermore, SKZ trained also welding supervisors according to DVGW GW 331 and deployed them on site. Within the scope of a subsequent additional training, they were instructed in the handling and welding of large-dimension PE pipes (**picture 6**).

Quality Assurance of PE Raw Material, Pipes and Welded Joints

SKZ has prepared a specification on the basis of which the quality of the raw material, the pipes and the butt welded joints produced on site are monitored within the scope of the third-party inspection. In addition, this specification defines which tests the pipe producer shall conduct within the framework of the internal quality control and which requirements shall be met by the welders/welding supervisors on site.

For company P.E.S. Co. pipes with an outer diameter of 1600 mm pose a new challenge. Up until the project start, the largest pipe dimension which had been extruded there was 1200 mm. Particularly for this large-dimension pipe project, the extrusion hall was extended and a new extrusion line was set up. However, since the welding staff had gathered experience in the production of PE pipes for several years, they had no problem coping with the dimension 1600 mm.

The raw material applied was to fulfil the requirements of DIN EN 12201-1 [3]. The pipe

Fig. 5: A staff member of P.E.S. Co. examining the outer pipe diameter with a circometer

Fig. 6: Welders during training course with CNC welding machine for the welding of large-dimension pipes

producer and SKZ examined material properties, such as MFR value, density and thermal stability (OIT) and compared these properties with the requirements / the test report of the raw material supplier.

The pipes were assessed on the basis of the stipulations in DIN EN 12201-2 [4]. In regular intervals, SKZ (within the scope of third-party inspection) and the pipe producer sample test pieces and determine as-delivered condition (surface finish, appearance), colour, dimensional stability (outer diameter, wall thickness and ovality), thermal stability (OIT), homogeneity, MFR value and elongation at break. The raw material used and the pipes fulfil the re-

Fig. 8: Welder and CNC-control unit of the welding machine with sun protection and air conditioning by means of a ventilator

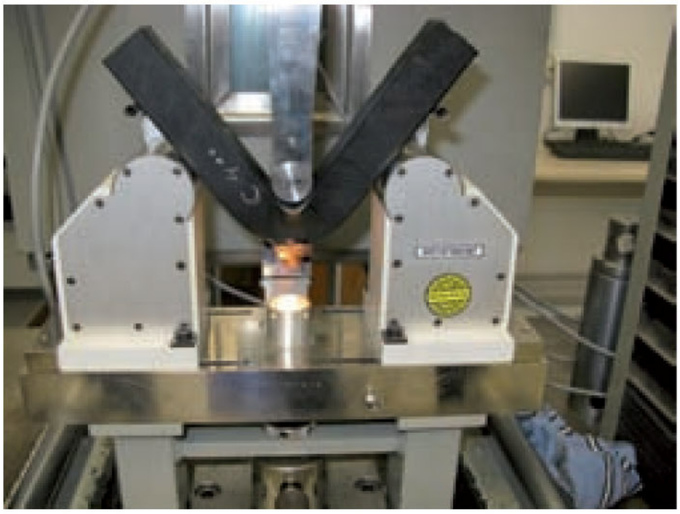

Fig. 7: Technological bending test according to DVS 2203-5 to examine the welding seam quality

quirements stipulated in the standard without any problems.

For the welding, 2 CNC heated tool welding machines of company Widos are used. Initially, reference samples were welded on each welding machine in the production plant close to Tehran. These reference samples were subject to a visual and destructive assessment according to DVS 2202-1 [5]. It turned out that due to the training measures they had completed the Iranian welders were in a position to apply the heated tool butt welding technology with very good results also on large-dimension pipelines. The welded joints complied with the DVS requirements. There did not occur any faulty welding seams. For assessing the quality of the welded joints, SKZ conducted also destructive tests. For this purpose, test pieces with welding seam in the centre were sampled throughout the pipe circumference. On these samples the short-term welding factor was determined according to DVS 2203-2 [6]. All samples exceeded the short-term welding factor of 0.9 , as required in DVS 2203-1, supplement 1 [7].

The technological bending test according to DVS 2203-5 [8] constitutes a further criterion for the quality of welded joints. DVS 2203-1, supplement 3 [9], stipulates a minimum bending angle of 20°. For all test pieces examined, the technological bending test was stopped once a bending angle of 100° was reached without any fracture (**picture 7**). Thus, also this requirement was surpassed by far.

Fig. 9: Artificial dock for the interim storage of the 250 m long pipelines

Fig. 10: Sealed PE pipeline is lifted into the dock by a crane

These preliminary examinations on the reference welds confirm on the one hand the suitability and serviceability of the welding machines applied and on the other hand the ability of the welders, to produce high-quality welded joints according to DVS.

Thus, the high pipe quality and successful training of the welders ensure the prerequisite for a successful implementation of the project in the Persian Gulf.

Welding on Site

Apart from the major challenge the welding of such large-diameter pipes constitutes anyway, extreme weather conditions on the Persian Gulf make the welding performance still more difficult. In August 2008, the establishing of the building site in Assaluyeh started. At this time of year, the daytime temperature sometimes exceeds 45°C in the shade at a very high atmospheric humidity. Since the welding point is directly on the coast, humidity, flying sand and wind constitute additional

Fig. 11: Storage and pushing forward of the pipelines on pulley blocks

problems which can impair the welding. Both the welding staff and the welding machines are subjected to extreme stress (**picture 8**).

Close to the building site, an artificial dock was established into which the welded pipelines are tugged (**picture 9**). In order to prevent the waves of the sea to impede the welding, the dock was filled up with sand again on the side facing the sea. The 12 m long pipe sections are welded together to approx. 250 m long pipelines, which subsequently are tugged into the artificial dock (**picture 10**). The pipeline ends are provided with a welding neck and a loose flange and sealed before they are tugged into the dock. The pipe sections and the pipeline are placed on special pulley blocks so that they can be moved and shifted for welding (**picture 11**). Caterpillar cranes and a truck-mounted crane are used for pushing the pipes forward and positioning the pipe sections in the welding machines. A 12 m long pipe section weighs approx. 3600 kg.

The welding point is provided with a concrete paving slab. In addition, there is a 10-t gantry crane for moving the welding tools (**picture 12**).

Welding is effected parallel on the two CNC-hot plate butt welding machines. Every day the welders work for 14 hours in two shifts performing approx. four to five welded joints per day and machine.

The 3.6 t pipe sections are placed in the welding machine with the help of the crane. Afterwards the planing of the pipe ends to be connected and the misalignment adjustment is effected. The heated tool for the adjusting of the pipe ends and for heating is moved with the help of the crane as well (**picture 13**).

Of each welding seam the welding parameters are recorded by the welding machine and can be read out later. Furthermore, the welders mark each welding seam individually by impressing a stamp from outside in the welding bead (**picture 14**). Thus, any possibly occurring faults or problems can be retraced and assigned to a particular welding seam.

Site Supervision

In advance of the project, it was agreed with the customer that in regular intervals of approx. 6 weeks, a SKZ staff member should inspect the welding tasks and sample welded joints alternately from each welding machine for the destructive tests. Within the scope of the site supervision, meetings with the welding supervisors on site and the customer take place. Problems which might have come up and their possible solutions are recorded. The welding reports of the CNC-machines are read out and checked, the welded joints are subjected to a visual assessment and samples for the destructive tests are taken.

By means of the check lists prepared in advance for welding machine, hot plate (temperature accuracy, calibration of the temperature measuring devices), accessories, welders, transport and storage of the pipes (also dimensional accuracy), processing sequence of hot plate butt welding and control of the welding seams, the necessary and most significant details are monitored by the SKZ inspector who, if necessary, suggests improvement possibilities.

With PE pipes of this dimension, the bevelled shrink of pipe ends due to the internal stresses from the extrusion process might constitute a problem. If the bevelled shrink is too large or differs too much between the pipe ends to be connected, it causes a mismatch during welding and, therefore, must be cut off by a saw. It became evident that the principle of „first-in-first-out“ should be observed on site. This means that the pipe sections should be welded in the order of their delivery. This way it is avoided that pipe sections are stored on site for different periods of time and, as a consequence, feature different ovalities. The latter result is problematic for the hot plate butt welding. On account of the heavy dead weight of the pipes in straight length, they deform after having been stored for some time and therefore are no longer round. This can be avoided by turning pipes, which have been stored for some time, around their longitudinal axis.

Dust due to wind and site vehicles poses another problem during welding. Dust or sand can contaminate the welding seam, thus reducing the weld strength. Moreover, the hot plate can be contaminated by sand. Wind can lower the heated tool temperature, thus causing poor welds.

For this reason, initially the setting up of a protective tent around the welding machine was considered. However, such a tent would make the handling of the welding tools and the positioning of the pipe sections in the welding machine considerably more difficult. As a compromise between optimal welding conditions and flexibility on the welding point, now during each welding the pipe end is covered with a foil. Thus, it is prevented that due to the chimney effect the wind cools off the welding element too much and flying sand reaches the welding seam or the heating element through the pipe end (see picture 12). The cleaning of the heating element prior to each welding continues to be of tremendous importance.

A significant experience gained during this project is the perception that the welders' awareness for regularly checking and maintaining the welding devices and equipment must be raised. Measuring instruments, e.g. temperature measuring devices, must be applied and calibrated regularly. The DVS rules with regard to welding and welding seam preparation shall be complied with continuously.

Fig. 12: Welding point with concrete paving slab and gantry crane. A pipe end is covered with a foil during welding to protect the heated tool from cooling and dust.

Fig. 13: Positioning of the heated tool by means of a crane

Fig. 14: Welding bead with stamp mark (Arabic series of numbers)

Summary

So far, the large-dimension PE pipeline project off the south coast of Iran in the Persian Gulf, within the scope of which welding started in August 2008, has turned out to be very successful. Prior to the start of the project, SKZ developed a quality assurance plan which considers both pipe material and pipes as well as the welding seam quality, thus ensuring that the product quality and the workmanship are inspected continuously. Training of the welders and welding supervisors form the basis for the hitherto successful project progress. It is of vital importance that the welders are aware of the significance and consequences of their tasks. There is always the danger that once the tasks have become routine the welding staff might become careless. This might result in poor welding seam qualities. The SKZ staff and the welders have always succeeded in solving problems which occurred on site, thus achieving a permanently good welding seam quality. All welded joints which so far had been subject to visual and destructive test methods have been without any objection. The project progress up until now has showed that the technical knowledge of the welders is very good and that they are able to put it into practice in conformity with the standards. In the meantime welding was completed by end of March 2009 and the next project stage, within the scope of which the pipes can be laid in the sea, is running at the moment.

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Pictures: SKZ, except for the map: Google Maps

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