Wall crawler MAGNUS for Ultrasonic inspections

Ulrike FAU 1, Steffen SCHOLZ 1, Michael WEISS 1

1 intelleiNDT Systems & Services GmbH, AREVA NDE-Solutions
Phone: +49 9131 900 98888, Fax: +49 9131 900 97229; e-mail: ulrike.fau@intelligendt.de,
steffen.scholz@intelligendt.de, michael-josef.weiss@intelligendt.de

Abstract
MAGNUS wall crawler is a magnetic scanner system useable on ferritic components. The applications are versatile e.g. inspections on pressure vessels, columns, reactor tanks or pressurizer surfaces from outside. Since it is possible to adapt up to four phased array UT probes, a time efficient inspection of longitudinal or circumferential welds as well as surface inspection is feasible. Due to its height of less than 200mm MAGNUS is suitable for hardly accessible areas with limited access for personnel e.g. because of concrete shielding or insulation. The scanner guarantees a highly reliable positioning accuracy but is still flexible in movement. This is due to a fixed active drive, a rotatable axis and a passive wheel for movement measurement. Success, MAGNUS has been performing inspections with EPRI & SQC qualified phased array UT technique in the USA and Sweden.

Keywords: ultrasonic, ferritic, phased array, crawler, magnetic wheels

1. Introduction

AREVA is a world leader in nuclear power. The group’s offer to utilities covers every stage of the nuclear fuel cycle, reactor design and construction, and operating services. Its expertise and uncompromising dedication to safety make it a leading industry player.

AREVA also invests in renewable energies to develop, via partnerships, high technology solutions.

Through the complementary nature of nuclear and renewables, AREVA’s 45,000 employees contribute to building tomorrow’s energy model: supplying the greatest number of people with energy that is safer and with less CO2.

AREVA NDE-Solutions is an AREVA global business entity specialized in Non-Destructive Examination. With regional inspection entities in France (Intercontrôle), Germany (intelligeNDT Systems & Services GmbH), the United States (part of AREVA Inc.) and nearly 700 employees, AREVA NDE-Solutions supports hundreds of customers worldwide. Its mission is to provide safe, reliable, innovative and competitive inspection services & products for both nuclear and industrial markets. AREVA partners with the industry to comply with mandatory and recommended non-destructive examinations assuring component structural integrity and contributing to the safety of installations, occupational safety, personnel health and environment preservation.

2. Background

AREVA NDE-Solutions as an NDE service provider has historically specialized in mechanized non-destructive testing (NDT) systems for the nuclear industry. Many of the applications were developed for extreme conditions, like underwater and for operations at elevated temperatures. Complex component geometries and the requirements from many different country specific codes demand very high precision scanning tools, software tools to explain the inspection physics and display the results in a simple and understandable way to non-specialist regulatory authorities and managers. The developments in the robotics and in the computer technology allow more advanced solutions and open new possibilities to achieve...
high quality results with reduced inspection times, with higher workload throughput, and at reduced per-piece inspection costs.

The greatest advantage of this portable service inspection manipulator MAGNUS is its flexibility to be shipped easily, because it is small in size and weight and able to readily mount to arbitrarily diverse ferritic components, like diverse vessels nuclear or non-nuclear used.

3. MAGNUS facts & figures

The MAGNUS manipulator is a magnetic wheeled remote controlled scanner. It is highly versatile and ideal for Phased Array, TOFD and Pulse-Echo techniques. The great benefit is that it can operate without any rail or other tools and needs only a gap of 200mm for inspection.

![Figure 1 – MAGNUS in gap of 200mm](image)

The scanner is EPRI and SQC qualified. It can be used for example to inspect longitudinal and circumferential RPV or Steam generator welds. The lifting capacity is up to 60 kg. An electronic water level and three on board cameras take care to follow an exact height and circumferential position. The MAGNUS manipulator was already used successfully for RPV inspections in the USA and Sweden.

3.1 Hardware

All the drive motors on MAGNUS are MicroMo Brushless DC Motors with Hall Sensors for commutation with planetary gearboxes. All are 24 volt motors which we operate from a 48 volt motor bus, pulse width limited not to exceed motor terminal voltage of 24V. All motors on MAGNUS are current limited to approximately 2 amps continuous current.

The MAGNUS has a passive Wheel Encoder. Its inclinometer is an absolute dual axis inclinometer.
A smart pneumatic system is used for Camera Lens Air Wipe (air knife in front of camera lens), Transducer Arms Up and Down to raise or lower transducers and Front Slide Tilt Up or Down. The rear Slide Tilt Retract/Extend has 90 psig air switches between two air lines to tilt rear slide up/down.

Water Supply (Air actuated valve) can be air switched on/off single airline to open/close water supply valve to MAGNUS.

The junction box near the control box has coaxial connectors for the three cameras on the tool. MAGNUS has two forward looking cameras (one on each edge) and one rear looking camera.

3.2. Steering and moving

Manual moves are accomplished in the window below. The green line represents the angular position of the rear (steering) motor relative to the drive motors. As shown the steering motor is parallel to the drive motor (zero degrees). The blue line represents the angle of the crawler relative to perpendicular to the vessel surface (inclinometer position feedback). As shown, the crawler is perfectly “square” to the surface.

The diamond area represents the possible commands to the drive motors. The center origin is a speed command of zero inches/sec for both left and right cart motors. As you move away from the centre origin the speed command increases from 0% to 100% rated speed.

Steering MAGNUS involves the two drive motors and the rear steering motor. As you position your cursor in the diamond area the software calculates the correct angle for the rear steering motor and moves it according. You will see some preset angle buttons in the window. You can also pre-set the angle of the steering wheel before engaging the left and right motors.
Once MAGNUS is positioned by the weld, the crawler is set to be vertical with the vessel surface (inclinometer at zero degrees). The arm motor is the left to right scan axis and the cart motors are the up and down scan axis. The cart motors are synchronized using a master-slave motion control mode so that they move in tandem by the same amount of travel. Due to slippage that may occur with these magnetic drive wheels; the passive encoder wheel is used to verify the travel distance of the cart motors.

Then the motion controller is set to perform a raster scan using these two axes. For better accuracy of the cart axis, the passive wheel encoder is used as the encoder feedback to the motion controller during the scan (rather than the cart motor).

4. Latest inspection on Core Shroud Stand weld in Ringhals 1

intelligeNDT was contracted for a core shroud stand weld inspection at Ringhals 1 in 2014. This scope included the qualification of equipment, procedure and personnel for data collection, detection and sizing. Furthermore the in-service inspection of Core Shroud Stand weld at Ringhals Unit 1 during outage 2014 with ultrasonic (UT).
5. Further inspection possibilities for MAGNUS

This magnetic crawler is applicable on all ferritic vessels. Because of the fact that it can operate without any rail or other tools and needs only a gap of 200mm for inspection this tool is flexible and suitable for areas with limited access.

To extend the range of inspection possibilities intelligeNDT is planning to rework the crawler and make it even more modular. This should result in an extension of feasible diameters to inspect. Furthermore the combination with other tooling like intelligeNDT’s Light Weight Robot arm for inspection of nozzles is planned.