ISSN 0852-4777

LIFE ASSESSMENT OF STEAM TURBINE – THE MICROSTRUCTURE AND GRAIN SIZE OBSERVATION OF TURBINE CASING

Amiral Aziz
Senior Mechanical Engineer for 10.000 MW Crass
Program Steam Power Plant Project
Gedung II BPPT lantai 20 Jl. M. H. Thamrin 8 Jakarta 10340

ABSTRACT

LIFE ASSESSMENT OF STEAM TURBINE – THE MICROSTRUCTURE AND GAIN SIZE OBSERVATION OF TURBINE CASING. This papers presents some results of the life assessment of steam turbine - the microstructure and gain size observation of turbine casing. The measurement of mechanical properties, the microstructure as well as the material composition of turbine casing have been performed. The chemical composition is found that both the lower and the upper casings are conforms to JIS G 5151 class SCPH 21. From the microstructure observation it could be confirmed that the microstructures consist of ferrite dominantly (white) and some of pearlite (dark), which is classified as Cr-Mo steel according to JIS G5151 class SCPH 21.It is also found that lower casing have smaller grain size (higher grain size number) than the upper casing .

Keywords: Life assessment, steam turbine, turbine casing, microstructure, chemical composition and hardness.

ABSTRAK

PENGKAJIAN UMUR TURBIN UAP – PENGAMATAN MIKROSTRUKTUR DAN UKURAN BUTIR DARI RUMAH TURBIN. *Tulisan ini menampilkan beberapa hasil dari pengkajian umur turbin uap– observasi mikrostruktur, ukuran butir rumah turbin uap. Pengukuran sifat mekanis, mikrostruktur dan lomposisi kimia dari rumah turbin uap telah dilakukan. Komposisis kimia dari rumah turbin sebelah bawah dan sebelah atas keduanya sesuai dengan JIS G 5151 class SCPH 21. Dari pengamatan mikrostruktur dapat dikonfirmasi bahwa mikrostruktur terdiri dari dominant Ferrite dan sebagian pearlite yang dapat diklasifikasi sebagai baja Cr-Mo berdasarkan JIS G 5151 class SCPH 21. Dari pengkajian ini didapat juga bahwa rumah turbin sebelah bawah mempunyai ukuran butir yang lebih kecil dibandingkan dengan rumah turbin bahagian atas.*

***Kata Kunci** : Pengkajian umur ,turbin uap, rumah turbin, mikrostruktur, komposisi kimia, kekerasan*

INTRODUCTION

The steam turbine generator is the primary power conversion component of the power plant. The function of the steam turbine generator is to convert the thermal energy of the steam from the steam generator to electrical energy. Two separate components are provided: the steam turbine to convert the thermal energy to rotating mechanical energy, and the generator to convert the mechanical energy to electrical energy. Typically, the turbine is directly coupled to the generator.

Present day electric power generation is largely by fossil and nuclear power plants. The typical general turbine arrangements used in modem day power plants is shown in figure 2 . There are many type of steam turbine that depends on the number of reheat stages, steam pressures, and turbine configurations as a function of the unit output.

For light water reactor nuclear plants, the turbines are tandem compound units operating at 1,800 rpm in 6O-Hz electrical systems and 1.500rpm in 50-Hz electrical systems. To take advantage of economies of scale, nuclear plants are usually large in size. This large size, in combination with low operating pressures and temperatures of 6.89 MPa) and 293.30 ^{o}C, results in large steam flows. To pass these large flows, long rotating blades (large turbine flow passage area) are required. The 1,800 and 1,500 rpm speeds can accommodate the longer blades while maintaining acceptable blade tip speeds.

THEORY

● BOILING WATER REACTOR PLANTS

Steam is generated directly in the nuclear reactor. The wet steam is dried in a water separator inside the reactor to saturated steam with very low remaining moisture content. This saturated steam is fed into the HP turbine. At HP turbine exhaust the steam has obtained a high degree of moisture and this is removed in a moisture separator, usually combined with a reheater. This reheat steam is then fed into the LP turbines, and subsequently condensed in the condenser. In figure 1. the typical steam parameters are:

- HP turbine inlet: 66 bar/280°C, <0.1% moisture
- HP turbine exhaust: 5 bars /150°C, 16% moisture.
- LP turbine inlet: 5 bars /250°C superheated.

LP turbine exhaust: 0.05 bar/33°C, 10% moisture.

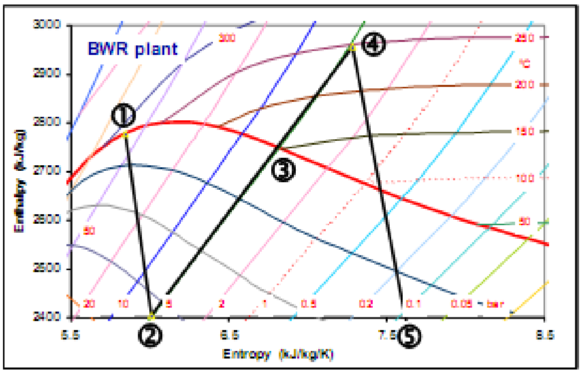

Figure 1. Typical BWR steam path in the Mollier diagram, simplified schematic.

1. HP turbine inlet
2. HP turbine exhaust
3. moisture separator outlet / Reheater inlet
4. LP turbine inlet
5. LP turbine exhaust. / Condenser inlet.

Figure 1 represents these key points in the Mollier diagram. The moisture separator typically removes 95% of the HP turbine exhaust moisture; in other words, 5% of the impurities contained in the water phase of LP exhaust steam pass through this device.

● LIFE TIME ASSESSMENT OF STEAM TURBINE COMPONENT

Most parts and components of steam turbines, as shown in Figure 2, are made of steels containing various amounts of the principal alloying elements chromium, molybdenum, vanadium and nickel, etc. Most high temperature rotors, valves and blades,

ISSN 0852-4777

etc. are made of high strength materials such as CrMoV steels and 12% Cr steels, but these materials are metallurgic ally degraded under long-term operation at high temperature. Existing steam turbines are required to operate under severe conditions now and in the future, which means that the inevitable accelerated deterioration of their parts and components such as high-pressure rotors and casing, etc. must be compensated.

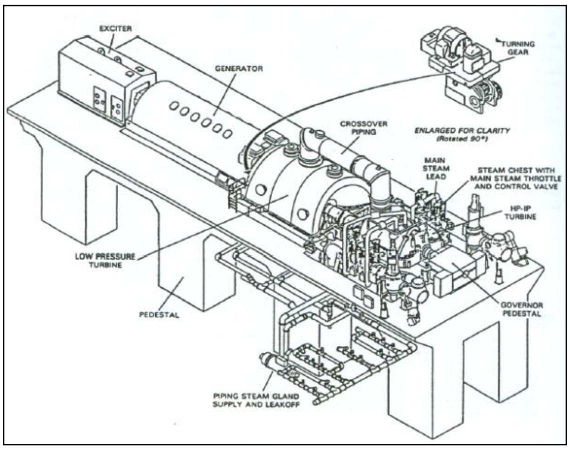

Figure 2. Steam turbine arrangement [2]

There are three kinds of examination method for metallurgical damage assessment as shown in Table 1, that is, the destructive method, the nondestructive method and the analytical method, but they are not always effective and accurate due to their individual advantages and disadvantages. First of all although the destructive method can directly evaluate the metallurgical property in laboratory testing devices, sample taking is extremely limited as operations because of the shape and construction of parts and components, and in addition, the analytical method must be used in combination in order to establish the test conditions. Secondly, among the several nondestructive methods, hardness testing and replica examination are convenient and familiar, but there is room for improvement in evaluating process and precision, because both methods are problematic in relation to shapes and construction.

Finally, as analytical methods can obtain the analytical temperature and stress distribution in the parts and components by using finite element analyses, they are effective to evaluate the residual life and future estimate, but there are pending issues between the evaluation and the actual metallurgical property. On the other hand, the combined method with the analytical and nondestructive methods is the most effective and useful in order to evaluate residual life as well as the cumulative damage due to creep, fatigue and the interaction of both, in combination with the numerous destructive examination results that are obtained from actual retired rotors, casings, valves and so on.

Table. 1.Comparison among life assessment method [6]

Method		Non-destructive method	Destructive method	Analytical method	Combined method with analytical and nondestructive
Feature		· Convenient · Not evaluating residual life	· Possible to evaluate residual life · Test specimen is required	· Possible to assess all areas · Possible to evaluate residual life	· Possible to assess all areas · Possible to evaluate residual life · Possible to reflect material degradation
Assessing Areas	Stress Concentrated Area	Possible but technical development required	Possible but technical development required	Applicable	Applicable
	Flat Area	Applicable	Applicable	Applicable	Applicable
Life Assessment	Creep	○	○	△	○
	Low Cycle Fatigue	○	×	△	○
	Creep-Fatigue Interaction	×	×	△	○
Assessable damage range	Creep	Applicable over 0.3 of Creep damage	Full damage range	Full damage range	Full damage range
	Low Cycle Fatigue	Lack of quantitative relationship	Not Applicable	Full damage range	Full damage range
	Creep-Fatigue Interaction	Not Applicable	Not Applicable	Full damage range	Full damage range

○ : Applicable, △ : Applicable, but not reflecting material degradation, × : Not applicable

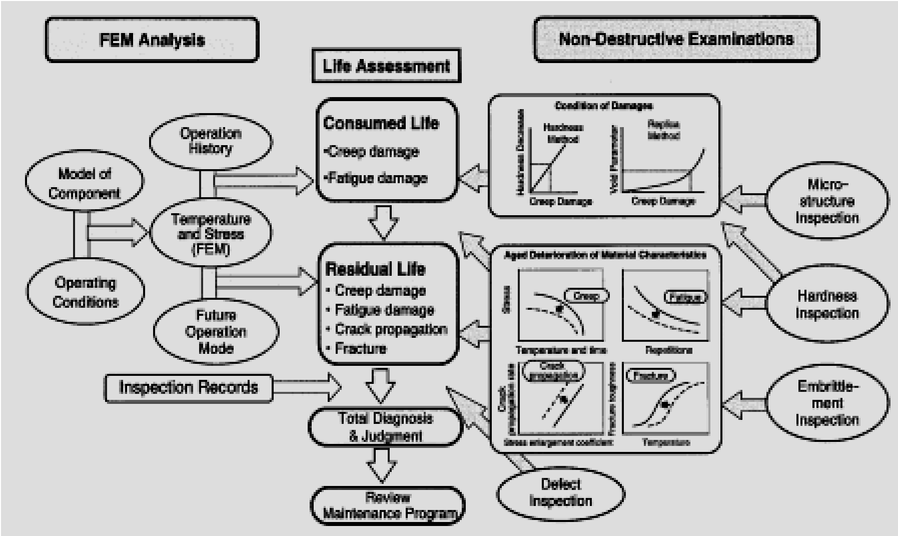

Figure 3. Life assessment methodology for steam turbine [4]

The objective of the life time steam turbine component in this study is to measure the mechanical properties and observing the microstructure as well as the material composition of the existing steam turbine component especially the turbine casing.

Figure. 4 Steam turbine casing

RESULTS AND DISCUSSION

There are three locations of the steam turbine casing (1 point at lower casing and 2 points at upper casing) were tested the chemical analysis by portable-spark emission spectrometer. Table 2 shows the results of chemical composition of the sample. From this table, it can seen that all samples from location 1 to location 3 can be classified as Chrome – Molly Steel (Cr-Mo Steel) and Conform to JIS G 5151 class SCPH 21 (Standard specification for Steel Castings for High Temperature and High Pressure Service) ([1,2]). The Carbon content of the sample no 2 and 3 are little bit higher than the sample no 1, where the carbon content is 0.22 wt.%. This because the material could be suffered from carburization process which was caused by the diffusion of carbon on their casing surface. From this results it is resumed that the chemical composition of both the lower and the upper casings are conforms to JIS G 5151 class SCPH 21.

Table .2 Chemical composition of the sample

Element	Number and location sample			JIS G 5151 (SCPH 21) (wt %)
	1 Outside lower	2 Outside Upper	3 Inside Upper	
Fe	96.94	97.12	97.15	REM
C	0.09	0.13	0.22	0.20 max
Si	0.49	0.34	0.29	0.60 max
Mn	0.74	0.62	0.65	0.50-0.80
Cr	1.07	1.13	1.04	1.00-1.50
Ni	0.019	0.027	0.023	0.50 max
Mo	0.50	0.50	0.48	0.45-0.65
Cu	0.065	0.058	0.059	0.50 max
V	0.042	0.039	0.043	n/a
W	0.00	0.00	0.00	0.10 max
Ti	0.00	0.00	0.00	n/a
B	0.0009	0.0004	0.0006	n/a
P	0.024	0.017	0.017	0.40 max
S	0.029	0.023	0.028	0.40 max

ISSN 0852-4777

The harness of turbine casing was carried out based on the Brinell Testing Method. The table 3 saw the results of the hardness testing for 5 location. The value is indicated that different structure had occurred in turbine casing during operation. The highest hardness is 160 HB at location 5 (the inside of upper casing), and the lowest hardness is 129 at location 3 (the outside of upper casing). Others are between 129 HB to 160 HB.

The higher value of hardness at the inside of upper casing may due to the higher amount of pearlite in the matrix as can be seen in Figure 8 compared by other microstructures. The pearlite structures contains the mixing of ferrite (a) and cementite (Fe3C) in the lamellar structure and the hardness of pearlite is higher than ferrite (a).

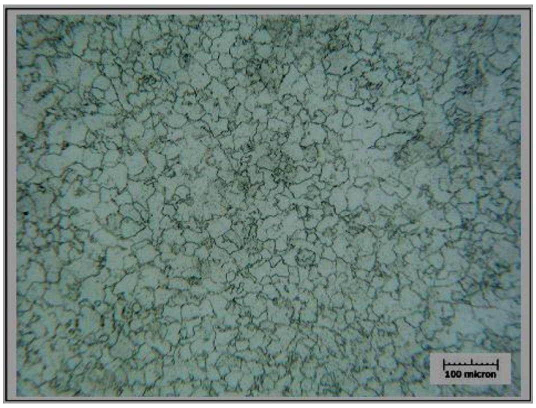

Figure 5. Microstructure of insitu metallographic sample No.1 at lower casing of steam turbine, consisting ferrite (white) and pearlite (dark). Etched with Nital 5 %, 100 X magnifications and the hardness of 137 HB.

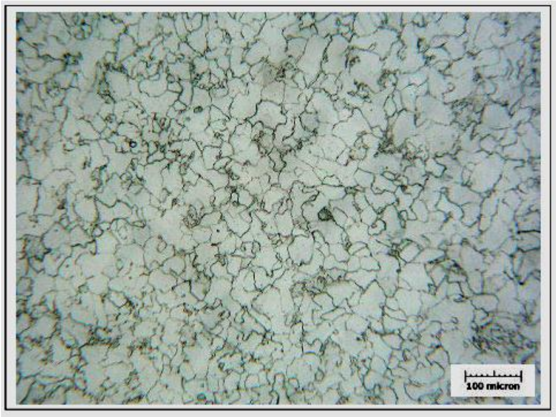

Figure 6. Microstructure of insitu metallographic sample No.2 at lower casing of steam turbine, consisting ferrite (white) & pearlite (dark). Etched Nital 5%, 100X & the hardness of 137 HB.

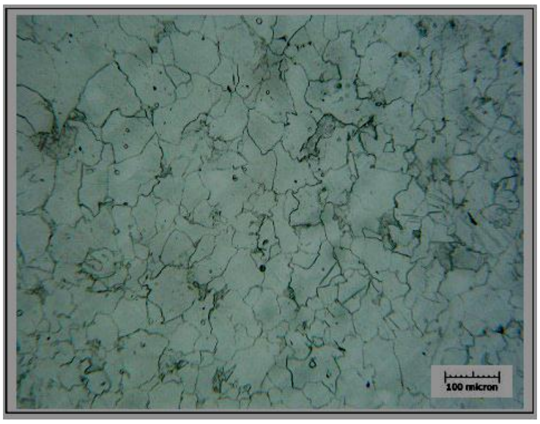

Figure 7. Microstructure of insitu metallographic sample No.3 at upper casing o f steam turbine, consisting ferrite (white) and pearlite (dark). Etched with Nital 5 %, 100 X magnification and the hardness of 129 HB

Table 3. Calculation of grain size number according to ASTM E 112 and hardness results.

Location	Grain size Number	Hardness (HB)	Remarks
1	6.7	137	Lower Casing (Out side)
2	6.9	137	Lower Casing (Out side)
3	6.1	129	Upper Casing (Outside)
4	6.4	158	Upper Casing (Inside)
5	6.2	160	Upper Casing (Inside)

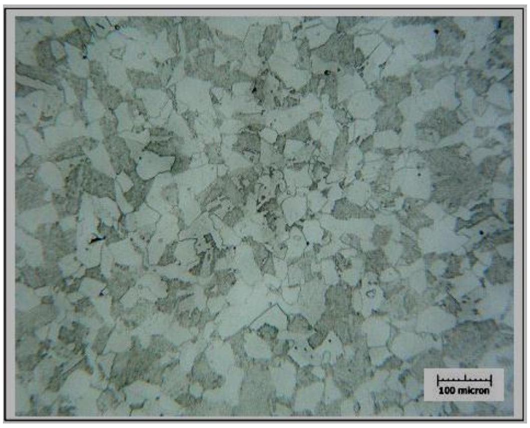

Figure 8. Microstructure of insitu metallographic sample No.4 at the inside upper casing of steam turbine, consisting ferrite (white) and pearlite (dark). Etched with Nital 5 %, 100 magnification and the hardness of 158 HB

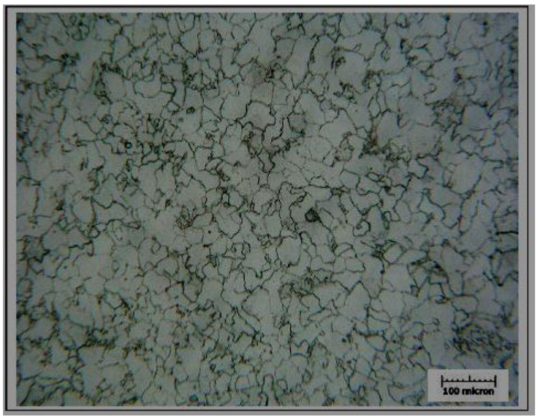

Figure 9. Microstructure of insitu metallographic sample No.5 at the left-inside upper casing of steam turbine, consisting ferrite (white) and pearlite (dark). Etched with Nital 5 %, 100 X magnification and the hardness of 160 HB

The microstructures of turbine casing were taken at the surface of base metal at the lower casing and upper casing. The total numbers of points taken for insitu metallography at both lower and upper casing are 5 points: 2 points at the lower and 3 points at the upper casing (consisting of 2 points for inside surface of casing and 1 points for outside casing). The insitu metallography was carried out with magnification of 100X and 200X or 500X which are shown in Figure 5 to 9. The results confirm that the microstructures consist of ferrite dominantly (white) and some of pearlite (dark), which is classified as Cr-Mo steel according to JIS G5151 class SCPH 21. In addition, all microstructures of turbine casing were performed the calculation of grain size number according to ASTM E112. The grain size of turbine casing is sow in the Table 2. From this table, it could be seen that the grain size number is varied from 6.1 to 6.9. The higher the grain size number, the smaller the grain size.

The result of insitu metallography shows that lower casing have smaller grain size (higher grain size number) than the upper casing. This is due to the fact that the lower casing has more thickness than the upper one. Therefore, the heat come from inside casing do not suffer the surface of lower casing.

CONCLUSION

From the above discussion it could be concluded that :

The chemical composition of both the lower and the upper casings are conforms to JIS G 5151 class SCPH 21.

The lower casing have smaller grain size (higher grain size number) than the upper casing. This is due to the fact that the lower casing has more thickness than the upper one.

ISSN 0852-4777

Therefore, the heat come from inside casing do not suffer the surface of lower casing.

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