3Pa4-13
Proceedings of Symposium on Ultrasonic Electronics, Vol. 32 (2011) pp. 395-396
8-10 November, 2011

Cavitation erosion mechanism of electroless Nickel plating
無電解ニッケルめっきのキャビテーション壊食機構

Shinobu Sugasawa[1†], Shigeru Akiyama[1], Susumu Uematsu[1], Toshiaki Shibata[1], Toshiaki Iwata[1], Naoki Miyauchi[2], and Fumihiro Fujita[2]
([1]National Maritime Research Institute; [2]Meltex Co., Ltd.)
菅澤 忍[1†], 秋山 繁[1], 植松 進[1], 柴田 俊明[1], 岩田 知明[1], 宮内 直樹[2], 藤田 文洋[2]
([1]海上技術安全研究所, [2]メルテックス（株))

1. Introduction

Cavitation erosion has been a serious problem in turbo machinery like ship propellers. If this problem is solved, we can expect the long service life and the improvement of efficiency of these machineries. One of the methods of improving anti-cavitation erosion property is to apply surface modification on a material exposed to cavitation impacts. For example, overlaying welding, spray coating, and plating are known as such modifications. One of Nickel aluminum bronzes called CAC703 in JIS is a widely used material for ship propellers. If the anti-erosion property of CAC703 is improved, the possibility of the design of ship propellers does not only widen, the efficiency of propellers can be improved. The authors have been studied the anti-erosion property of electroless nickel phosphorus plating (ENP) plated on CAC703.[1)] As a result, we found that ENP brings about great improvement on CAC703. We have already discussed the erosion mechanism of coating itself made of ENP. On the other hand, we did not make clear in that discussion that the erosion behavior of ENP after pits on coating generated by cavitation impacts reach the substrate. In this paper, we report how pits generated by cavitation imapcts and reaching at substrate progress and discuss the origin of pits and erosion mechanism in such case.

2. Experimental Method

We used as a substrate CAC703 and low phosphorus type ENP that showed most excellent anti-erosion property in several ENPs. The surface of a substrate was polished to become a mirror. ENP was plated on this surface after Ni strike processing because of the improvement of adhesion between ENP and the substrate. The thickness of ENP was about 30 μm and that of Ni strike layer (NSL) was 2 – 3 μm. Figure 1 shows a SEM image of the cross section of a specimen on which ENP and NSL were laminated. In addition, specimen was made hardened by heat treatment at 350°C for an hour. The Vickers hardness increases above Hv900 by this treatment.

Cavitation was generated by a vibratory instrument based on ASTM G32; the conditions of generation of cavitation were as follows: frequency of vibration was 19.5 kHz, amplitude of vibration 50 μm p-p, and the diameter of specimens 15.9 mm. Experiment was done in a 3L beaker filled with deionized water of which temperature was 25±1°C. This water was under atmospheric pressure throughout the experiment. Specimen was exposed on cavitation for 1200 min.

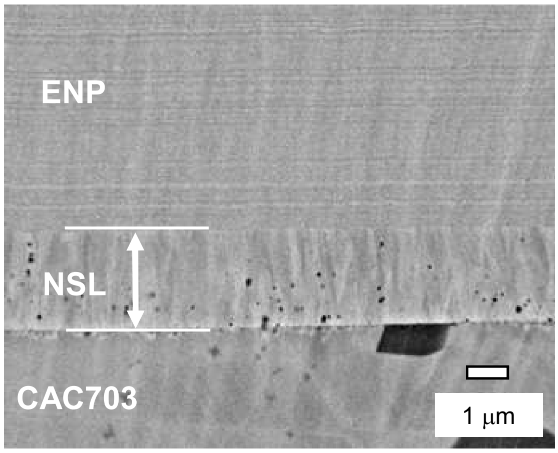


Fig. 1 SEM image of cross section of specimen.

In the experiment, the surface of specimens was recorded regularly by digital camera and the development of eroded region was observed. After the experiment, the cross sections of the specimens were observed by SEM.

3. Results and Discussions

Figure 2 shows the result of cavitation erosion test of CAC703 and ENP plating on CAC703. The anti-erosion property of CAC703 is greatly improved by ENP coating. Figure 3 shows the photographs of eroded surfaces of ENP (a) and CAC703 (b) at several test times. Since heat treatment changes the color of the surface of ENP, the color of ENP at 0 min became yellow.

It is observed from Fig. 3(b) that an annulus region inside the outer circumference of the surface is more eroded than the other region. It is known that this situation holds generally in case of the

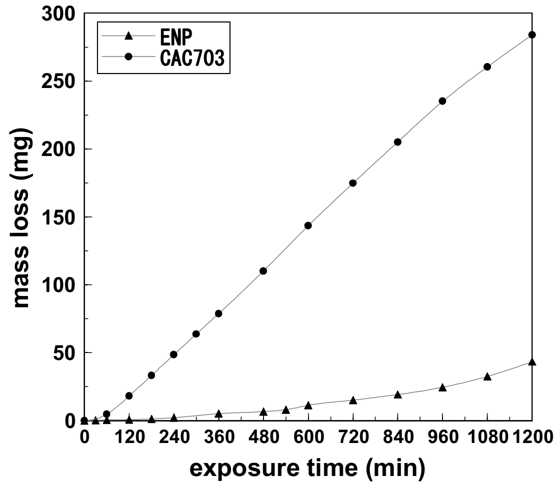
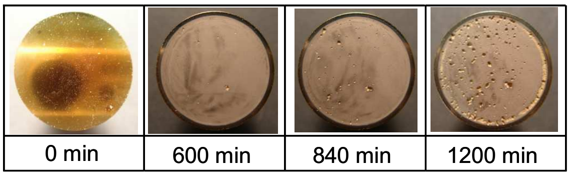
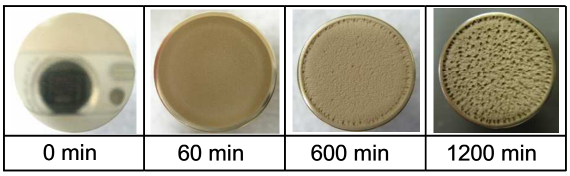


Fig. 2 Cavitation erosion property of ENP and CAC703.



(a) ENP

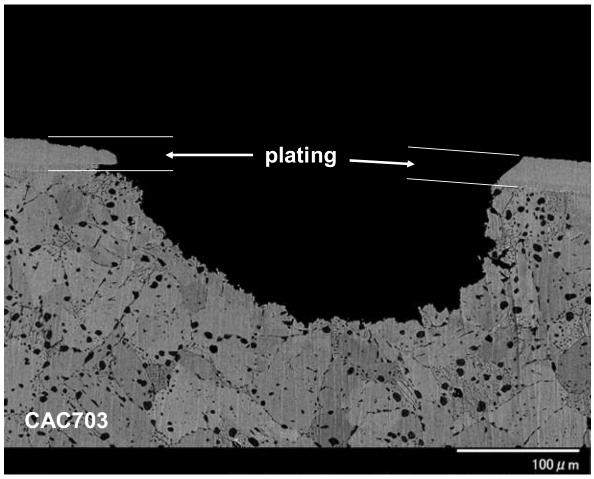


(b) CAC703

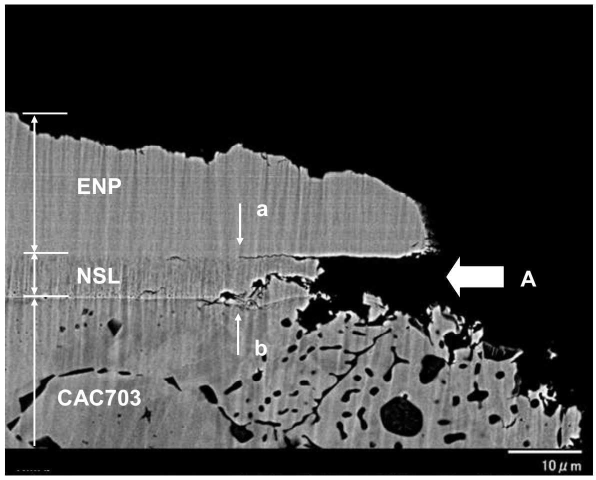
Fig. 3 Photographs of eroded surfaces of specimens.

erosion test condition we adopted. On the other hand, pits in Fig. 3(a) are initially generated in the central part of the surface rather than the annulus region. One reason for the difference of erosion behavior between ENP and CAC703 is the following. The result of salt spray testing shows that the existence of pinholes is difficult to avoid in low phosphorus type ENP.[2)] Therefore, since the fracture mechanical properties of the region around a pinhole in plating are inferior to that in the region not containing a pinhole, it is thought that a pinhole becomes a starting point of a crack generated by cavitation impacts.

Next, we discuss the erosion mechanism after a pit on plating reaches a substrate. Figure 4 shows a SEM image of the cross section of one of pits at 1200 min test time in Fig. 3(a). Granular or ribbon regions with black color in CAC703 are intermetallic compounds called κ phase. The cause of the inclination of the right side of plating will be plastic deformation caused by cavitation. On the other hand, it is observed from Fig. 4(b) that



(a) Cross section structure of a pit



(b) Enlargement of the left side of (a)

Fig. 4 SEM image of cross section of a pit in ENP at 1200 min test time.

delaminations take place between ENP and NSL (arrow a) and between NSL and CAC703 (arrow b) and that NSL under plating is removed (arrow A). In addition, plastic deformation is also observed around arrow b. This delamination is thought to cause a horizontal destruction of the pit. However, some force along the direction of arrow A is necessary for this delamination. An impact by microjet is considered as the origin of cavitation erosion.[3)] Though they only observed a microjet that strikes a specimen perpendicularly, Fig. 4(b) suggests the generation of a microjet in a pit that strikes a specimen transversely.

References

1. S. Sugasawa *et. al.*: Papers of National Maritime Research Inst. **11** No.1 (2011) 1. [in Japanese]
2. R. Weil. *et. al.*: Plating and Surf. Finish. **76** (1989) 62.
3. C. L. Cling *et. al.*: Trans. ASME Ser. D **94** (1972) 825.