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AN IN-SITU EVALUATION OF STRUCTURAL DAMAGE IN A HIGH POWER SPALLATION NUETRON SOURCE

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ABSTRACT

Intensive proton beam is injected to the mercury target to induce spallation reaction and produce neutrons in MLF/J-PARC. The moment the proton beams bombard the target, pressure waves are generated in the mercury by the thermally shocked heat deposition, which generates cavitation and influence the structural integrity. An in-suite monitoring system on the pressure wave response and cavitation phenomenon was developed and installed in the spallation neutron source in MLF/J-PARC. Innovative data analysis method was developed based on wavelet analysis technique.

Keywords: neutron, spallation, mercury, pressure wave, cavitation.

INTRODUCTION

Neutrons are used for the innovative research that will bring about breakthrough in scientific and engineering research fields, i.e. fuel cell, hydrogen embrittlement, protein structure, medicine, etc. High power spallation neutron sources are developed in the world. Liquid metals; mercury, lead, lead-bismuth eutectic, have the benefits for pulse spallation neutron sources because of the high neutron yielding efficiency and usage as a coolant, and is available as high power target materials to produce intensive neutrons by spallation reaction that is caused by the bombardment in liquid metals with high-energy protons. The pulsed spallation neutron sources with mercury are being operated at the MLF (Materials and Life science experimental Facility) in the J-PARC (Japan Proton Accelerator Research Center) in Japan and SNS (Spallation neutron Source) in US, which are standing on the way to increase the power up to MW-class. Herein, the mercury cavitation becomes severe problem to increase the power.

The relationship between damage, cavitation aggressiveness, pressure waves, and proton beam power has been discussed based on the experimental data obtained under in-beam and out-beam conditions. Also, mitigation technologies have been discussed, theoretically and experimentally, in order to reduce the pressure waves due to thermal shock (Futakawa, 2008). Therefore, the cavitation phenomenon gets to be a crucial issue to increase the power in the mercury target for the pulsed spallation neutron sources.

The laser Doppler vibrometer (LDV) system was installed to investigate the dynamic responses of the target vessel induced by the proton beam injection into the mercury as shown in Figure 1 (Teshigawara, 2010). In order to mitigate the pressure wave, He-microbubbles were injected into the flowing mercury in the target vessel. Through the LDV system, the correlation among the proton beam power, microbubble injection, vibration amplitude was investigated by using the newly developed data analytical method.

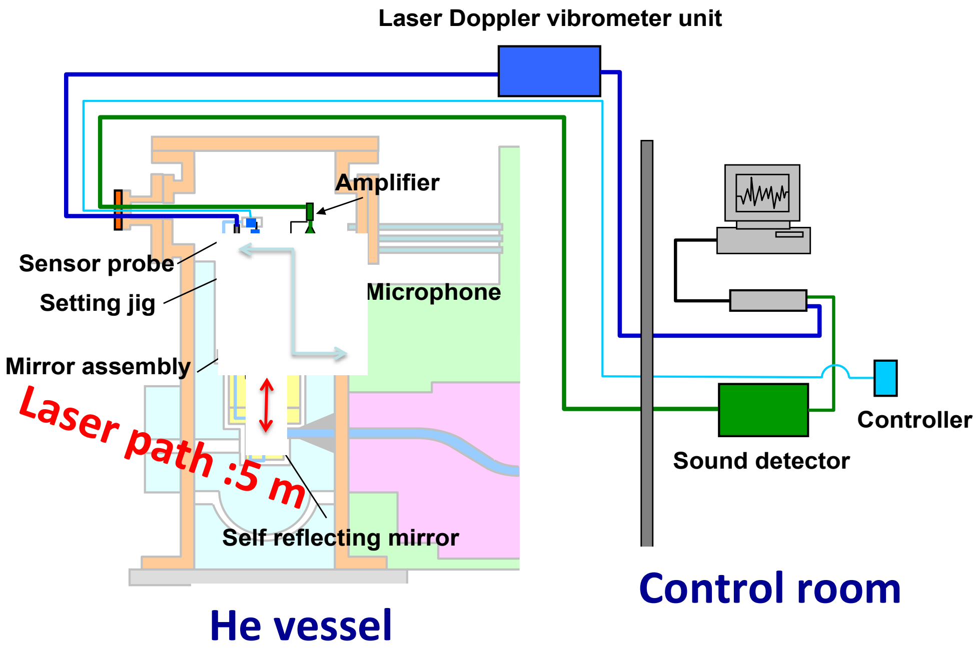

Fig. 1 - Laser Doppler vibrometer unit

RESULTS AND CONCLUSIONS

The vibrational time-responses of target vessel were successfully measured and measured data were analyzed by using the newly developed technique based on the wavelet analysis. The frequency components were divided into some phenomena: structural vibration SV, acoustic vibration related with cavitation incidents AVC, flow induced vibration FIV. The SV is almost linearly related to the power and the AVC has the threshold and increased with the power beyond the threshold and the FIV is hardly dependent on the power. These data were compared with the laboratory experimental data. In the future, the big-data analysis will be applied to predict the replacement timing of the target vessel before the catastrophic failure incident.

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