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NSLSII RF-SHIELDED BELLOWS OFFSET TESTING

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Abstract

The NSLSII storage ring contains over 180 RF shielded bellows over its 792 m circumference. Three of these bellows are instrumented with RTD temperature sensors on the internal components to monitor and validate expected performance. The temperature data showed an increasing internal temperature trend during successive 500 mA beam operation on one of these bellows. This bellows and many other installed bellows throughout the ring, are near to or over the vertical and horizontal offset tolerance. Offsets can create an RF path between the sleeve and fingers, which raised concern there was degradation of performance resulting from the offset condition. The bellows was removed and inspected with some visual signs of discoloration and loose RTD anchor points were also observed. With the prospects of moving from 400 mA to more permanent 500 mA operation, a test was conducted to confirm internal temperatures were safe. Two fully instrumented bellows were remotely offset under steady beam operation while observing the internal temperatures. The bellows with offset geometry was also studied with GdfdL code. The experimental results will be presented and compared to the wake-potential calculations.

INTRODUCTION

The design of the RF-shielded bellows used in NSLSII underwent careful impedance evaluation during the design stage [1]. Furthermore, the bellows design was tested in the APS storage ring [2]. Both the analysis and testing showed acceptable performance.

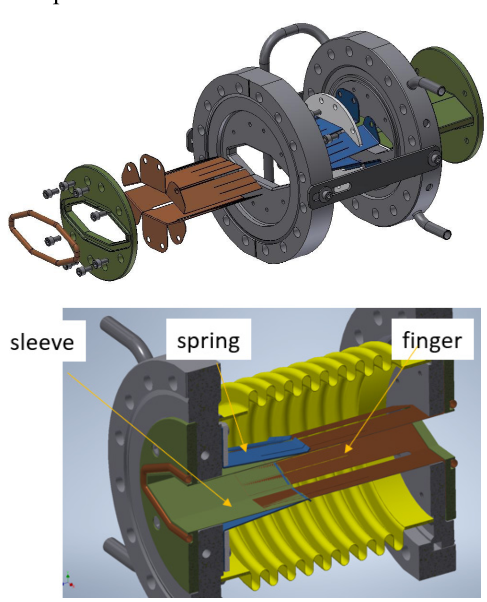

Figure 1: Exploded and section view of RF-shielded bellows.

NSLSII machine commissioning involved careful evaluation of the vacuum system performance including both the monitoring of dynamic pressure as well as vacuum component temperature. The later included the installation of temperature sensors on all vacuum flanges and potential locations of high temperature. The storage ring includes over 180 RF shielded bellows. The bellows includes fingers that are pinched between a sleeve and spring assembly as shown in Fig. 1.

Only three bellows were instrumented with temperature sensors to monitor the internal RF components during commissioning and installed in straight sections where higher temperatures typically occur. A total of six thermocouple sensors are located on the sleeve, spring and finger. Three on the top and three on the bottom. These special bellows are shown in Fig. 2.

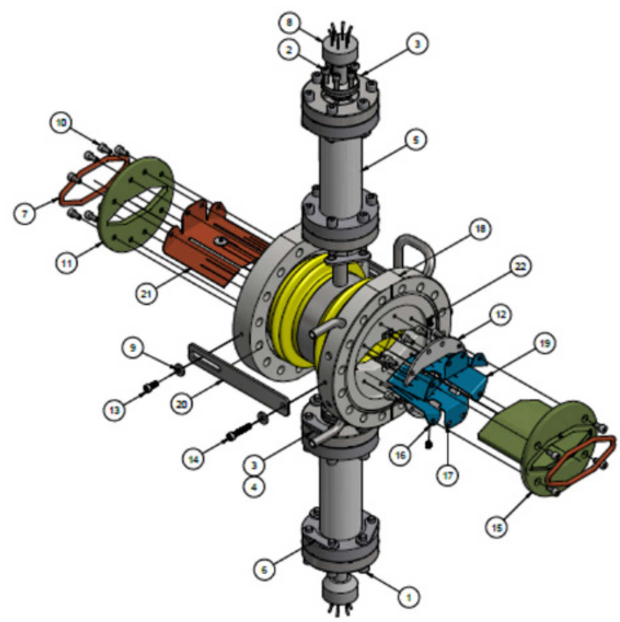

Figure 2: Instrumented bellows with internal thermocouples.

Temperatures were stable and acceptable during commission up to and including 400 mA operation. However, during periodic study periods of 500 mA, temperatures on two of the three bellows increased (Fig. 3). All external sensor connections and modules were confirmed good.

The offsets of the bellows were measure and C18 was found to have the greatest misalignment and near the design limits of ±2 mm vertical and ±1 mm horizontal. The measured value was 1.45 mm (V) and 0.83 mm (H). The trend showed successive worsening during each 500 mA study. A FLIR camera did not substantiate high internal temperatures due to unknown emissivity and thermal shielding, but did show higher heating on the top leading to some concern the sensor readings were accurate (Fig. 4).

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The high downstream flange temperature may be a result of RF spring contact and unrelated to the offset heating.

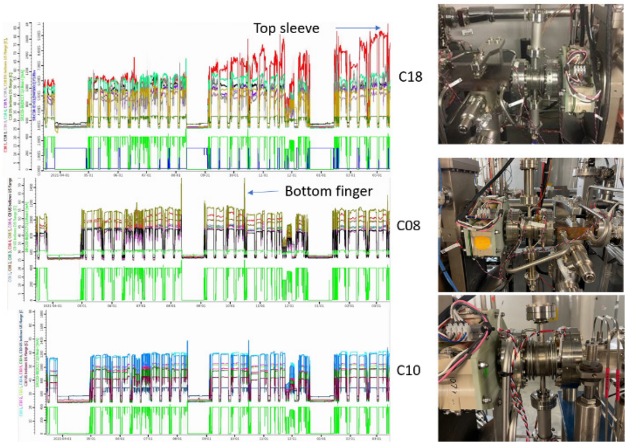

Figure 3: Measured internal temperatures during 500 mA commissioning.

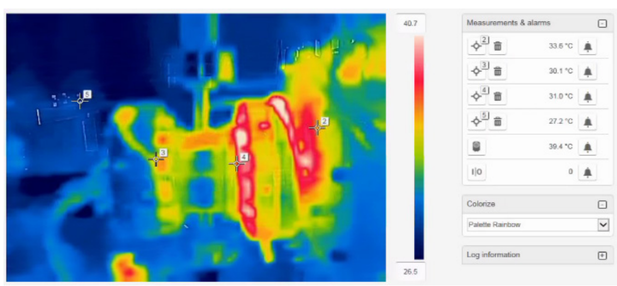

Figure 4: IR camera showing temperature distribution on C18 bellows.

The bellows was removed for inspection (Fig. 5). Some visual evidence of localized heating was found on the top spring fingers. The bellows was fixtured with its installed offset and an observable gap was formed between the finger and sleeve. This gap grows larger with larger bellows offsets. It is unclear if the original impedance simulations with 2 mm offset included the geometry of the gap created between the sleeve and fingers [1]. An experiment was devised to empirically measure temperatures with real beam-based operation to determine if the gap plays a role in excessive heating. Impedance simulations were also carried out with geometry to reflect this gap.

During disassembly the internal sensor connections at the sleeve were suspected to be loose. The bellows was reinstalled and temperatures returned to normal. During the investigation it was found many of the installed bellows throughout the ring had offsets outside of the nominal tolerance. It was decided to conduct a simple test to measure internal temperatures as a function of offset. Furthermore, the impedance of the bellows was simulated with offset to determine if wakefield-induced heating could be responsible.

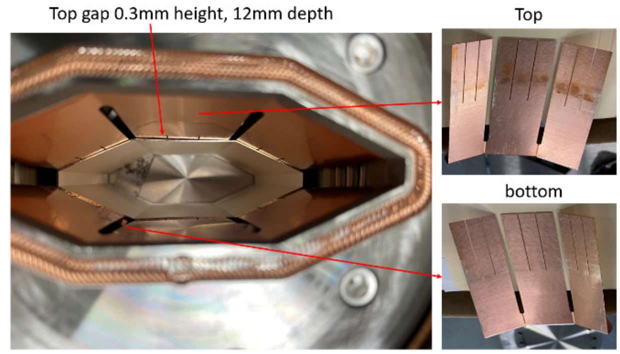

Figure 5: Disassembly showing discoloration and also gap between sleeve and fingers due to offset.

EXPERIMENTAL

The experimental setup is shown in Fig. 6. A spool pipe was supported on a movable stage with two instrumented bellows on either side. The stage would be moved vertically in both directions up to ±2.8 mm (maximum of stage) during beam operation while monitoring the internal temperatures.

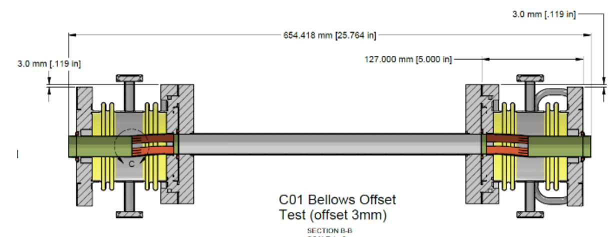

Figure 6: Test setup showing expected bellows behavior with movable spool pipe.

RESULTS

The maximum internal temperature observed was 75°C at any point during testing with maximum offset of 2.8 mm. Figure 7 shows the measured temperature as a function of vertical offset at a beam current of 500 mA.

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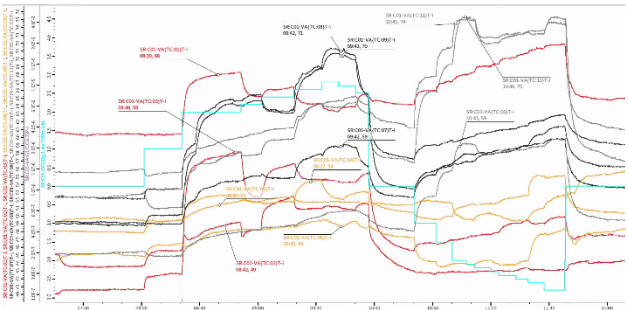

Figure 7: Temperature as a function of offset at 500mA beam current.

With the stage moved either up or down, there was a corresponing increase in temperature associated with a gap created between the sleeve and finger. Furthermore, the temperatures on the downstream bellows were slightly higher than those on the upstream. It should be noted the downstream bellows is oriented such that the gap faces the beam direction when offset, while the upstream bellows gap faces away from the beam. Additionally, the increase in temperature was not linear with offset and resultant spring-sleeve gap, pointing to a potential observation of nonlinear resonance. However, the overall temperatures were all well within acceptable limits.

Impedance simulations were performed with a 3mm offset and with the gap included in the geometry model (Fig. 8). The wakepotential for a bellow with and without offset is shown in Fig. 9.

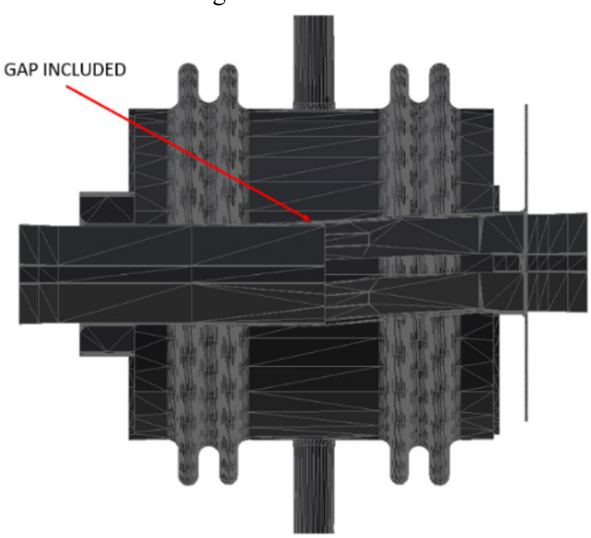

Figure 8: Geometry model including the measured gap used in the GdfidL simulation.

The resulting loss factor for a single bellows is 20.75 mV/pC for NSLS-II beam parameters. This is lower than the original value of 37 mV/pC for a 2 mm offset geometry [1].

The power loss for asingle bellows is 1.1 W in the fully aligned configuration and increases to 10.4 W with a 3 mm vertical offset. This level of power dissipation remains within acceptable limits.

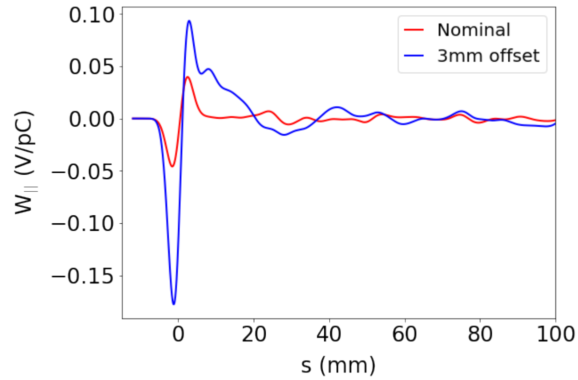

Figure 9: Comparison of wakepotential for a single RF-shielded bellows with and without vertical offset.

The maximum temperature of under 100°C is well within a safe limit of the design of 250°C maximum. The measured temperatures are also lower than the 150°C temperature observed with a NSLSII prototype bellows at APS with single bunch current of 6.3 mA [2].

CONCLUSION

Early commissioning efforts at 500 mA exposed a potential issue with excessive internal bellows heating. Because of the careful approach to reaching full design beam current of 500 mA, we felt it prudent to not just inspect the overheating bellows, but to evaluate the risk of bellows heating resulting from misalignment offsets. This simple test revealed reasonable internal temperatures with the same vertical offset seen in bellows installed throughout the ring. The runaway temperature observed was likely a loosening connection internal to the bellows as the condition has not returned with significant operational time at 500 mA. Without doing an FEA thermal analysis, this power deposited into the bellows sleeve and fingers appears to correlate reasonably to the measured temperatures in the test. The testing validates the design and should prove a robust component for the life of the machine.

ACKNOWLEDGMENTS

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