VIBRATION EVALUATION FOR UTILITY INSTRUMENTS AND WATER PIPING SYSTEM IN TLS*

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Abstract

The purpose of this paper is to estimate the vibration source from water systems and the piping system in utility system. Analysis the vibration path from piping system is the first step. Then, propose the feasible proposals to eliminate the vibration source and reduce vibration propagation. The construction standards for water systems will be established before design. The test is based on TLS operating systems. Besides, the distance and path between utility building and storage ring is another factor for vibration propagation. Elimination the vibration source and propagation path in TLS will be the next step. The experimental results will be the guidline of TPS construction in the future.

INTRODUCTION

In order to design the new synchrotron light source in NSRRC, the vibration issue is more restrict. Vibration source from utility systems is one factor of instability. In 2004, ANL[1] studied the mechanical vibration control systems and the specifications for all rotational facilities. TLS has also investigated on water induced vibration[2] and ground vibration. In order to find out the vibration propagation from the utility systems, the dynamic signal analyzer also need to be studied.

LAYOUT AND PIPING SYSTEM IN UTILITY

The utility systems in 1st utility building (UT-1) are shown in Fig.1. There are air conditioning systems and de-ionized water (DIW) systems in the 1st utility building. The DIW systems and air conditioning systems are the two major cooling systems in the TLS. The DIW systems consist of three subsystems, the copper system, the aluminium system and the RF system.

The copper DIW system supplies DIW to magnets and magnet power supplies. The aluminium and RF DIW systems supply DIW to vacuum chambers and to RF transmitters and cavities, respectively. In each DIW loop, there are two heat exchangers in order to adjust the DIW flow temperature. After the heat exchangers, the DIW flow to the storage ring by the water pumps with variable frequency drive. The DIW piping is cross through the trench to the core area and was divided into 12 loops. Each DIW loop flows to half of the section in order to cool the half section. The inlet and outlet DIW were divided into subsystems here.

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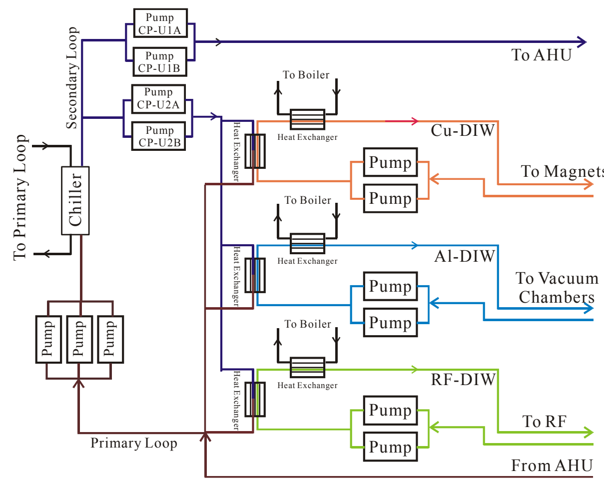

Figure 1: Layout of UT-1.

THE EXPERIMENTAL SETUP

The vibrations were measured by the portable spectrum analyzer COMMTEST VB2000 and piezoelectric type accelerometer IMI 603M56. The spectrum range is from 4 Hz to 200 Hz, and the resolution is 800 lines. The experiments were average for four times and recorded in displacement or accelerometer by the spectrum analyzer.

THE CHILLER VIBRATIONS

The chilled water is produced by three centrifugal chillers (YORK) in UT-1. Each capacity is 320 RT. The vibration on the top side of the chiller is much higher than the base of the chiller, which the significant frequency is ~60 Hz produced by the compressor. The cooling water side of chiller is connected to the cooling tower and the power for these 4 motors is 75 HP with fixed 1800 rpm. On the base of chillers, the rubber pad is located between the chiller and the ground. The experimental results show that the vibrations from 4 Hz to 200 Hz reduce for 2.1 to 4.5 times by using the rubber pad depends on the vibration amplitude.

VIBRATION PROPAGATION FOR DIW SYSTEMS

There are three DIW subsystems in UT-1, the copper system, the aluminium system and the RF system. Because of the DIW is delivered direct to the magnets and vacuum chambers, the vibration propagation is very important to the beam stability. The vibration propagation for the Al and Cu DIW systems are tested as follow.

Motors with Variable and Fixed Frequency Drive

The pumps with variable frequency drive (VF pump) are useful for auto adjust water pressure and stable the outlet and inlet water pressure. Its operation condition is depended on the local loading. The operation frequency for chilled water pump is about 43 Hz during testing. The DIW systems also use the VF water pump. The redundant pumps supply the DIW to the storage ring and avoid any accident from the pump incidents. It also helps to reduce the vibration effectively. The operation frequency for Al DIW pump is about 48.3 Hz. And the operation frequency for Cu DIW pump is about 50 Hz.

The pumps used in utility system were fixed frequency drive (FF pump) for several years ago. The fixed outlet water pressure was adopted by the by-pass system. Therefore the inlet water pressure and the local loading could not be adjusted. And the FF pump always operate in full energy output, it also produce larger vibration sources.

Vibration Propagation for Al DIW System

The measurement points for the vibration propagation for the Al DIW system is shown in Fig. 2. The first experimental point is located in Al DIW pump (P1), next located in the outlet pipe of the pump (P2). The DIW piping is connected through the trench (P3) and to the intersection point inside the storage ring R3-1 (P4). There are three quadrupoles, R3-Q1D (P5), R3-Q2F (P6), R3-Q3D (P7), in the first part of section3.

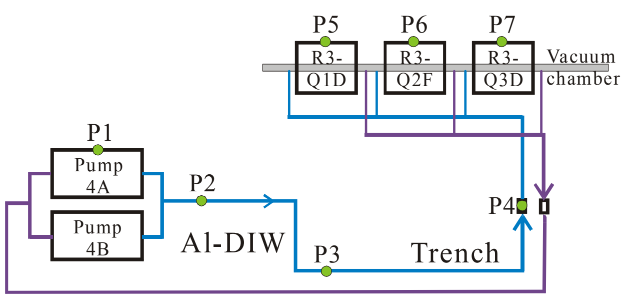

Figure 2: Layout of Al DIW System.

The experiments were recorded in acceleration from 4 Hz to 200 Hz with 0.25 Hz resolution and average for four times. Fig. 3 shows the vibration of P1 in vertical direction.

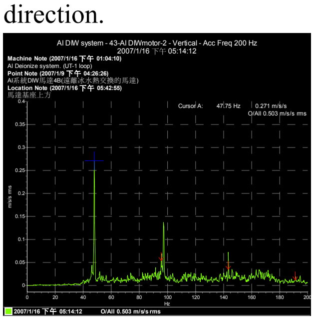
Figure 3a: Vibration of VFD motors (~48 Hz)

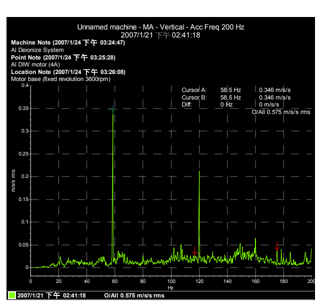
Figure 3b: Vibration of FFD motor (~58.5 Hz)

The frequency for VF pump (4B) is 47.75 Hz shown in Fig. 3a. The VF system used two 25HP (max. output) motors to maintain redundant, so the output power for each pump is less than 25HP. The frequency for FF pump (4A) is 58.5 Hz shown in Fig. 3b. The FF system used only one 25HP (max. output) motor with ~3600rpm, so the output power is almost 25HP. One 25HP power motor with maximum frequency drive is enough for outlet water pressure. The experimental results shows that the vibration produced by the VF pump is 271.32 mm/s^2(47.75 Hz), and he vibration produced by the FF pump is 346.16 mm/s^2(58.5 Hz).

The experimental results for vibration propagation are shown in Table 1. The left hand side of Table is vibration propagation for the VF pumps. The right hand side of Table is the vibration propagation for FF pump.

Table 1: Experimental results for Al DIW Vibration.

	Location	VF pump 4B Freq.(Hz) /a(mm/s^2)	VF pump 4A Freq.(Hz) /a(mm/s^2)	FF pump 4A Freq.(Hz) /a(mm/s^2)
P1	Base of pump	47.75 /271.32	48.25 /120.20	58.5 /346.16
P2	outlet side	47.75 /224.43	48.5 /80.05	58.5 /366.08
P3	Pipe in trench	47.75 /79.80		58.5 /104.20
P4	Intersection	47.75 /2.16		58.25 /10.90
P5	R3-Q1D	47.75/0.31		58.25/0.80
P6	R3-Q2F	47.75/0.68		58.5/1.04
P7	R3-Q3D	47.75/0.34		58.5/0.40

The two VF pumps operate in different frequencies, one is 57.75 Hz (pump 4B) and the other is 58.5 Hz (pump 4A). The vibration for the outlet water side is 224.43 mm/s^2 for 4B and 80.05 mm/s^2 for 4A. The spectrum is obvious in 47.75 Hz from P3 to P7, because of lower vibration source propagates less vibration. Compare with FF pump in 4A, the vibration produced by one pump with max. power is larger than two pumps for VF system. The vibration reduces 2.8 times from P3 to P2 for VF pumps and 3.5 times from P3 to P2 for FF pumps. There are bellows between P3 and P4, so the vibrations reduce 36.9 times and 9.6 times for VF and FF pump. From P4 to P5, the vibrations reduce 7.0 times and 9.6 times for VF and FF pump. The distance between P2 and P3 is ~50 m and the distance between P4 and P5 is ~ 10 m. Although P4 to P5 is shorter than P2 to P3, vibration decay is still larger. Because of the piping material is rubber from P4 to P5 and the piping material is stainless steel from P4 to P5. The vibrations decay through non-metal material. The experimental results show that the bellows and rubber piping material could reduce vibration propagation effectively.

Effects and Difference Between FFD and VFD Motors in Vibration Propagation

The advantages for the VFD motors are stable for the outlet water pressure, raise up the pressure while one of the pump failure, auto-adjust the local loading to maintain the lower inlet water pressure for the pump itself. The most important reason is the lower generated vibration and propagation. Although there are two pumps operating for VF system and only one pump operating for FF system, the vibration produced in VF system is still less than FF system.

Vibration Propagation for the Cu DIW System

The measurement locations for the vibration propagation for the Cu DIW system are shown in Fig. 4. The first experimental point is from Al DIW pump (P1), next point is the outlet pipe of the pump (P2). The DIW piping is connected through the trench (P3) and to the intersection point inside the storage ring R3-1 (P4). There are three quadrupoles, R3-Q1D (P5 & P8), R3-Q2F (P6 & P9), R3-Q3D (P7 & P10), in the first part of section3. The Cu DIW piping was sent direct to the magnet to cool down the magnet temperature. The test points are applied to the piping inlet and top side of magnet.

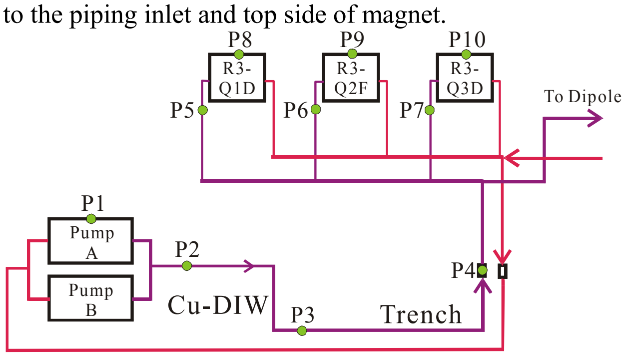

Figure 4: Layout of Cu DIW System.

The experimental results are shown in Table 2. The Cu DIW system used two 75HP motors to maintain redundant for fixing outlet water pressure. The frequencies of VF pumps are 50 Hz. Compare with the experimental results with the Al DIW system, the vibrations produced by Cu DIW pump (75HP) is less than Al DIW pump (25HP). This result indicates that the vibration for the pump is very important. Every motor should be calibrated before assembling in NSRRC, and the vibration specifications must be set. There is multiple frequency 100 Hz vibration around the pumps, and the vibration amplitude is even larger than 50 Hz (max. 197.76 mm/s^2). Vibrations about 100 Hz is vanished close to trench, so higher frequency vibration can not propagate for long distance.

Table 2: Cu DIW System. (Vibration peak @ 50 Hz)

	Cu DIW Location	Accel. (mm/s^2)
P1	Base of pump	107.18
P2	outlet pipe	91.45
P3	Pipe in trench	17.68
P4	Intersection point	1.26
P5	R3-Q1D (Piping)	1.78
P6	R3-Q2F (Piping)	3.72
P7	R3-Q3D (Piping)	3.10
P8	R3-Q1D (Magnet)	0.12
P9	R3-Q2F (Magnet)	0.52
P10	R3-Q3D (Magnet)	0.52

The vibrations for the water piping inlet point to the quadrupole are larger than magnet itself. This means that the vibration decay by different material and its intersection. There are some interest phenomena that the Al DIW frequency (~48 Hz) appeared in the piping system in the Cu system. It perhaps caused by the same piping girder and magnet girder.

VIBRATION FOR CHILLED WATER SYSTEMS

The vibration propagation for the chilled water system was also tested here. The frequency around 29.5 Hz was obvious existed everywhere in NSRRC before because almost all of the motors used FF pumps with 1800rpm. Now, the chilled water systems also changed to VF pump. In order to compare 29.5 Hz vibration propagation, the following experiments show the vibration propagation in piping for AHU loop and DIW loop in FF condition, shown in Table 3.

Table 3: Chilled Water System. (@ 29.5 Hz)

Location a(mm/s^2)	FF pump AHU loop	FF pump DIW loop
P1	36.88	154.12
P2	48.73	140.48
P3(Cu)	4.85	4.78
P3(Al)	7.39	4.54

Both water pumps to AHU and to DIW produce 29.5 Hz vibration in FF operation. The chilled water loop has no direct relation with DIW loop, so vibrations in P3 for Cu and Al system were not obvious. The vibration source from UT-2 and other pumps is not included.

CONCLUSIONS AND DISCUSSIONS

The advantages for the VF pumps are stable for the outlet water pressure and the lower vibration produced. The experimental results identify the vibration propagation from the utility system and give some clues about the modification for utility facilities and piping methods.

The vibrations (29.5 Hz) were larger during FFD operation. The vibration propagation almost vanished in the trench. The 29.5 Hz vibrations could be possibly produced by the local pumps or other systems.

Higher frequency vibrations can not propagate for long distance. The different frequency of vibrations could propagate by the same piping girder, magnet girder or ground.

REFERENCES

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[2] D. J. Wang, H. C. Ho, Jeremy Wang and Z. D. Tsai, "Water Induced Vibration in the NSRRC", PAC'05, 2005, Knoxville, Tennessee, USA.