Studies on unifying method of multi-system displacement monitoring system to global coordinate system in particle accelerators

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Abstract: The researching installation of multi-system position monitoring system (MPMS) has been designed and established to take position monitoring and obtain benchmarks in high accuracy, by which the monitoring data can be reviewed in the global coordinate system and relative position displacements can be transformed to absolute position displacements. The system consists of Hydrostatic Leveling System (HLS), Wire Position Sensor (WPS), SpotOn System and Inclination Sensors (IS). The transformation from the initial Sensor coordinate systems to the platform coordinate system is done by using target ball bases of laser tracker in the platform and by combining the measurement data of CMM and laser tracker. The transformation from the five platform coordinate systems to the MPMS coordinate system is completed by combining the measurement data of WPS and laser tracker. Finally, the MPMS coordinate system is transformed to the Global system by the spatial measurement data from laser tracker.

Introduction
Combining the previous research results of National Synchrotron Radiation Laboratory (NSRL), we designed and constructed an MPMS. An HLS, a WPS and a Inclination Sensor are fixed to a stainless steel plate. A coordinate-measurement machine (CMM) calibrated the plate to establish the coordinate system. Five of these plates constitute the MPMS, and the sag of the stretched wires in WPS is compensated to create a straight line. The coordinate transformation from the sensor coordinate system to the MPMS coordinate system was deeply studied. An experimental MPMS has been setup in a 20-m tunnel at NSRL to test its feasibility.

Design of the MPMS
The MPMS includes three types of position sensors, i.e., an HLS, a WPS and a IS. These sensors are fixed to a plate made of stainless steel, which has a coefficient of thermal expansion of 10.1ppm·K. The plate is considered a nondeformable object, and the relative positions and orientations of the sensors are constant in the laboratory temperament. Several sensor plates are linked be an MPMS by combining the HLSs and the WPSs. Five sensor plates are constructed the system which is installed in a 20-m tunnel at NSRL.

Construction of the MPMS
Calibration is necessary to ensure the measurement accuracy of these sensors before constructing the MPMS. A design of this plate and mechanical support equipment is developed and updated multiple times based on the shapes and weight of these sensors. The thickness of these plates and the diameter of the support pillars are 10 mm to keep the system stable when all the sensors are attached on them. Six holes that can support 1.5 inches diameter survey reflectors are distributed on these plates. These holes establish the plate coordinate system and to ensure the relationship between the sensors on that plate. Screws affix the sensors to the plate. The mechanical support equipment includes a load support, an adjusting mechanism and a plate fixed mechanism.

 Establishment and transformation of the sensors coordinate system
The establishment of the HLS coordinate system is based on point D (x0, y0, z0) of the plate. The first record of h0 of the HLS is considered to be the datum reference, and the following data are recorded as h. The difference δh = h0-h is the displacement of the point in the vertical direction, and therefore, the coordinate value of the HLS is (x0, y0, z0+δh).

Three 6.35 mm diameter of ceramic balls are used to establish the WPS coordinate system. The centers of the ball O are considered to be the coordinate origin of the WPS. The normal of the plane that is constructed by the three balls is considered to be the y-axis. The line from ball O to the midpoint between ball a and ball b is considered to be the x-axis. The ball O gives the position of the sensor. Because it is free along an axis, ball a determines the pitch and yaw. As 0 is in contact with a surface, it determines the last degree of freedom of the sensor, i.e., the roll. The interface coordinate system is built with respect to the kinematic effects of each point.

Conclusion
The researching installation of multi-system position monitoring system (MPMS) has been designed and established to take position monitoring and obtain benchmarks in high accuracy, by which the monitoring data can be reviewed in the global coordinate system and relative position displacements can be transformed to absolute position displacements. The system consists of Hydrostatic Leveling System (HLS), Wire Position Sensor (WPS), SpotOn System and Inclination Sensors (IS). The transformation from the initial Sensor coordinate systems to the platform coordinate system is done by using target ball bases of laser tracker in the platform and by combining the measurement data of CMM and laser tracker. The transformation from the five platform coordinate systems to the MPMS coordinate system is completed by combining the measurement data of WPS and laser tracker. Finally, the MPMS coordinate system is transformed to the Global system by the spatial measurement data from laser tracker.