Towards Automated Concrete Spraying

By Lauro Lacerda and Marjo Koivisto

Operating a remotely manipulated shotcrete placing system is one of the most demanding tasks in underground mining and tunnel construction. Experienced and skilled operators are becoming more difficult to find, and as a result the quality of the shotcrete application can vary significantly from one operator to another. Equipment manufacturers have been increasingly asked to develop their products so the impact of the operator on the final result is minimized, and productivity, along with safety, increased. The SmartSpray System by Normet is a first step towards developing a shotcrete machine capable of fully automated shotcrete placement.

Traditional control of a spraying boom means that every boom position and nozzle orientation is separately controlled by the operator to achieve the desired shotcrete placement. The in-place shotcrete quality and even longevity of the machine can vary greatly between operators. The need for improved performance prompted Normet to design and build a fully automated spraying system. Normet's Spraymec family of shotcrete sprayers is currently available with SpraySmart System as an option. This version includes two features to assist the operator—coordinated and point-to-point control modes built on top of the standard boom control system—allowing the machine to be operated in either a semi-automated or traditional control configuration.

STATE-OF-THE-ART SHOTCRETE

Recent developments in shotcrete equipment incorporated into Normet sprayers include low-pulsation concrete pumping, constant flow accelerator dosing systems, and high-voltage power systems. These advancements combined with operator training through simulators and other means promote best shotcreting practices and optimum hardened shotcrete characteristics.

There are two categories of sprayers with many configurations offered. Five sprayer models are designed for mining and six sprayers for tunneling. Several compact Normet equipment models are designed specifically for use in smaller cross sections, while many models are larger to handle larger mining and tunneling headings.

SMARTSPRAY 1—FIRST STEP TOWARDS AUTOMATION

Normet launched its first version of the SmartSpray 1 system in June 2017. SmartSpray 1 is an extension of the NorSmart system, which provides seamless control and diagnostics for

Fig. 1: Sprayers in action: (a) tunnel portal spraying with Spraymec 8100 VC; (b) equipment suitable for small, medium, and large headings; and (c) delivery and shotcrete application in mining projects around the world

all machine functions. These systems combined, allow the machine operator to use computer assistance to control the concrete spraying boom and nozzle with either a coordinated control mode or a point-to-point control mode.

In coordinated control mode, the operator controls only the spraying nozzle; boom functions are automatically controlled to stay in alignment with the nozzle position. Thus, only a single joystick is needed to perform basic concrete spraying movements. Spraying direction can be maintained automatically during the movements if desired using an automatic nozzle control feature, which simplifies the spraying task for human operators.

When using point-to-point mode, the operator defines a line between two points. After activation, the spray nozzle automatically follows this line. If the nozzle angle is locked, it is automatically retained in position against the tunnel profile. The operator only has to move the boom to the next position needed for spraying. Nozzle position can be fine-tuned, and controls overridden manually if needed. This functionality is useful for spraying large smooth surfaces.

With the redundant nature of movement positions for shotcrete booms, to assist with boom control, the Smart-Spray system allows the middle point of the boom to be moved in three axes by the operator using one of the control

levers while pressing an activation button. Position of the boom can be controlled to avoid collisions or to prevent the boom from being driven to impractical positions. Operator-controlled movements of the middle point do not alter movement of the shotcrete nozzle. A second feature allows middle joints (two joints in the boom) to be made rigid using an on/off switch. These joints remain in the position during coordinated movement of the nozzle, which is especially useful in narrow tunnels.

Also included with the Normet SmartSpray 1 system is a coordinated frame where the control works can be reoriented by pressing a button. This new orientation is set to sync with the current orientation of the upper part of the boom. Essentially this only changes interpretation of the control lever signals, which define the movement speed of the nozzle. It also includes an automatic back-and-forth rotation and tilting of the shotcrete nozzle. Choosing between on/off or proportional steering of nozzle turn and tilt are similar to those in direct manual control state.

SMARTSPRAY 2—CURRENTLY IN DEVELOPMENT AND TESTING

When speaking about "robotic spraying," worries concerning incorrect thickness and inconsistent quality of sprayed concrete arise. These issues have been considered from the beginning of the SmartSpray development process.

Normet customers have asked for a system where the nozzle is kept within a certain range of distance from the wall to keep fluctuations of nozzle distance from affecting the final quality of the shotcrete. At this stage in development, however, it was still expected that the operator keeps responsibility for other spraying parameters so that the shotcrete quality in place does not fully rely on equipment and technology. We have also had many requests for development of a system to spray a required thickness of concrete, more or less automatically. Development work for this SmartSpray 2 System, with easy profiling of an area to be sprayed, is in the testing phase.

Fig. 2: SmartSpray 1 system being tested at Normet's R&D facilities in Finland

Operator experience and knowledge of proper shotcrete techniques is essential to quality placement. Normet shotcrete placing equipment is being developed and refined to provide more automation and ease of use to assist the operator in doing a quality job throughout the work day.

SMARTSPRAY 3—THE NEXT BIG STEP

Normet is working on more elaborate software and measurement systems to provide "semi-automated" spraying equipment with thickness control. Normet strives to be a leader in concrete spraying automation. Its ultimate goal, though farther in the future, is development of a fully automated concrete spraying system. Normet's progress so far shows the company is heading in the right direction and this is an achievable goal. By use of unique scanning features in Normet's sprayers, the company foresees a fully automated concrete spraying system complete with accurate thickness control and reporting. Normet's customers will directly benefit from this fully automated system through improved productivity, quality of application, and optimal concrete material usage.

Detailed information on the complete Normet spray concrete equipment line is available at **www.normet.com/process/concrete-spraying**.

Lauro Lacerda *received his bachelor's and master's degrees in mining engineering from the University of Idaho and is a licensed professional engineer in Nevada. Lacerda has 20 years of experience working at various metal mines in the United States and Canada. He also has 5 years of experience working for a TBM and NATM/SEM tunneling contractor. Lacerda is member of SME, CIM, and ASA, and a 2007 recipient of ASA's Carl E. Akeley award. For the past 2 years, he has been working on various tunneling and mining projects in North America as Manager of Ground Control and Construction Technologies for Normet Americas Inc., based in Salt Lake City, UT.*

Marjo Koivisto *received her bachelor's degree in vehicle design from Lahti Institute of Design, Finland, and is working towards her Master of Arts degree in collaborative and industrial design and minor in international design business management from Aalto University, Finland. For the past few years, she has been working at Normet as a Designer, designing everything from communications and customer experience to user interfaces and concept vehicles.*