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SUBMERSIBLES OF CASTED MARAGING STEEL

Olavi Piha[1], M.Sc. (Tech.), Tanja Saarelainen[1], Lic.Sc. (Tech.) and Juhani Orkas[1], Professor, D.Sc. (Tech.).
[1] Aalto University School of Engineering, Department of Engineering Design and Production,
Foundry Engineering. PO Box 14100, FI-00076 AALTO, FINLAND.
Corresponding author, E-mail: olavi.piha@aalto.fi

In 1982, the Soviet Union Academy of Sciences enquired whether a Finnish company Rauma-Repola would be interested in manufacturing two research vehicles capable of diving to a depth of 6 kilometres. The contract was signed on May 1985 and the vehicles signed off into service in December 1987. The most critical challenge was to determine how the personnel's spheres could be formed as they were required to protect personnel from pressures reaching 600 bar. Maraging steel was finally selected as the material for their construction. Large parts had never before been poured in this material. The foundry developed ultra-high strength MVD steel for the manned sphere. This material contained low level of impurities and underwent a specific heat treatment to attain the required properties: Yield strength R_e 1650 N/mm^2, Tensile strength R_m 1730 N/mm^2, Elongation A_5 6 %. The chemical analysis was C < 0.02 %, Ni 17-19 %, Mo 4-6 %, Co 10-13 %, Ti < 0.35 %. Those values can only be reached using vacuum technology.

Keywords: *steel foundry, ultra-high strength maraging steel, vacuum technology, centerline shrinkage, Tevo Lokomo Ltd.*

1. Introduction

Rauma-Repola shipyards had after World War II delivered around a thousand different types of vessels to the Soviet Union. By 1972, the firm had started the production of oilrigs. The Lokomo works, which was part of the machinery sector of Rauma-Repola, had delivered casted parts for the oilrigs. Rauma-Repola considered the Lokomo works to be the most suitable designer and producer of the research vehicles. Lokomo's potential was also well known to the Soviet Union. The Soviet Union Academy of Sciences had previously ordered two vessels with a diving capacity of 2 kilometres from a Canadian company. The company however, could not offer vehicles of 6 kilometres due to insolvency. France, Sweden and Switzerland had not been willing to offer them at the time. It was told, that, these types of vessels were required to research and collect nodules from the bottom of sea. It is uncertain how productive this exercise had been, as no results have been disclosed to the public. A rumour even stated that the vessels were needed due to a Soviet navy nuclear submarine having sunk to a depth of 6 kilometres in the Atlantic Ocean. [1]

2. Quality Control

Before precipitation glowing of the spheres, the company used penetration liquid due to the non-magnetic austenite structure. After precipitation glowing, it was possible to use magnaflux control, as the structure became martensitic. Ultrasound control was verified by random checks using radioisotope imaging (iridium 192). When asked about the required level of the NDT control, Igor Mikhaltsev – a professor of the Soviet Union Academy of Sciences and supervisor of production, stated: "No visible defects are found with modern control methods". [2]

Figure 1: The heat treatment of the sphere halve at the Lokomo steel foundry. [3]

The production of the pressure-resistant personnel sphere was a real engineering triumph for Rauma-Repola. It succeeded thanks to top metallurgy and the diligent work of the whole project team. The company bravely signed the contract before there was absolute certainty that the method would work. Therefore the company took a considerable albeit well controlled risk both in technical and commercial respects. Due to the high purchase price, there was room for error thus reducing pressure on succeeding on the first attempt.

The material used was maraging steel, of which Americans had forged small and demanding pieces. It had exceeded the required yield strength (min 1650 N/mm^2). Large pieces had never before been cast out of this material. The metallurgists of Lokomo saw an opportunity to succeed, above all thanks to the VODC vacuum converter purchased in 1982, and the modern testing equipment (spectrometers, electronic microscopes, highly developed pressure testing equipment) manned by highly skilled and professional technicians.

3. Vacuum Oxygen Decarburization Converter

To fulfil the high quality standards of the cast and forged steel parts of the oilrigs made by Rauma-Repola, the Lokomo steel works purchased a VODC converter (Vacuum Oxygen Decarburization Converter) in 1982. [4]

The benefits of the VODC converter:

- Low gas contents, eg. hydrogen < 2 ppm
- Low carbon contents, C < 0.02 %
- Low sulphur contents, S < 0.007%
- Low other impurities
- Low emissions due to a closed process

4. The production of the personnel spheres

The spheres were cast in two halves, and these halves were joined together at the assembly stage using bolts. After pouring, the walls of the halves were 200 mm thick. The final wall thickness was 40 mm, so there was a large amount of additional material. Most of this additional material was removed (machined) from the inside, so that the potential areas of centreline shrinkage and impurities associated with thick sections during solidification could be removed. The result was a fine granular and clean convex-like outer surface. [5]

Heat treatment of the sphere’s halves:

- Homogenising treatment 1200 °C
- Soaking treatment 850 °C
- Precipitation treatment 450 °C

With the help of the first two heat treatment phases, the chemical analysis and microstructure was homogenised. This treatment also allowed homogenisation of the remaining impurities, and the precipitation treatment gave the sphere the required hardness or toughness. This final microstructure was a low carbon slat martensitic steel. The hardness increased by 500-800 HV. [6]

Figure 2: The sphere’s halves joined together with bolt joints. The remaining hemisphere is exhibited at the Lokomo steel foundry which is nowadays called TEVO Lokomo Ltd. [7]

Due to the high price of the vessels, it was also possible to produce large pieces out of this steel of similar quality as in small pieces. Because of the purity requirements of this steel, the converters and ladles had to be relined. Some further modifications of the normal casting methods were also required. On the other hand, the steel could easily be cast, which made testing significantly easier. The successful heat treatment also required separately cast test pieces. Thanks to the equipment available and knowhow of the Lokomo steel foundry these tests could be undertaken on site alongside the production.

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