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Process characteristics of pretreatment system under H_2S circumstance for bio-gas micro gas turbine power generation

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Abstract−As distributed generation becomes more reliable and economically feasible, it is expected that a higher application of the distributed generation such as Micro Gas Turbine Power system would be interconnected to the existing grids. This paper describes the results for the mechanical and environmental tests of pretreatment system for Livestock bio-energy Micro Gas Turbine (MGT) Combined Heat & power. It is very important for bio-energy pretreatment system to design MGT power generation. Especially, mechanical and corrosion characteristics of H_2S removal system make differences between parent and weldment material, notch existence/non-existence and air/H_2S conditions. As a result, the life of pipelines needs to be maintained and fit for the operating period. Based on actual situations, the tension test of pipe welding-parts is carried out varying the exposure time to hydrogen sulfide and a fatigue resistance test is also performed inserting a notch into the pipe welding part, being exposed to the hydrogen sulfide environment for 180, 360, 540, 720 hours.

Key words: Micro Gas Turbine (MGT), Bio-energy, Fatigue, H_2S Removal System, Pretreatment System

INTRODUCTION

Recently, the increasing rate of nuclear power plant facilities has tended to slow down due to insecurity on the facilities and the enormous construction cost; furthermore, thermal power and water power generation are put under continuous surveillance by environmental groups. In addition, the rapid growth in our economy and the industry structure has caused power consumption and environmental pollution to be at the peak, and such situations are bringing about the extinction of energy resources, leading to the environmental destruction [1,2]. To cope with these problems, new and renewable energy begins to be utilized to produce and supply power and that has changed from power supply and demand system from centering large-sized power plants to a distributed generation system considering demand and control of power, and expanding from them [3]. Such a distributed generation needs to consider introducing small but highly efficient and environment friendly power sources, instead of the existing large-sized power facilities based on the maximum use of national resources such as bio-gas [4]. Since existing thermal, water and nuclear power plants with a big size have several disadvantages compared with a small-sized eco-environment system, it is a co-generation system using bio-gas micro gas turbine that attracts interest. This is now a field of active research as a small-sized environment friendly system mainly in the developed countries and which will be a regular type of generation system to be utilized in the future [5]. This study conducted experiments to secure the soundness of pipe materials in the pretreatment system of micro gas turbines toward exposure to hydrogen sulfide. Stainless pipes in the stages prior to the flue gas desulfurization, that is, in the stages where the high-concentration of H_2S flows, have a 40A Standard, and are made of SUS 304 and connected through Tungsten Inert Gas (TIG) welding. Also, this paper will have strategy for system safety to analyze between H_2S corrosion test data and FEM analysis results.

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SYSTEM PROCESS AND TEST

1. Preparation of Test Specimen

This study dealt with the pretreatment system of micro gas turbine (MGT). Fig. 1 shows (a) MGT and (b) schematic diagram of the

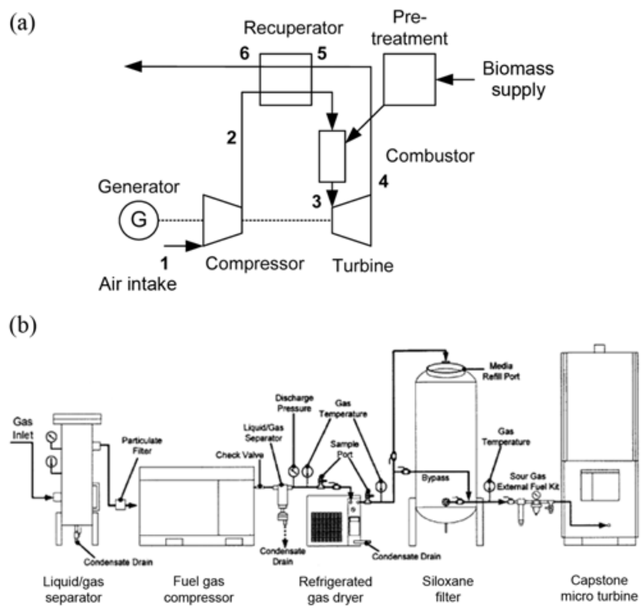

Fig. 1. (a) Schematic diagram of micro gas turbine of capstone. (b) Schematic diagram of pretreatment system.

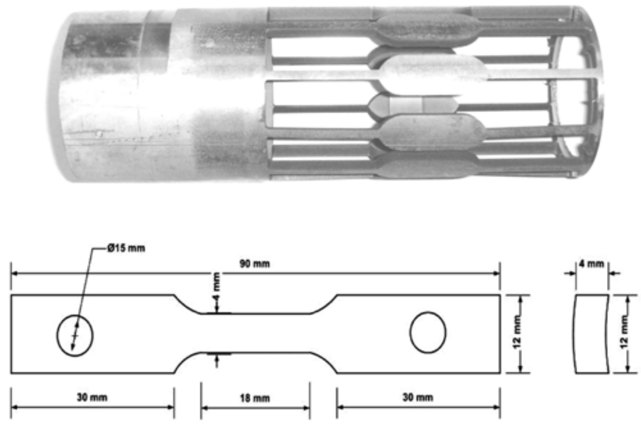

Fig. 2. Shapes of test piece.

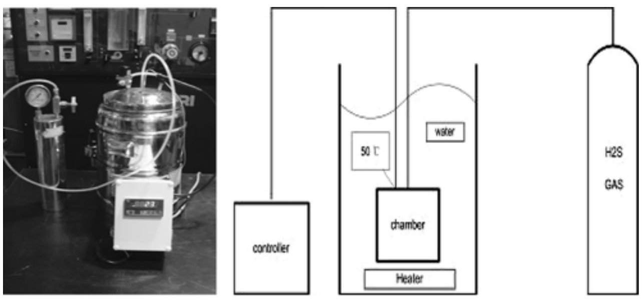

Fig. 3. H_2S exposure testing equipment.

pretreatment system. The pipes of the pretreatment system used TIG welding. Fig. 2 shows the test piece produced based on ASTM E8 and E21. Four types of test piece were prepared: a base metal, weld metal, and base and weld metals having a notch.

2. Hydrogen Sulfide Exposure Test

Fig. 3 shows the experimental equipment including a hydrogen sulfide chamber in which the test piece was corroded to H_2S.

The hydrogen sulfide chamber was immersed in water to keep it from leaking out because the gas has toxic hazards to the human body. A temperature controller was attached to the chamber to maintain the temperature of the chamber at 50 °C. To investigate the corrosion characteristics, a specimen such as base and weld metals, and base metals with notches and weld metals with notches made in advance was put into the chamber. The exposure time to H_2S was 180, 360, 540 and 720 hours. Fig. 4 shows a hydraulic universal testing machine used for tension and fatigue tests. After exposing the test piece to H_2S varying exposure time, a tensile strength test was carried out for each type of specimen. As for the fatigue test, base and weld metals were exposed to H_2S for 720-hour and those in normal temperature were not exposed to H_2S.

3. Finite Element Analysis Considering Residual Stress

Through FEM (finite element method), the residual stress was analyzed. Fig. 5 shows the analytical process and Fig. 6 is a picture of 3D modeling by using I-DEAS 10. ABAQUS 6.4 was used for analyzing the stress structure.

For the finite element analysis of welding parts, the element regeneration method was used. Three-dimensional modeling was designed for a quarter of the pipes to reduce the analysis time. For

Fig. 4 Hydraulic universal testing machine.

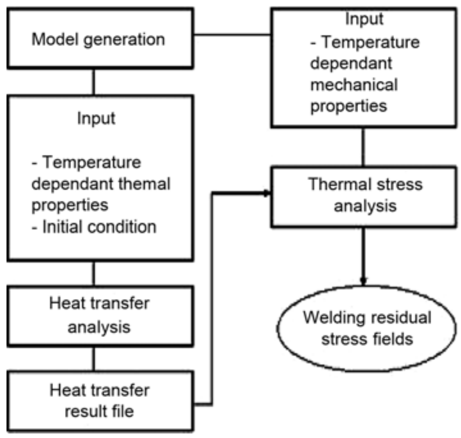

Fig. 5. Residual stress analysis process by FEM.

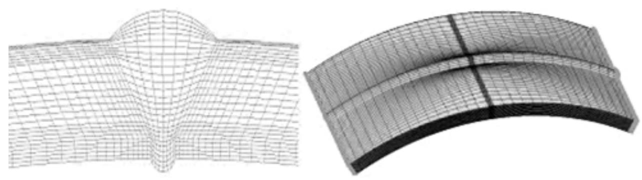

Fig. 6. 3D modeling for FEM.

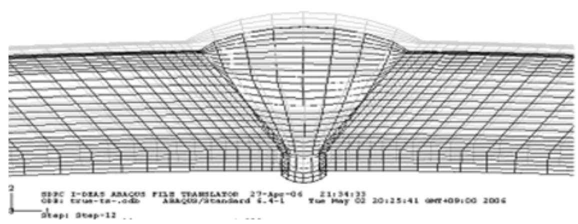

Fig. 7. Welding parts deformation by thermal effects.

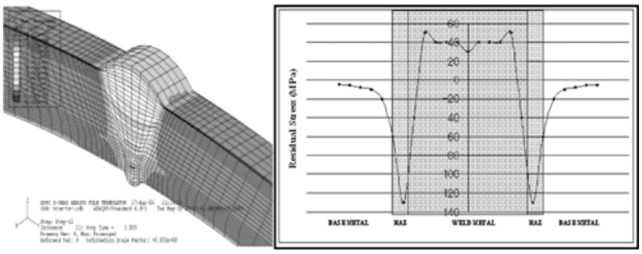

Fig. 8. Residual stress distribution for a direction of the axis.

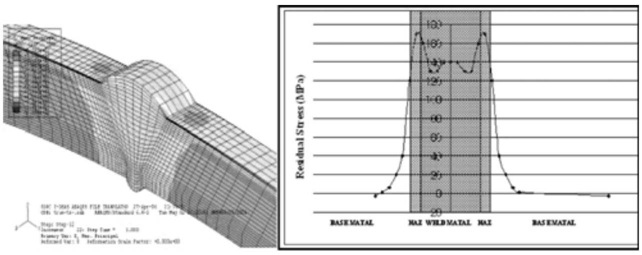

Fig. 9. Residual stress distribution for a direction of the circumference.

mesh works, the method of 8 nodal points and solid mesh was used as shown in Fig. 6. Fig. 7 shows the distorted condition by thermal stress. Each edge of pipes was restrained and welding parts had free edges for the boundary condition.

EXPERIMENT RESULTS

1. Analytic Results

Fig. 7 illustrates deformation by welding heat by enlarging it with 10 magnifications. As shown in Fig. 8, shrinkage occurs centering welding parts, and it is considered that the tensile residual stress appears after welding. Figs. 8 and 9 show an analytical result of the finite element for the model in Fig. 6, and illustrate the distribution of residual stress in pipes welding-parts as well.

In Fig. 8, the area of weld metals and weld toe boundaries, and in weld bead has a higher tensile stress value compared with the residual stress distribution for a direction of the axis (vertical direction for the line of welding). As for the residual stress distribution for the direction of the circumference, the center of welding parts has the highest value of the compressive residual stress. It might be due to the restraint for a direction of the circumference in pipes themselves.

2. Results of Tension and Fatigue Tests

Fig. 10 shows the results of the tension test for base and weld metals according to the exposure time to hydrogen sulfide. The tension strength appears to be a little higher with the test piece having less exposure time to hydrogen sulfide than that having much exposure time to hydrogen sulfide. Comparing the maximum tensile strength, the test piece of base metals has a higher value than that of weld metals. Fig. 11 shows the results of a tensile strength for base and weld metals having notches, according to the exposure time to hydrogen sulfide. Tensile pattern appears to depend on exposure time and notch. Depending on the exposure time to hydrogen sulfide, tensile patterns between 180 and 360 hours are quite similar, while that of 180 hours and 720 hours are significantly different.

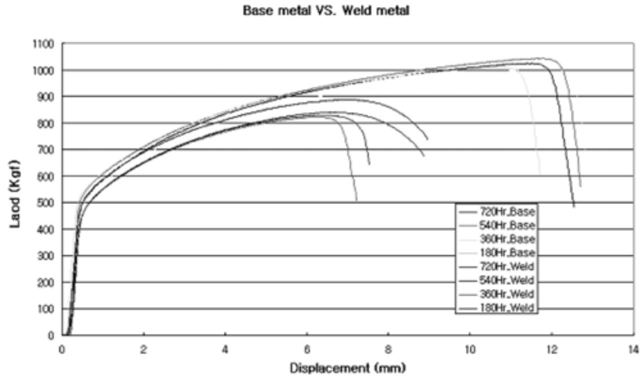

Fig. 10. Tension test results according to exposure time to H_2S for base and weld metals.

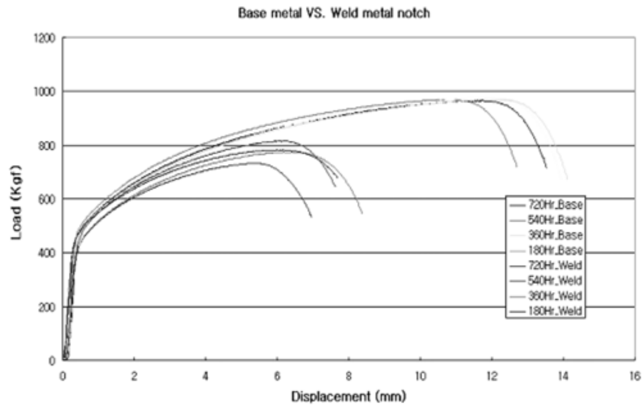

Fig. 11. Tension test results according to exposure time to H_2S for base and weld metals having notches.

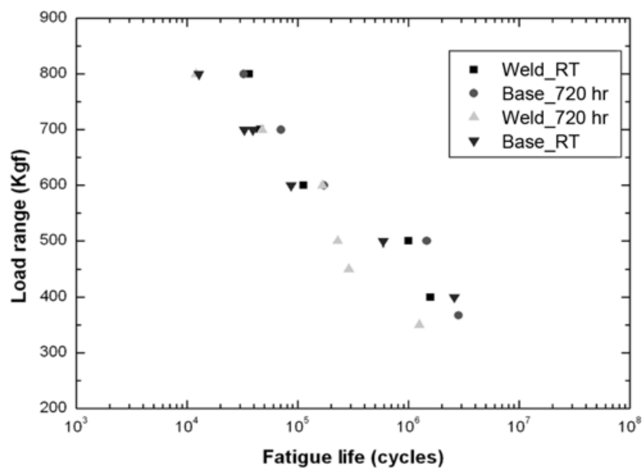

Fig. 12. Fatigue test results of base and weld metals exposed to H_2S VS base and weld metals.

Referring to Fig. 10 and Fig. 11, notches also have an effect on the tensile pattern.

Fatigue test was carried out: based on ASTM E206, ASTM E466 and ASTM E467, the ratio of load (R) was 0.1 and the infinite fa-

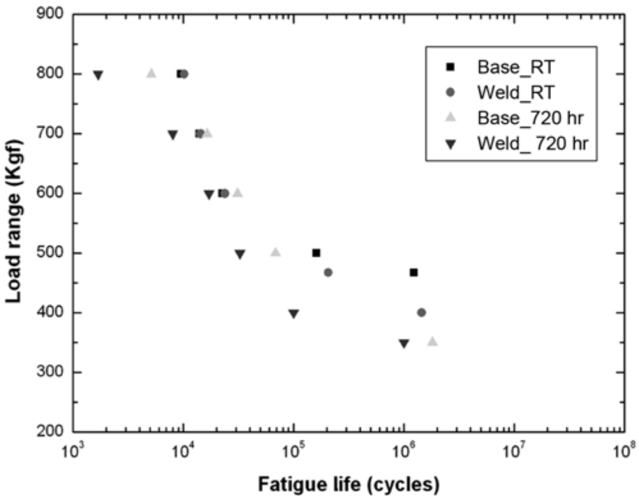

Fig. 13. Fatigue test results of base and weld metals exposed to H_2S VS base and weld metals (notches inserted).

tigue life (Nf) was 10^6. Figs. 12 and 13 show the results of the fatigue test. Fig. 12 is the results of the fatigue test for base and weld metals exposed to hydrogen sulfide, and Fig. 13 shows the results of the test for base and weld metals having notches inserted.

CONCLUSIONS

1. Residual Stress Test for Welding-Parts of Actual Pipes

- For analytical verification of residual stress existing in actual pipes welded, elastic and plastic analysis was carried out through analyzing the finite element.

- As a result of FEM analysis, applying 3D modeling, it is found that a residual stress of about 60 MPa exists and it shows the residual stress does not have a great operation, but it is the value to be considered.

2. Tensile Strength Analysis according to Time

- The stainless pipe welding was cut and the test piece was made, its surface was coated with silicone, excluding the inside of pipes, and then exposed to hydrogen sulfide. The exposure time was 180, 360, 540 and 720 hours and the welding strength was estimated by a tension test.

- Figs. 10 and 11 show the results, and the test pieces with a longer exposure time have a lower strength of tension, according to the exposed time.

3. Fatigue Strength Analysis through the Test Piece of Pipe Welding Parts

- The fatigue test piece was produced by inserting notches into stainless pipe welding parts.

- Exposing it to hydrogen sulfide for 720 hours (about 30 days) to cause an artificial corrosion, the fatigue test was conducted. The endurance limit appears to be similar and there are a few differences, same as the results of the tension test.

4. Final Estimation

- A residual stress of pipe welding parts was examined and test pieces exposed to hydrogen sulfide were used for a tension test for re-examination. There are a few differences between tension strength according to the exposure time to hydrogen sulfide, but any significant change is found out.

- As shown in Fig. 13, the fatigue strength also has a slight difference between the original materials and pipe welding parts having corrosion.

- For more detailed further research, experiments are needed to find the characteristics of corrosion through an electron microscope.

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