SIS100 Inspection robot – development and status report

N. Schweizer[*1] *and I. Pongrac*[2]
[1]TU Darmstadt RMR, Darmstadt, Germany; [2]GSI, Darmstadt, Germany

During maintenance work or upgrade measures of large particle accelerator vacuum systems, randomly as well as deliberately introduced foreign objects may inhibit the particle beam significantly, usually leading to a considerable high risk of a complete shutdown of the accelerator. Considering reported incidents from several different particle accelerator laboratories, where e.g. bottles, screws, dropped down inserts, and in the case of SIS18, a crumpled aluminum foil, have been found within the vacuum system, a novel platform for a mobile inspection device is currently being developed and is foreseen to be deployed in SIS100.

Development of the robot design

The vacuum system of SIS100 offers a challenging topography for any mobile inspection robot where a multitude of steps, deep gaps, as well as chambers with limited apertures have to be traversed reliably. Ideally, during each shutdown and prior to closing the vacuum system, the inspection robot shall traverse the complete vacuum system of the SIS100 and visually examine the beam pipe vacuum for any obstacles, damages or anomalies.

In order to design a suitable semi-autonomous robot to be used in the SIS100 vacuum system, the geometries of the different vacuum chambers and pipe sections have been analyzed. The robot is designed in such a way that steps and gaps can be detected and traversed in a safe way. In addition, the robot is able to move forwards and backwards in case an insurmountable obstacle is detected.

The ab initio modular concept of the robot where several modules can be attached successively to increase the total length ensures a high degree of flexibility for the inspection robot to be able to traverse most vacuum chamber topographies. Fig. 1 illustrates the current modular prototype design.

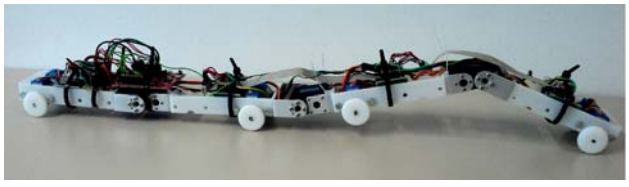

Figure 1: Fully functional prototype model of the SIS100 inspection robot.

* nicolai.schweizer@rmr.tu-darmstadt.de

Simulations and current status

After the determination of the fundamental robot design, extensive 3D simulations have been performed to test and to verify that the robot can traverse as many vacuum sections of SIS100 as possible. Thus, the probability of malfunctions (e.g. the robot gets stuck) can be minimized. Various locomotion strategies have been simulated in realistic test environments based on actual SIS100 CAD data. Additionally, several experiments have been successfully executed with real vacuum chambers or replicas. In Fig. 2 a typical simulation scenario is exemplarily illustrated.

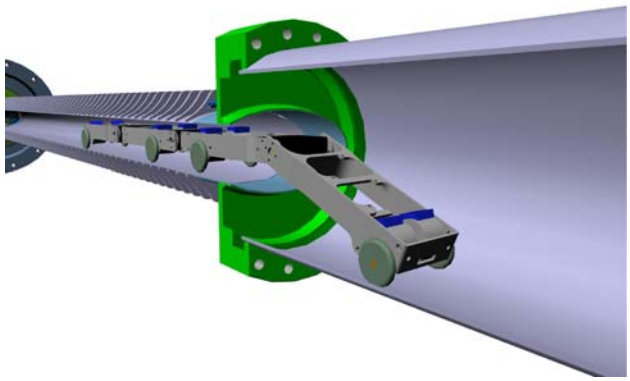

Figure 2: 3D simulation with the Gazebo [1] robotics simulator: A step is traversed as an example of a typical locomotion sequence of the inspection robot.

Outlook and further steps

Consideration of more complex chamber geometries (e.g. double steps), adaptations for curved vacuum chambers (dipole chambers) as well as ongoing maneuver strategy optimizations are currently under development. Battery management, communication possibilities and the implementation of a suitable on-board camera are the principal topics of ongoing work. Further experiments as well as simulations are crucial to allow the SIS100 inspection robot to become a universal tool for particle accelerators.

References

[1] N. Koenig and A. Howard, “Design and use paradigms for Gazebo, an open-source multi-robot simulator”, IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), pp. 2149-2154, vol. 3, 2004

DOI:10.15120/GR-2017-1