**DAMAGE ESTIMATION METHOD FOR GAS TURBINE HOT SECTION COMPONENTS BASED ON NDI MICROSTRUCTURE ANALYSIS**

M. Nagae[1], A. Kanaya[1], S. Imano[2], H. Doi[2] and K. Ichikawa [2]
[1] Kyusyu Electric Power Co.,inc, Fukuoka, Japan; [2] Hitachi LTD, Tokyo, Japan

**Abstract:** Damage of heavy-duty gas turbine hot section components is very sensitive to their metal temperature under service. It is possible to estimate metal temperature under service using microstructural information after service [1)2)], because microstructure evolution is also sensitive to temperature. Most of high strength superalloys are strengthened by very fine precipitates called γ’ phase ($Ni_3Al$). In the case of material for combustor parts (Nimonic263), the diameter ofγ’ phase is about 0.02μm for virgin material, and 0.05□1μm after service. Coarsening of γ’ phase depends on time and temperature. We can estimate the metal temperature under service from the operation time and the diameter of γ’ phase after service. Sinceγ’ phase is very fine, we must use TEM or FE-SEM to evaluate its diameter. It is difficult to measure the diameter of fineγ’ phase using a conventional NDI replica method. To estimate the damage of heavy-duty gas turbine hot section components, we studied the microstructure of aged and stress agedγ’ phase strengthened alloys for combustor parts and bucket. Using these results, we established a method for estimating metal temperature, creep damage and material degradation based on the diameter of fineγ’ phase. We also established a NDI replica method to evaluate the diameter of fineγ’ precipitates using a unique etching technique and FE-SEM. In this presentation we show some examples of the damage estimation process and results based on microstructural information and the unique NDI replica method.

**Introduction:** We studied Nimonic263, which is used for combustor transition piece[3)]. Nimonic263 is strengthened by fineγ’ phase and we use the diameter of this phase for damage estimation. It is difficult to measure the diameter of γ’ phase by NDI replica analysis, because the diameter ofγ’ phase is about 0.02 μm for virgin Nimonic263. So we must do a distractive inspection before the following NDI replica method is established. We also studied first stage bucket material, and established damage estimation methods based on microstructural imfomation[4)]. Since first stage buckets are coated with MCrAlY, it is difficult to inspect the microstructure using the NDI method. We tried to inspect the microstructure of the bucket surface during the recoating process, which is done after service.

Table1 Chemical Composition of Specimens (wt.%)

| Cr | Co | Mo | Ti | Al | C | Ni |
|---|---|---|---|---|---|---|
| 20 | 20 | 6 | 2.2 | 0.5 | 0.05 | bal. |

Table2 Aging Condition

| Temperature(℃) | Time(h) |
|---|---|
| 750 | 4000 |
| 800 | 2000 |
| 850 | 2000 |

**Results:** The chemical composition of the specimen is shown in Table 1. This material is used for gas turbine combustor transition pieces. Table 2 shows the condition of additional aging after standard heat treatment. Fig. 1 shows an illustration of the etching method for the NDI replica method (this work). Photos 1(a) and (b) show a SEM micrograph of the replica taken from the aged specimen. Table 3 shows the result of the SEM image analysis. Mean diameter and area fraction were measured using a digital image processor.

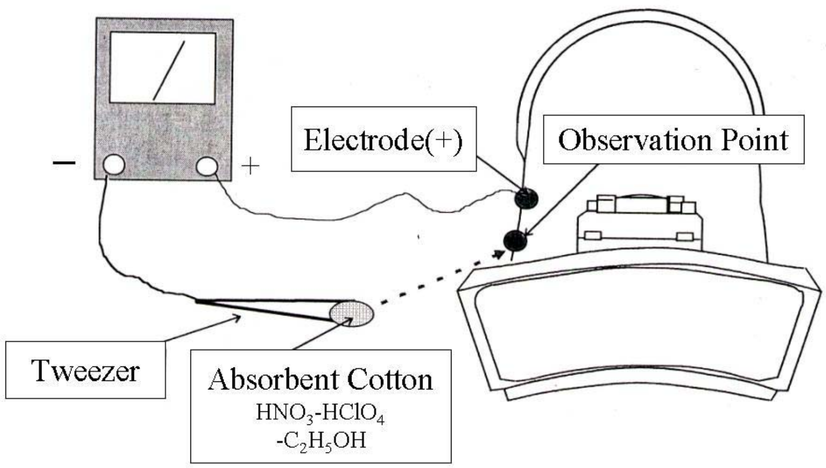
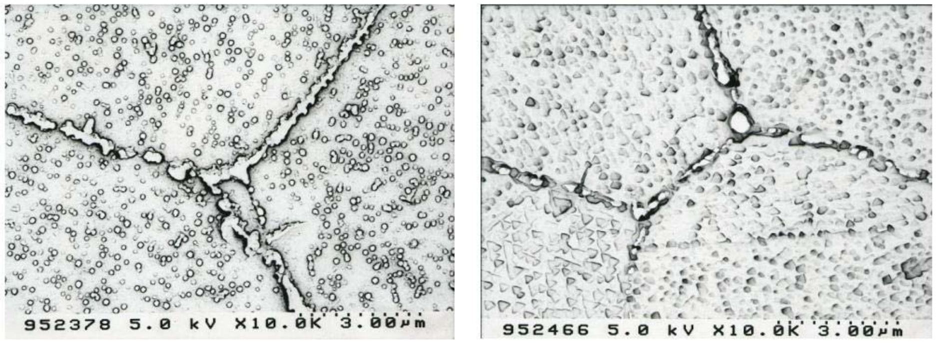



Fig.1 Illustration of The Etching Method in This Work

These values are compared with actual values, which is evaluated from direct observation. The value evaluated from a conventional replica ($HNO_3$-HCl etched) is larger than the actual value. The value evaluated from the replica using a dissociation etching method (illustrated in Fig. 1) is the same as the actual value. Fig. 2 shows the relationship between the mean diameter of γ'phase evaluated from the replica using the dissociation etching method and the actual value of aging specimens. Fig. 3 shows the estimated temperature from the mean diameter of γ'phase and the aging time using a LSW rerationship[3]. These values are then compared with the actual aging temperature. According to these results, it is clear that we can evaluate the microstructure and estimate metal temperature based on the microstructural analysis using the NDI replica method. Fig. 4 shows the result of the microstructural analysis using the NDI replica method of a transition piece after 20,000h service. We also performed a NDI inspection of a first stage bucket. The bucket was stripped and recoated with MCrAlY after about 20,000h service and installed to the same unit again. The NDI inspection was performed during the recoating process. Photo 2 shows the SEM image of the replica taken from the stripped bucket surface.




(a) Replica(This Work) (b) Replica (Conventional)

Photo1 SEM Micrograph of Aged Specimen (750℃, 4000h)

Table3 Microstructure Analysis Result ( γ ’ phase)

| Sample( 800℃, 2000h ) | Mean diameter | Area Fraction |
|---|---|---|
| Replica(Conventional) | 0.191 μm | 16.4% |
| Replica(This Work) | 0.150 μm | 9.98% |
| Actual | 0.163 μm | 10.0% |

**Discussion:** As shown in Fig. 2, replica analysis using the unique dissociation etching method presented here is effective for inspecting γ’ phase strengthened superalloys. Most conventional etching methods dissolve γ’phase rather than the matrix, and it is difficult to observe very fine γ’phase even using a substantial specimen. But the dissociation etching method presented here dissolves only the matrix, and we can observe fine γ’phase using FE-SEM. We can observe the exact 3-d shape of γ’phase easily using this dissociation etching method. This is the advantage of the NDI replica method presented in this work. The replica film must be coated with Pt or Au, and the electron acceleration voltage of the FE-SEM must be reduced compared to normal observation to avoid damage and charging of the replica film in order to get a high magnitude image from the replica. We selected 5kV for high magnitude FE-SEM observation. We can estimate the metal temperature during service using the presented NDI replica analysis and method for estimating metal temperature based on the diameter of γ’ phase[2)3)]. We can estimate material degradation, creep damage and residual life. In the case of the bucket, solution treatment or HIP treatment is commonly performed during the recoating process, and these processes recover creep damage and tensile properties. So estimation of residual life and material degradation are irrelevant for the inspected bucket. But it is useful data for optimising the life and repair interval of other buckets installed in the same unit. The estimated metal temperature under service conditions is useful for correction of FEM metal temperature analysis. According to the result shown in Fig. 4, an extension of life of the transition piece was achieved.

**Conclusions:** Using the NDI replica method presented in this work, it is possible to evaluate the mean diameter of fine γ’phase accurately. This method is effective to inspect the hot section components of gas turbines, and effective to consider optimal life and repair schedule of hot section components.

**References:** 1) Jose M.Aurrecoechea and William D.Brentnall: EPRI Life Assessment & Repair Technology for Combustion Turbine Hot Section Components Conference Proceedings, (1990),165. 2) H.Doi, T.Kashimura, H.Tamaki and Y.Fukui: CAMP-ISIJ, 5(1992), 1882. 3) S.Imano, S. Nakamura, A. Kanaya, J. Kusumoto and H. Watanabe:ASME Paper 97-GT-349. 4) Y. Gotoh, M.Nagae, S. Imano, H.doi and K.Ichikawa :CAMP-ISIJ Vol.16(2003)-1459.

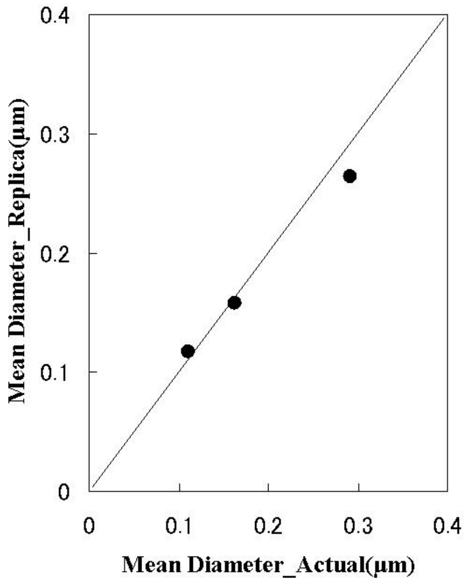



Fig.2 Result of Replica Analysis of Aging Specimens

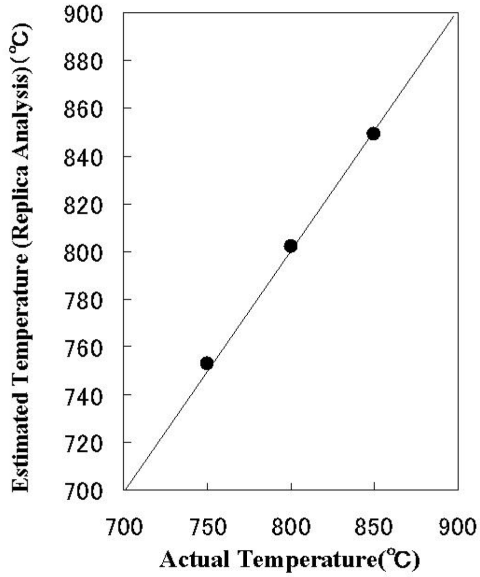



Fig.3 Result of Metal temperature Estimation of Aging Specimen

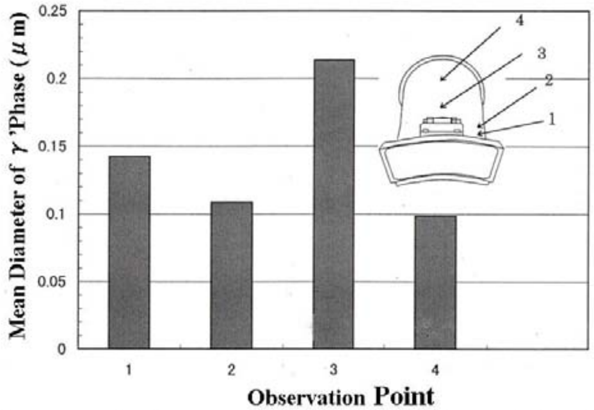



Fig.4 Result of NDI Replica Inspection of Transition Piece
( 20,000h After Service)

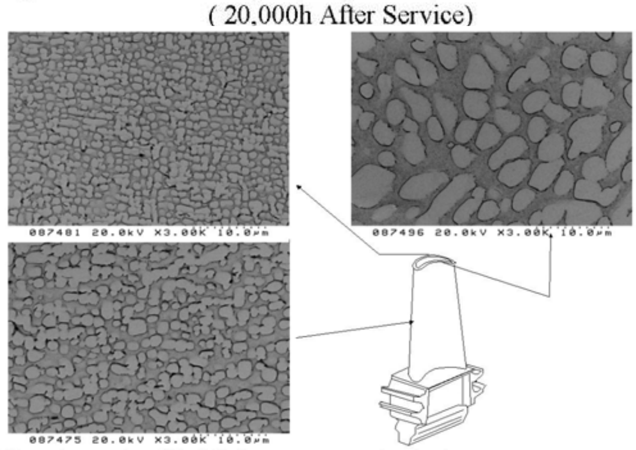



Photo2 Result of NDI Microstructure Analysis
of First Stage Bucket