# Additive Manufacturing of Co-base Alloy for Nuclear Application; Wear Property

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## 1. Introduction

Load-following operation of nuclear power plants has been one of the key issues in the nuclear industry as well as in the scientific research area in the country. This operation type proved to be necessary and effective in the case that the nuclear power generation portion is one major electricity resource in a country, and shall become more important or vital to be competitive with other types of resources in the ever changing environments of energy mix.

For the nuclear power plants to be operated in the load-following mode the relevant components should be improved in their characteristics on top of the enhanced core monitoring system able to evaluate the local power density distribution more precisely and quickly [1]. Control rod drive mechanism (CRDM) may need to move much more frequently in the load-following operation mode, and consequently the contact area of the control rod and the latch arm shall be more wear resistant. Hard martensitic stainless steel is one candidate material for the control rod, and the contact area of the latch arms may be hard-faced with wear resistant cobalt-base alloy such as Stellite 6™ (Fig. 1.).

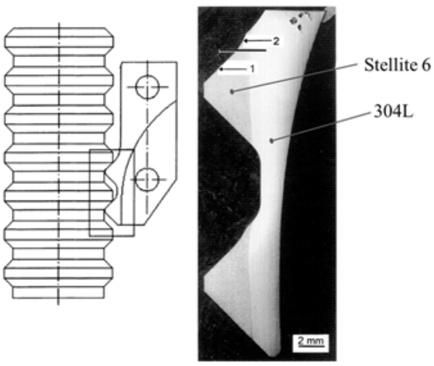


Fig. 1. Schematic diagram showing the contact area between the drive rod and the gripper latch arm; micrograph of a latch arm revealing worn area of hard-faced alloy [2].

In this study additive manufacturing (AM) technology and the conventional PAW (plasma arc welding) hard-facing technology were utilized to prepare samples. And the wear properties of the samples of AM and hard-facing are tested at room temperature

## 2. Experiment and Result

Wear resistant cobalt-base Stellite 6 alloy™ powders were additively deposited by DED method on 20 mm thick Type 316L stainless steel base plates. To estimate the effects of temperature gradient during the AM process, the stainless steel base plates were held at room temperature and at 300ºC, respectively. Cobalt-base alloy powders were 50-125 micron in diameter, and the chemical compositions of the alloy powders is shown in Table I.

Table I: Chemical composition of cobalt-base alloys

| | Cr | W | C | Ni | Mo | Si |
|---|---|---|---|---|---|---|
| Stellite 6 | 29.70 | 4.64 | 1.12 | 2.23 | 0.18 | 1.20 |

For the DED AM process ytterbium fiber laser was used. The laser power was 600-980 W, and the beam traverse speed was about 850 mm/min (14.1 mm/sec). For the first several layers up to five mm of height, AM processing was carried out in one direction parallel to the rolling direction of the stainless steel base plate, and the next layers of another five mm of height were alternately deposited in perpendicular direction to the previous deposition direction. Each AM deposition layer corresponded around 450 micron in height. Part of AM sample was HIP (hot isostatic pressing) processed at 1150ºC under 104 MPa for 4 hours.

Another set of hard-faced specimens were prepared by PAW (Plasma Arc Welding) of the same cobalt-base alloy powders on type 304L stainless steel plates.

Grain size distribution, grain morphology and pore formation were observed by using SEM; and dendritic growth of alpha cobalt phase with lamellar structure of $M_7C_3$ carbide within the inter-dendritic region were also identified by using SEM/TEM/EDS.

According to ASTM G99-17 wear characteristics of the AM specimens and hard-facing ones were evaluated by pin-on-disk method at room temperature. Test pins were prepared from KS STB2 high carbon steel rod, and the hardness reached about HRC 60 by heat treatment.

™ *Stellite is a registered trade mark of Kennametal Inc.*

Table II : AM and Hard-facing Parameters

| | AM (DED) / Hard-facing (PAW) |
|---|---|
| Filler | ERCoCr-A |
| Powder Size (μm) | 50 ~ 125 / 50 ~175 |
| Power (KW) | 0.6 ~ 0.9 / 4.0 |
| Travers Speed (mm/s) | 14.2 / 1.5 |
| Deposited Height (mm/Layer) | 0.45 / 2.5 |
| Base Plate Temp. | R.T, 300 / 315 °C |

Vertical load during the wear tests was 50N, the rotation speed of the disk sample was about 0.220 m/s with rotation radius of 11.5 mm. Wear tests were carried out for 0.5, 1, 2, 3, 4 hours intermittently, and the wear loss was measures during the intervals

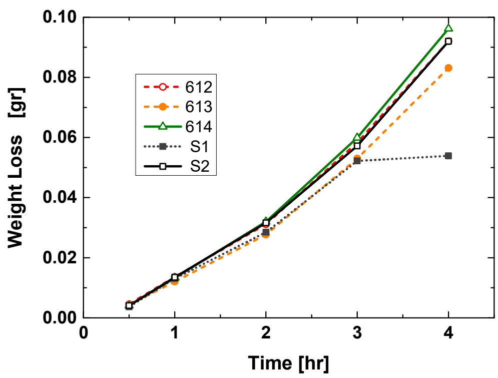


Fig. 2 Wear test results of AM and hard-facing specimens according to ASTM G99-17 Pin-on-Disk method

## 3. Summary

Wear resistant cobalt-base Stellite 6™ alloy powders were deposited by AM DED method, and PAW hard-facing technique, respectively.

Wear performance of the samples were evaluated by Pin-on-Disk method at room temperature up to 4 hours at room temperature according to ASTM guide. The wear properties of the AM sample and hard-facing ones were not explicitly different up to 4 hours, except on specimen. That is assumed to attribute to the different pore fraction.

**Acknowledgements**

AM samples and hard-facing ones with Stellite 6 alloy powders in this study were prepared by INSSTEK, and Myung San Co. Ltd., respectively. Wear tests were carried out through the help from Daegyeong Regional Division, KITECH.

## REFERENCES

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