INTRODUCTION

Subsea steel pipelines represent today the most important infrastructure for the transport of oil and gas to onshore facilities in Norway and the rest of Europe. In fact, the North Sea network of offshore pipeline transportation systems for natural gas is the world’s largest, comprising more than 6000 km just on and from the Norwegian Continental Shelf (Berge, 2005a). Up to now, large-diameter subsea pipeline tie-ins and repair have been carried out with the assistance of divers, present in the seabed habitat to install equipment on the pipe for cutting, machining and welding. However, the welding has been controlled from a support vessel using Gas Tungsten Arc Welding (GTAW) in a narrow groove. So far, more than 70 tie-ins have been made using the pipeline repair system developed and run by StatoilHydro and their partners (Akselsen et al., 2006a).

The recent trend of oil and gas exploration moving to deeper waters imposes an extreme challenge, not only for pipelaying, but even more for eventual repair and hot tapping. Because StatoilHydro has decided that diver-assisted operations will not be used below the 180-m sea depth, the fully remote controlled welding process must be used. Technology is now prepared to perform remote-operated pipeline repair with no need for diver intervention. Ongoing development programs will push the technology further to cover 44-in pipelines as well as smaller dimensions down to 4 in, and water depths of 1000 to 2000 m depending on need (Berge et al., 2004). Further, the development of remote-operated tooling systems for hot tapping is ongoing (Berge et al., 2005b; Woodward et al., 2007). Additional equipment information, including detail on the structural design and installation of the hot-tap tee, can be found in the literature (Apeland et al., 2006). Such a new remote system will represent substantial cost reduction: By itself, the offshore vessel used for the remote equipment costs approximately half the daily cost of an offshore vessel with diver support, without factoring in the additional cost of diver qualification. Even more importantly, the system will extend the capability of the hot-tapping method beyond diver-limited water depths.

As part of the development program on gas metal arc (GMA) welding, the present investigation was initiated to study welding in shallower water, i.e., up to 35 bar, with the focus on mechanical properties using a low-alloy steel and an Inconel 625 welding wire, including an evaluation of the base plate dilution. This water depth level is lower than previously reported in studies using the same welding wires (Woodward et al., 2006, 2007).

MATERIALS AND EXPERIMENTAL PROCEDURE

Materials

Plates corresponding to API X65 steel were selected for welding since this quality is frequently used in subsea pipelines. These plates were 27 mm in thickness and cut to 500 mm in length and 130 mm in width, using a 60° V joint without root gap. Table 1 shows the base plate chemical composition, revealing low carbon content with Mn concentration of 1.58%, and small amounts of Ni and Cu. Two types of filler wires were applied; one low-alloy metal cored wire supplied by ESAB, the HBQ Coreweld, and one solid Inconel 625 wire. The wire diameter was 1.0 mm and 0.9 mm, respectively. Table 1 outlines their chemical composition.

Welding

Welding trials were performed at pressures of 12, 25 and 35 bar in a cylindrical chamber with a volume of 100 litres and internal diameter of 350 mm, without the use of strongbacks. The chamber was equipped with a conventional wire feeder and a GMA welding torch rigged up for butt welding of plates in the flat position, as shown in Fig. 1. The welding power source comprised 3 modified Fronius Transpocket TP450 in series. The chamber