HARD FACING WITH COBALT BASE ALLOY – STELLITE-1

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(This paper, presented at the National Welding Seminar-1995 at Cochin, has received the K.C.P. Award for the First Best Paper on Fabrication)

INTRODUCTION

Primary Heat Transport (PHT) System Pumps are used for circulating Heavy Water at high temperature in the PHW Reactors. A pair of stationary and rotary S.S. mechanical seals are used in these pumps. To provide sufficient wear resistance, corrosion resistance and a variety of additional properties, the hard cobalt based alloys are faced on the mating surfaces of the pair of mechanical seals. Initially, Stellite-6 was hard faced on the seals. Since the seals were wearing out fast, the need for a much harder facing material, to extend the life of the machanical seals, was felt. Hence, Stellite-1 was an obvious choice. Nevertheless it was not an easy task to replace Stellite-6 with Stellite-1.

This paper deals with the problems encountered on the shop floor in hard facing with Stellite-1, and attempts to explain the cause and methods of overcoming the difficulties, and suggests a procedure for defect-free deposition. It also discusses the various tests conducted to verify the quality of the bond between the hard faced material and the parent material.

AIM

The aim of the paper is to, principally, explain the nature of the problems encountered; secondly to discuss the root cause of the problems and effect of different techniques on the end result; thirdly to suggest a technique suitable for achieving the desired result; and finally to explain the methods of NDT examination of the bond followed by discussion on the result of such examinations and the metallurgical study of the bond.

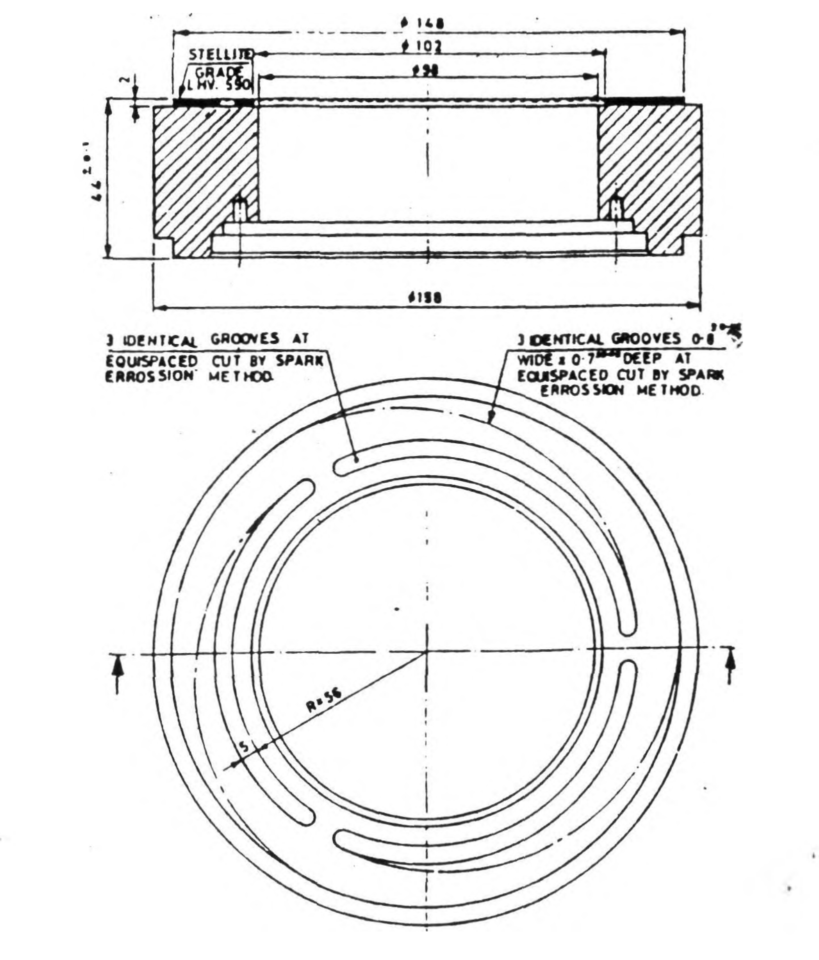


Fig. 1 : Primary Seal (Rotary Face)

PREAMBLE

The primary seal rotary and stationary faces of PHT circulating pump are made out of 44 mm thick S.S. of dia 158/98 mm. One face each of these seals is deposited with Stellite-1 providing a clear hard thickness of 2 mm after machining. The pump seals are shown in **Figs. 1 & 2**.

Initially, it was planned to prepare a groove on the face to a depth of 3 mm and provide extra material on the OD and ID of the blank piece. The idea was to deposit the weld metal in the groove and then machine to finished size so that the end defects due to welding may be cleared. TIG welding was the process selected and weld runs were planned to be made in a sequence of a number of annular runs to a thickness of 4 mm. Based on the previous experience, the following parameters were selected :

Filler metal	– Stellite grade-1, dia. 5 mm (Co-55.5%, Cr-30%, W-12%, C-2.5%, Hardness-55-60RC, UTS-5560 Kg/cm^2)
Welding current	– 130 A
Arc voltage	– 18 V
Welding speed	– 55 mm/min.
Preheating & Post-weld heating	– 500°C

When actual welding was carried out, it was found to be cracking. Most of the defects were transverse to the weld bead. Repairing and rewelding also resulted in similar cracks. The cracks were so deep that they extended upto the parent metal. Majority of the defects were on the outer edge and predominantly near the closing point. In order to overcome this problem, it was planned to temporarily attach a run-off ring along the periphery so that the end defects could be shifted to a location away from the useful zone and could be machined afterwards so that main area would remain defect-free. But this procedure also did not result in crack-free deposit. It was noticed that an attempt to remove the crack by gouging through flexible shaft grinder had resulted in propagating the cracks to the adjoining area.

INVESTIGATION

At this juncture, a thorough examination was made to identify the root cause of this weld defect. Several shop models as described below were tried.

i. Linear welding by bead on plate **(Fig. 3)**
ii. Circular layer on a thick plate **(Fig. 4)**
iii. Circular layer on a thin plate, say 6 mm **(Fig. 5)**

The results of the examination revealed that in the Model-1, no cracks were found irrespective of whether the welding was done on a thin or a thick plate.

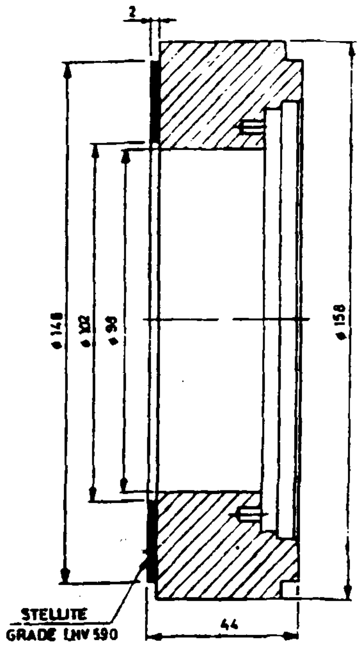


Fig. 2 : Primary Seal (Stationary Face)

Model-2 revealed the same type of defects as encountered in the actual job.

Model-3 was found to be defect-free but the parent material was heavily distorted.

By examining the models, the following inferences were arrived at :

i. The very hard stellite material cannot take the shrinkage stress, and invariably the stress gets relieved through the so-called "Stress Relief Checks" manifest in the models described above.

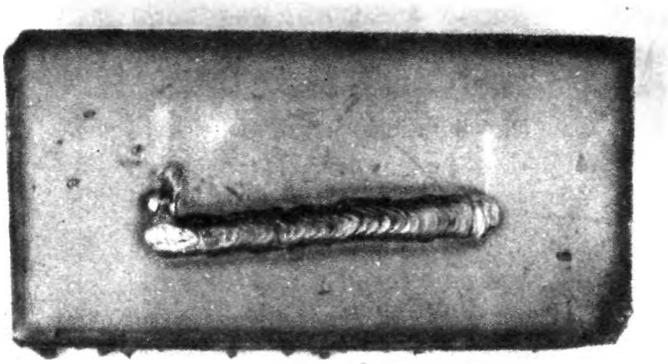


Fig. 3 : Linear Welding by bead on plate

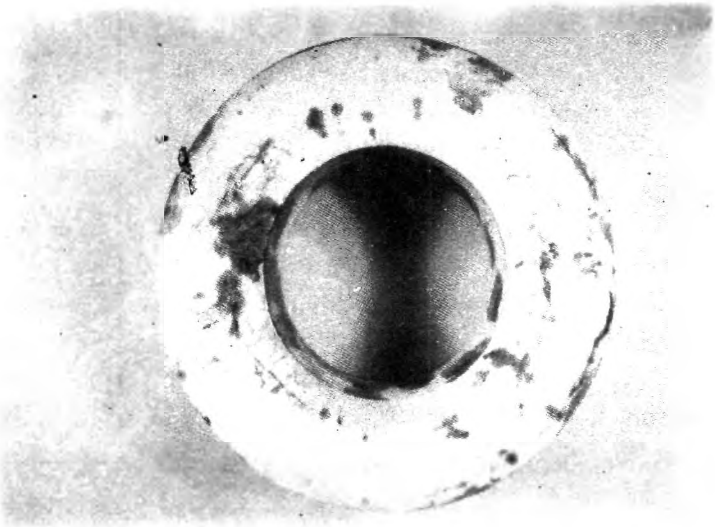


Fig. 4 : Circular layer : Thick plate

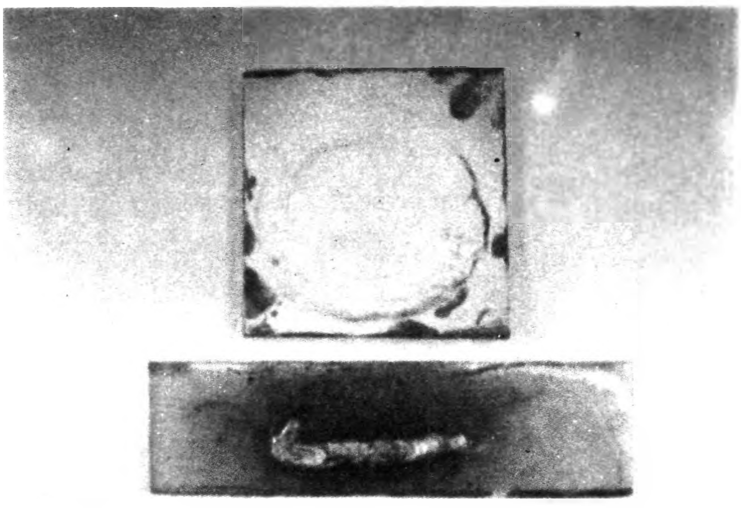


Fig. 5 : Circular layer : Thin plate

ii. If the parent metal could accommodate shrinkage stress by distortion the weld metal remains defect-free.

iii. The shrinkage stress is more severe in an endless circular bead than in the straight bead with open ends.

The cumulation of these inferences led to the inevitable necessity for developing a new welding technique which could avert the defects.

MODUS OPERANDI

The earlier difficulties and the consequent analysis have enthused the authors to contemplate on a new technique to reduce the shrinkage stresses to a minimum. The first choice was to weld for short lengths, say to a length of 30-35 mm, following a typical weld sequence. When this idea was envisaged on a circular bead for a considerable width, an unattractive weld appearance was visualised. This led to an idea to weld radial beads. The result was excellent and indeed amazing, with an increased weld speed as well. On the spot, the ingenuity of the welder has further improved the method for a better result and in countering the tendency for defects at the closing joint of the loop. The technique followed is shown in **Fig. 6**. At this stage, the redundancy of the groove was noticed and the process of machining a groove for weld deposit was given up.

Trial-1

The job was preheated to 500°C in the furnace and the following parameters were followed :

Current	– 130 A
Arc Voltage	– 18 V
Welding speed	– 45-50 mm/min
Process	– GTAW
Filler wire	– Stellite-1, size dia. 5 mm

This process gave a good result with no major defects. Small cracks were noticed across the bead near the closing pass These were removed by mild gouging and a second layer was welded with the same parameters. Cracks were found near the closing pass again. The cracks were isolated by making radial grooves on either side of the crack as shown in **Fig. 7** Grinding with a flexible shaft grinder to make grooves resulted in the propagation of these defects. But they were contained between these grooves The defective layer between the grooves was removed by milling.

Trial-2

An improvement to the above process was thought out and tried as described below'

First Layer

Filler Wire	– Dia. 5 mm. Stellite-1 rod
Welding current	– 90-130 A
Arc voltage	– 18 V
Welding speed	– 55-60 mm/min
Preheating	– 650 C

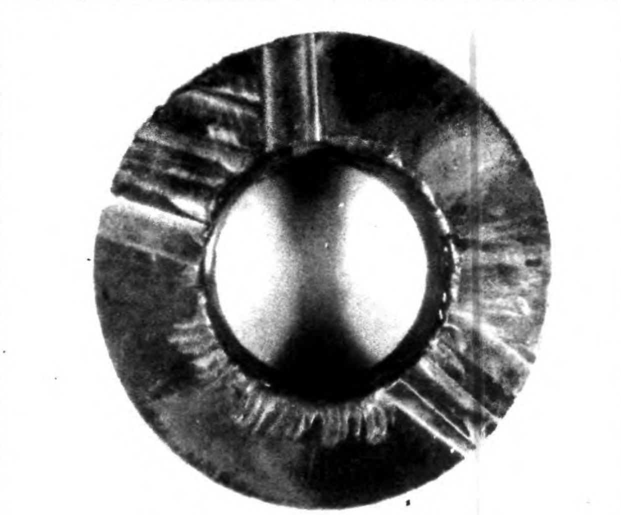


Fig. 6 : Welding of radial beads

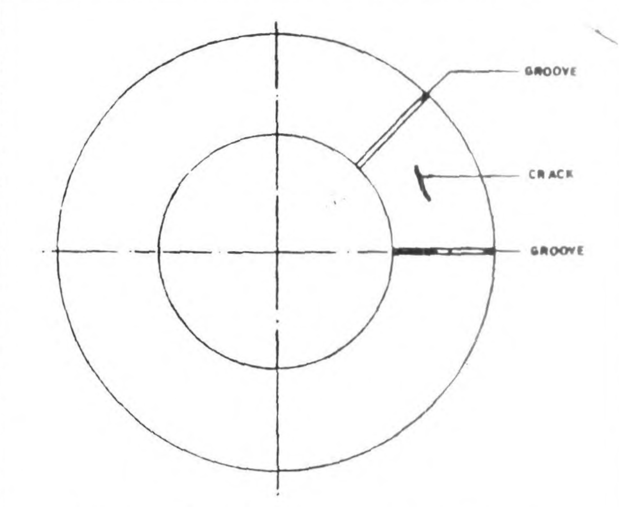
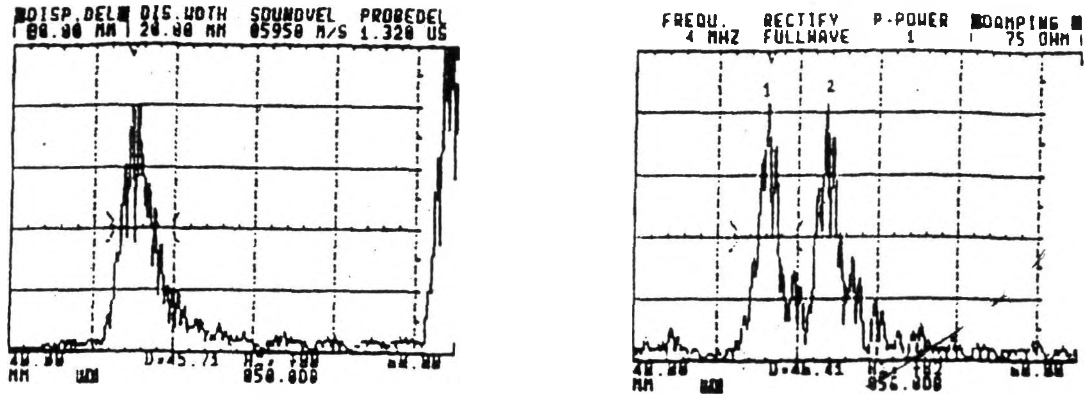


Fig. 7 : Cracked Job with Isolation Grooves



REF. : 2 mm ϕ hole on CS at 45 mm

Stellite Ring [CWS]

1. Without Stellite Layer (Base Metal)
2. With Stellite Layer

Fig. 8 : CRT Output

Interpass temperature	–	600°C
Deposition thickness	–	2-2.5 mm per layer
Post-weld heat treatment in the furnace	–	600°C for 1 hr and slow cooled

Job was removed from furnace at 100°C. On visual examination, no defects were found except some acceptable level porosities. Dye check also was carried out to ensure the weld quality.

Hardness measured	–	58-60 HRC

Dye penetrant examination was carried out to ensure defect-free overlaying. The job was free from defects.

Second Layer

Same method and parameters were followed as for the first layer. The job, after removal from the furnace, was found to have a linear indication near the closing pass. When the surface was machined to an extent of 1 mm, the defect was cleared. Dye penetrant examination was carried out to examine the surface, which revealed no defect.

EXAMINATION

The visual and L.P. examinations were carried out to ensure that the surface was free of defects.

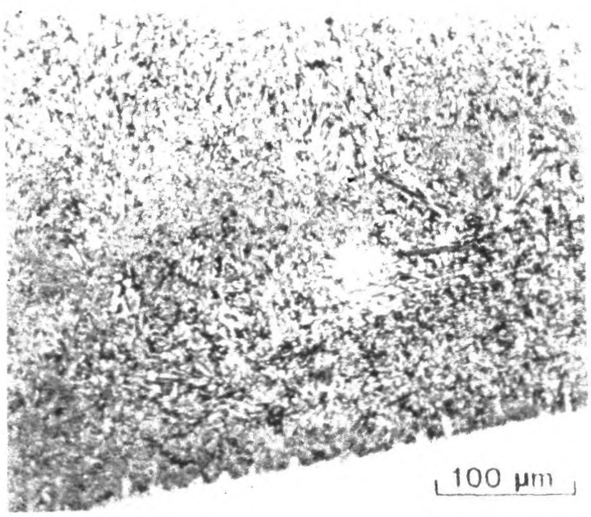


Fig. 9 : Inter-Face

Fig. 10 : Middle of Facing (+1.5 mm)

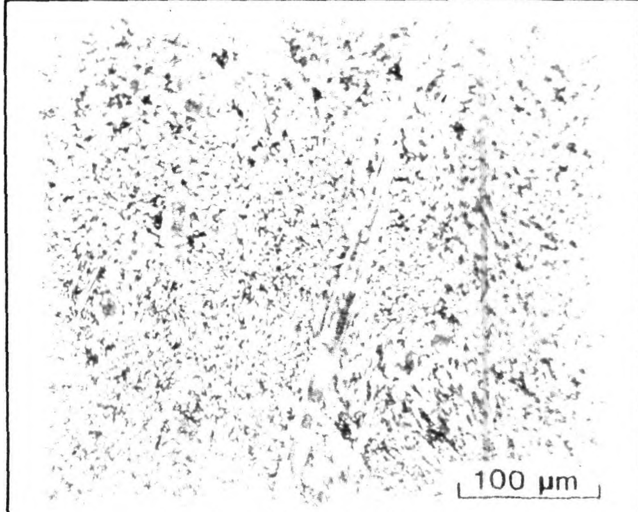


Fig. 11 : Top of Facing

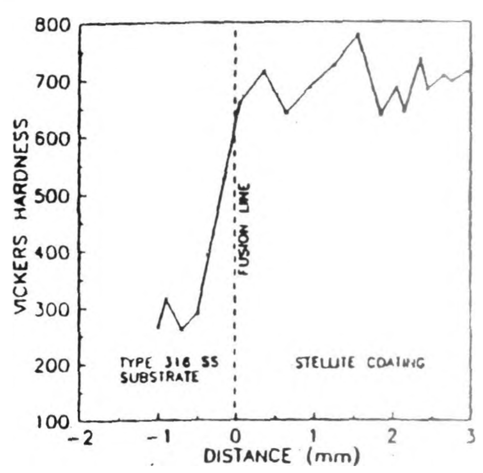


Fig. 12 : Hardness profile

U.T. was also conducted. Further micrographic examination was carried out. The results of examinations are discussed below.

Non-Destructive Examination

Besides visual and L.P. examinations, U.T. was also conducted to examine the soundness of the bond, and the stellite layer was volumetrically examined by employing both normal and angular probes. A 2 mm dia side drilled hole was used as reference. The scanning was employed on the opposite face of the stellited portion with 10% overlap. This examination revealed defect-free bonding. The CRT output report is shown in **Fig. 8**.

Metallographic Examination

The Stellite-1 overlayed specimen was subjected to metallographic examination to assess the microstructure and hardness gradient. The specimen of size 30 X 20 mm was taken perpendicular to the plane of hard facing and prepared metallographically. Etching was carried out using boiling Murakami reagent. The stellite substrate was found to be free of defects such as porosities and cracks (**Fig. 9**). This indicated that a good metallurgical bond had formed between stellite and substrate. The hard facing consisted of plates and particles of chromium carbide in a hard matrix. The bottom layer had a finer structure of carbide (**Fig. 10**) than the top layer (**Fig. 11**), where hexagonal carbides and plates were bigger.

Hardness Variations

The profile of the hardness readings is shown in **Fig. 12**. The hardness data shows that the value increases from the substrate hardness of 265 VHN to about 650-700 VHN in the hard facing. This value was verified by full scale vicker test, which gave a reading of 195 VHN at substrate and 627-760 VHN in the faced area.

CONCLUSION

The overlaying of Stellite-1 is a difficult task. By its very nature, it offers stiff resistance to defect-free welding. Understanding the nature of the material, the cause of the problem and a patient analysis to find the ways and means to counter the weld difficulties led to this successful event. The concerted effort of the Shop Team with an indomitable desire to tame this extremely difficult-to-weld material has paid a rich dividend. The object of this paper is to share the experience gained with the welding fraternity, as well as the benefit of those who work with this material.

ACKNOWLEDGEMENT

Authors express their gratitude to Director, IGCAR for his encouragement, and for granting permission to present this paper. The authors also thank Shri V. Shankar, MDD, and Shri M. Palaniappan, QAD of IGCAR for useful discussions and facilities provided for carrying out metallographic examination and NDT.