OPTICAL TOOLING AND ITS USES AT THE SPALLATION NEUTRON SOURCE (SNS)*

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Abstract

Optical tooling has been a mainstay of the accelerator alignment community for decades. Even now in the age of electronic survey equipment, optical tooling remains a viable alternative, and at times, the only alternative. At SNS, we combine traditional optical tooling alignment methods, instrumentation, and techniques, with the more modern electronic techniques. This paper details with the integration of optical tooling into the electronic survey world.

INTRODUCTION

The modern world of accelerator alignment relies strongly on futuristic electronic equipment such as laser trackers, total stations, electronic levels, etc. Although the electronic medium is certainly "the instrument of choice", its dependency upon sophisticated coordinate network systems and clear lines of sight – neither of which is readily available at all times – remains a common drawback. As a result, the SNS Survey & Alignment Department re-examined proven optical tooling principles and integrated them into the overall alignment strategy.

INSTRUMENTATION

The optical tooling instruments used most frequently at the SNS include optical transits, levels, and the required ancillary equipment including optical tooling scales, targets, target holders, and a significant number of specialized items designed for specific alignment applications. These instruments are widely utilized throughout the SNS (covered later in this paper) where the present state of the component will not lend itself to electronic alignment.

Although these optical tasks may seem somewhat conventional, this is not always the case. A great deal of effort has been made to incorporate and integrate optical tooling techniques, fixturing, and measurements into the world of "adjusted data" through the following means.

Component alignment, whether accomplished by laser tracker or optical tooling, is performed using the same alignment data base. In the case of optical tooling, CAD packages are used to establish offset alignment measurements relative to known coordinate survey monument locations. Optical tooling targeting is also designed to emulate laser tracker reflectors. With this scenario, components can be aligned with respect to beam in any of the three coordinate axes, by either optical or digital means, using the same survey monuments.

PRINCIPLES OF OPTICAL TOOLING

While relatively few in number, the principles of optical tooling – which are essential for successful alignment – facilitate significant supplementary solutions at SNS. The following principles pertain exclusively to calibrated transits and include precision plumbing, bucking in, autocollimation, collimation, and collineation.

Precision Plumbing

Precision plumbing is the process where the vertical axis of the instrument is set parallel to gravity. This precision plumbing is what allows the instrument's line of sight (LOS) to sweep a vertical and horizontal plane. This is important for the fact that an instrument can be set to a reference line time and time again with repeatable results.

Bucking In

Bucking in is a technique where an instrument's line of sight (LOS) is set through two known points. The SNS accelerator tunnel and target building have thousands of known points in a precision global network that has been established with the laser tracker. With the use of a 1.500" optical target ball (which coincides with the 1.500" Laser Tracker prism) and the global network, a reference line can be established at any time.

Autocollimation

Autocollimating establishes an instrument's line of sight (LOS) normal to a surface. In most instances, autocollimation is performed by mounting a precision-ground mirror to the surface which requires a perpendicular reference.

Collimation

Collimation is the process of setting two instruments' lines of sight (LOS) parallel to each other but they do not share the same vertical and/or horizontal plane. Collimation is commonly used when one wants to establish a line (or plane) parallel or perpendicular to an existing reference line.

Collineation

Collineation is the technique of setting two instruments so that they share the same horizontal and/or vertical line of sight (LOS). Collineation is commonly used when one wants to extend a reference line past an obstacle or check different reference lines.

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APPLICATIONS OF OPTICAL TOOLING

Optical tooling applications, (in some form or another), have been used at the SNS from the beginning at the Ion Source/RFQ to the end of the Target and beyond. Many applications were able to take advantage of the global network system (established by electronic equipment) and the 1.500" floor monuments located throughout the tunnel but other applications required establishing and maintaining reference lines with adhesive targets.

Ion Source/LEBT/RFQ/MEBT

Because of the line of sight problem associated with the laser tracker and its inability to see fiducials located on the equipment side of the components, an optical level was used in conjunction with optical tooling scales and an invar extension kit to set the equipment side "Y" position.

The locations of the upstream and downstream apertures of the RFQ were checked using optical tooling. This measurement was achieved by setting a transit parallel to theoretical beam line using the global network floor monuments. A second instrument was collimated parallel to the first instrument at theoretical beam line and measurements of the apertures were observed.

Drift Tube Linac (DTL)

Again, due to the line of sight problem restrictions associated with the laser tracker and its inability to see fiducials located on the equipment side, an optical level was used in conjunction with optical tooling scales and an invar extension kit to set the equipment side "Y" position on the DTL tanks.

Cavity Coupled Linac (CCL)

The optical level was used to set the "Y" position of the four CCL stands and all of the CCL cavities' cross members before the cavities were ever installed. This decreased the time needed by the laser tracker for final positioning of the CCL cavities.

Superconducting Linac (SCL)

Of all the LINAC, the SCL region saw the most activity for the use of optical tooling. Not only were the 23 cryomodules and 32 warm sections set in the "Y" position by an optical level, but also, an optical transit was used to align the 12 ceiling mounted diagnostic laser boxes and the 9 dummy cryo beam pipes. This was accomplished using a single transit along with our precision global network system to measure optical tooling scales. Performing these tasks with the laser tracker would have been time-consuming and, hence, not feasible.

High Energy Beam Transport (HEBT)

The requirements of the High Energy Beam Transport (HEBT) for optical tooling consisted of using the optical level to set the "Y" location of all the stands and the three collimators (two HEBT and one momentum). The two HEBT collimators required a single transit bucked in to the global network for positioning on beam line, while a two transit set up using collimation was required to set the LINAC dump end flange.

Ring

Again, the Ring needs for optical tooling consisted of setting stands, Ring collimators, and the RF structures using an optical level, while using a single transit bucked in to the global network for positioning the Ring collimators and the RF structures on beam line.

Ring/Target Beam Transport (RTBT)

Since the extent of work in the RTBT is not yet at the same point of installation as other parts of the accelerator, the only requirement for optical tooling consists of positioning in "Y" the magnet stands.

Target/Instruments

The bulk of the optical tooling needs at the SNS occurred in the areas of Target and Instruments. This is because the ongoing construction in the Target building has not yet permitted a climate-controlled environment, which is a requirement for the construction of a precise global network with the Laser Tracker. Some of the tasks using optical tooling instrumentation and techniques included: 1) positioning of the inner support cylinder, which ultimately set the core vessel, 2) setting of the outer support cylinder, 3) as-building and ultimately the setting of the target cart liner, 4) positioning the target cart rails and the supporting equipment, 5) locating the mercury collection tank, 6) as-building the shine door in the hot cell, 7) as-building the core vessel inserts, 8) aligning of guides in the core vessel insert, 9) aligning of guides in the shutter assemblies, 10) positioning the rear shutter assembly guide block, 11) establishing perpendicular reference centerlines from each of the 18 core vessel flanges, etc.

Optical tooling and electronic instrumentation are a complement to each other as was proved during a recent exercise. A comparison was made between the entrance beam line from the RTBT to the Target and the theoretical exit beam line from the Target through the Hot Cell. The RTBT to Target beam line was established using an optical transit bucked in to floor monuments of the global network (which was established by the laser tracker one year ago). A second optical transit was bucked in to a reference line located in the Hot Cell. This reference line was established three years ago by optical tooling methods and this line has been used to position components in the Target Monolith and the Hot Cell region. The two reference lines were compared for parallelism using collimation and offset using collineation. The results showed the two beam lines were exactly parallel to each other and the Target/Hot Cell reference line was offset by 0.035" from the RTBT/Target reference line.

CONCLUSION

Optical tooling may be viewed by some as the "dinosaur" method of alignment in this day of sophisticated electronic alignment instrumentation, but it has proved to be a viable solution in applications at the SNS where electronic instrumentation is infeasible.