REACTOR PRESSURE VESSEL FLANGE SEALING SURFACES PROFILOMETRY SYSTEM

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***ABSTRACT -** VVER 1000/1200 Reactor Pressure Vessel (RPV) and Reactor Pressure Vessel Head (RPVH) sealing surfaces inspection is one of the crucial RVP inspections which assures safety of the operation. HRID has developed camera - laser based system for the determination of the profile of the sealing surface. Results of such profilometry can induce corrective actions which will ensure better fitting of the reactor pressure vessel and reactor pressure vessel head providing leakage free operation.*

***Keywords:** reactor pressure vessel, VVER 1000, sealing surface, profilometry, laser, camera, eddy current*

1. INTRODUCTION

To assure excellent interface between reactor pressure vessel sealing surface and reactor pressure vessel head sealing surface the profilometry of both sealing surfaces is a must. Such inspection assures trouble free operation of reactor vessels. This article describes the state of the art design of the HRID reactor flange sealing surfaces profilometry system. The name of this HRID system in further text is HPROF (HRID PROFilometry).

2. HPROF INSPECTION SYSTEM

Inspection system for reactor pressure vessel (RPV) sealing surfaces uses three different independent systems with the aim to collect independent information about status of sealing surfaces. Those systems are the following:

1. Laser inspection system which is use to establish profilometry of the sealing surfaces.
2. Video inspection system which is used for identification of status of the surfaces (dirt, corrosion products, cracks, dents, etc.)
3. Eddy current inspection system which has purpose to justify results of video and laser findings but also identify small cracks under corrosion products, or of such sizes which cannot be detected by video or/and laser techniques.

Use of three independent systems is great advantage of HRID HPROF solution and assures all relevant information regarding status of VVER 1000 reactor sealing surfaces.

The general concept of inspection system is given in Figure 1.

3. TECHNICAL DESCRIPTION of HPROF SYSTEM

The design of the system for the inspection of the control tubes provides the following characteristics:

- failure-free operation;
- long lasting durability;
- easy serviceability;
- easy maintenance.

The system is designed with all precautions in regard to safe operation, user friendly utilization and environment.

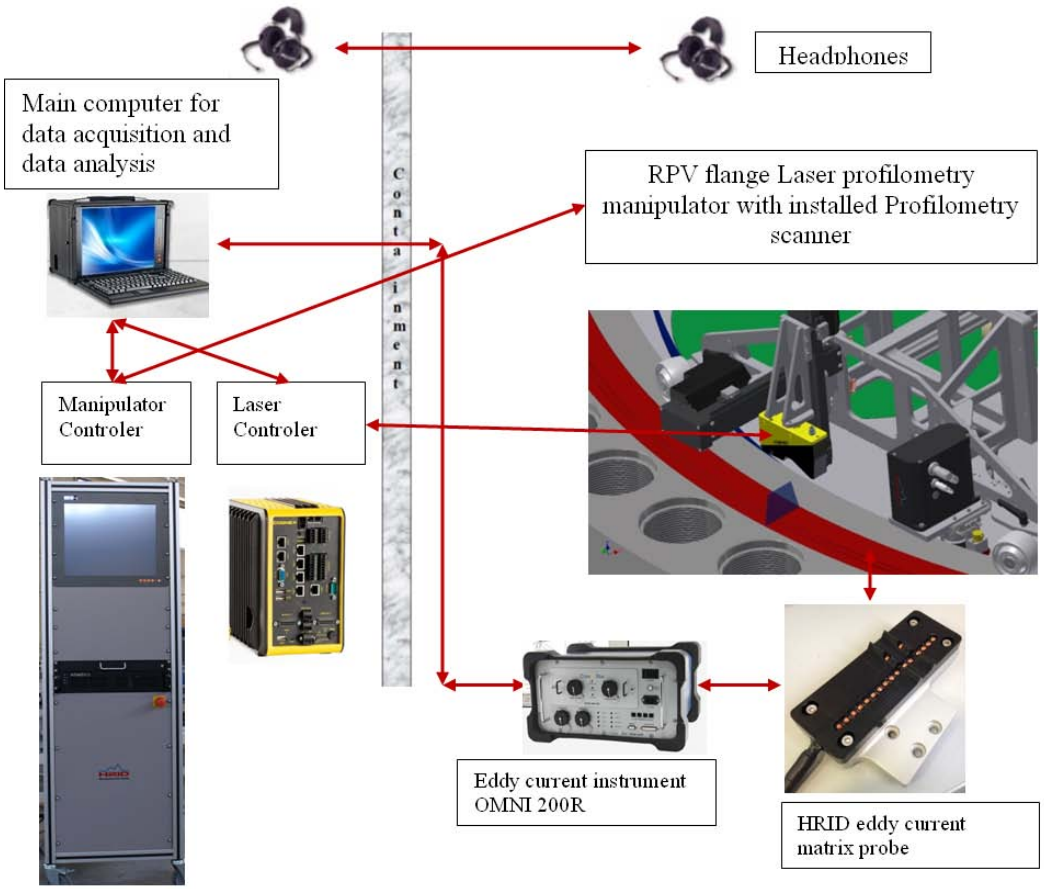

Figure 1 *HRID HPROF inspection system*

4. EXAMINATION APPROACH

The examination techniques that are used for pre-service and in-service inspections are evaluated against inspection goals defined by applicable codes/standards. The goals are defined as follows:

- To examine all defined examination areas/ volumes by optimized scanning sequence and to the maximal possible extent;
- To provide simple operation of the inspection equipment;
- To minimize the inspection time with no effect to data quality
- To apply the state of the art equipment and/ or components which are proven in the VVER inspections;
- To minimize exposure rates to the personnel involved in examinations and equipment manipulation;
- To define the examination system which will fulfill all predefined requirements;
- To provide all technical evaluations for detection of minimal defect size defined in applicable codes.

In addition to previous basic requirements, HRID defined its additional goal which needs to provide more reliable and high efficiency examinations. These additional goals include application of the system with capability of permanent data storage. Stored data can be analyzed at any time after inspection is performed.

5. MANIPULATORS DESIGN

For scanning sealing surfaces on reactor pressure vessel one type of manipulator is used and for scanning sealing surfaces of reactor pressure vessel head the other type of manipulator is used. Both manipulators use wheels for its fixing on object of inspection but their design is different because of location of sealing surfaces.

In Figure 2 all details of manipulator for reactor pressure vessel sealing surfaces is given with related details. In Figure 3 is given picture of reactor pressure vessel (RPV) sealing surface scanner. In Figure 4 all details of manipulator for reactor pressure vessel head (RPVH)) sealing surfaces is given with all related details. In Figure 5 is given picture of RPVH scanner

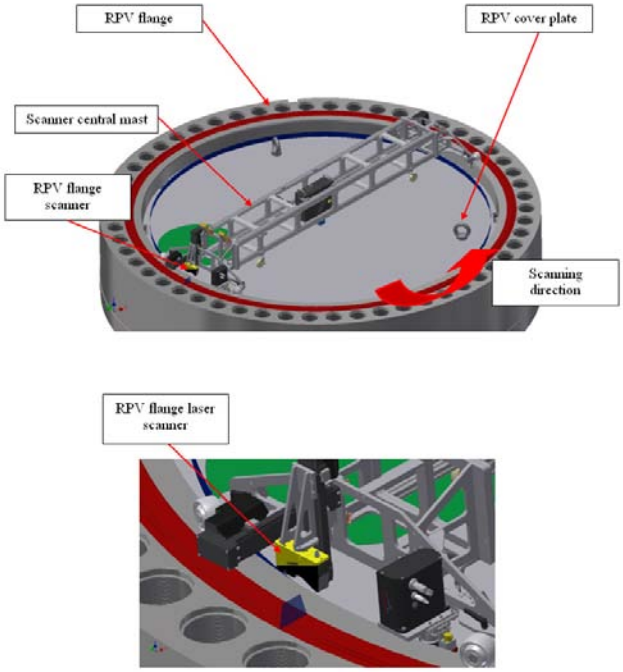

Figure 2 *Manipulator for reactor pressure vessel sealing surfaces*

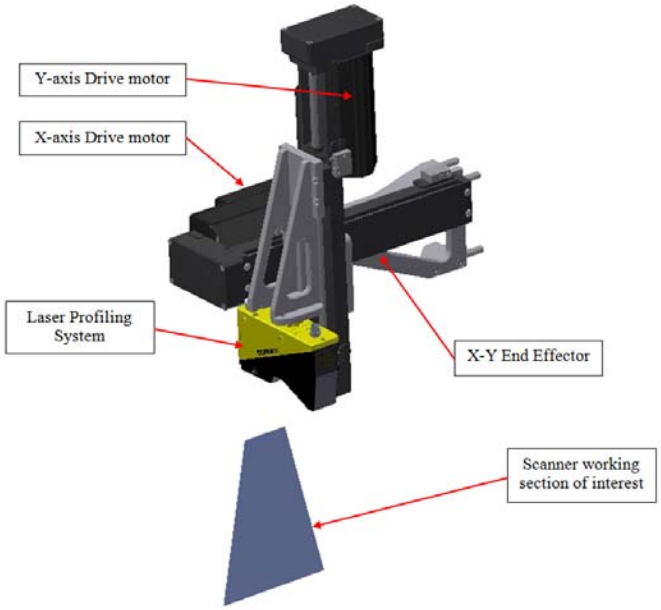

Figure 3 *RPV flange scanner for sealing surfaces*

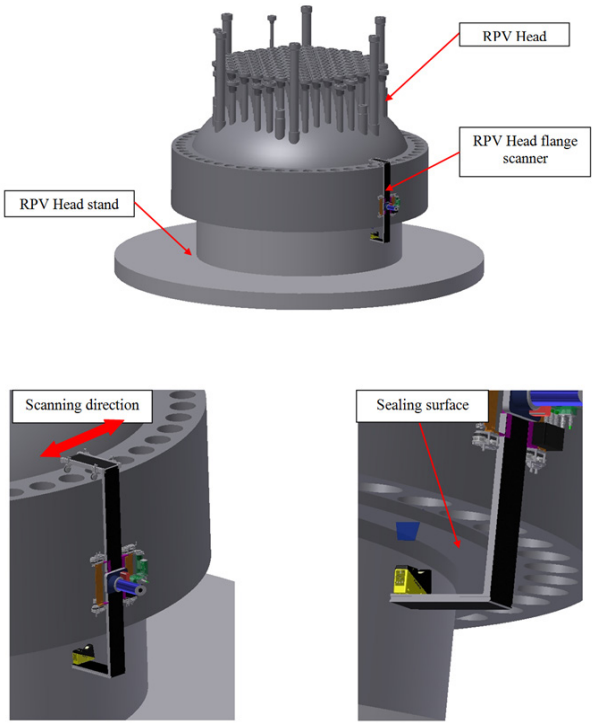

Figure 4 *Manipulator for RPVH sealing surfaces*

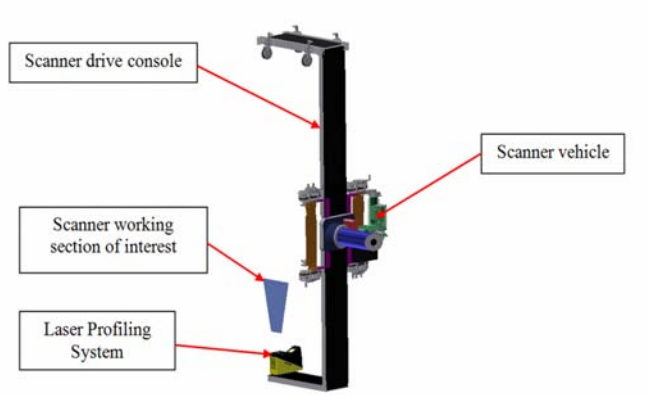

Figure 5 *RPVH flange scanner*

6. LASER PROFILOMETRY EQUIPMENT DESIGN

Laser profilometry measuring techniques give unparallel precision of measurement shapes, surfaces etc. For purposes of RPV and RPVH sealing surfaces profilometry Laser measurement system was chosen. This system assures accuracy of measurement on the level of 0,016 mm.

The technical characteristic of the Laser 3D profilometry measuring system are shown in Table 1.

Table 1 *Technical characteristic of the Laser 3D profilometry*

Specifications	DS1050
Near Field of View (mm)	43
Far Field of View (mm)	79
Clearance Distance (mm)	87
Measurement Range (mm)	76
Laser Class	2M, 3R
Resolution X (mm)	0.059-0.090
Resolution Z (mm)	0.004-0.014

Other specifications are shown in Table 2.

Table 2 *Other specifications*

Specifications

Dimensions	93.3 mm to 115.2 mm (H) x 50 mm (W) x 167.06 mm (L)
Weight	700 g
Operating Temperature	0°C to 50°C (32°F to 113°F)
Storage Temperature	-10°C to 60°C (-14°F to 140°F)
Maximum Humidity	85% (non-condensing)
Housing	IP65 (with Cognex recommended IP65 Ethernet and power I/O cables)
Shock	50 gs (11 ms half-Sine pulse)
Vibration	8 gs (10-500 Hz for 30 minutes)
Discrete I/O Operating Limits	Trigger input voltage limits: -24 VDC – +24 VDC Input ON: > 10 VDC (>6 mA) Input OFF: < 2 VDC (<1.5 mA)
Encoder Input Specifications	Differential: A+/B+: 5-24V (50 kHz max) A-/B-: Inverted (A+/B+) Single-ended: A+/B+: 5-24V (50 kHz max) A-/B-: +0VDC=½(A+/B+)

Power Supply	Voltage: +24 VDC (22-26 VDC) Current: 500 mA max
Scan Rate	Up to 10 kHz
Software	Cognex Designer software
Ethernet	Gigabit Ethernet interface Integrated link and traffic LEDs Standard M12-8 female connector
Certifications	CE cULus
Accessories	Ethernet cable: 5m, IP65-rated Power: + I/O + Encoder cable, IP65-rated Mounting bracket Stainless steel enclosure, IP69K-rated for the food industry
VC5 Controller	Intel i5 processor Precision I/O Real Time Communication 207 mm (H) 132.6 mm (W) x 229.5 (L)

In Figure 6 is given picture of Laser profilometry system – Sensor Head. In Figure 7 is given example of software presentation of sealing groove profile.

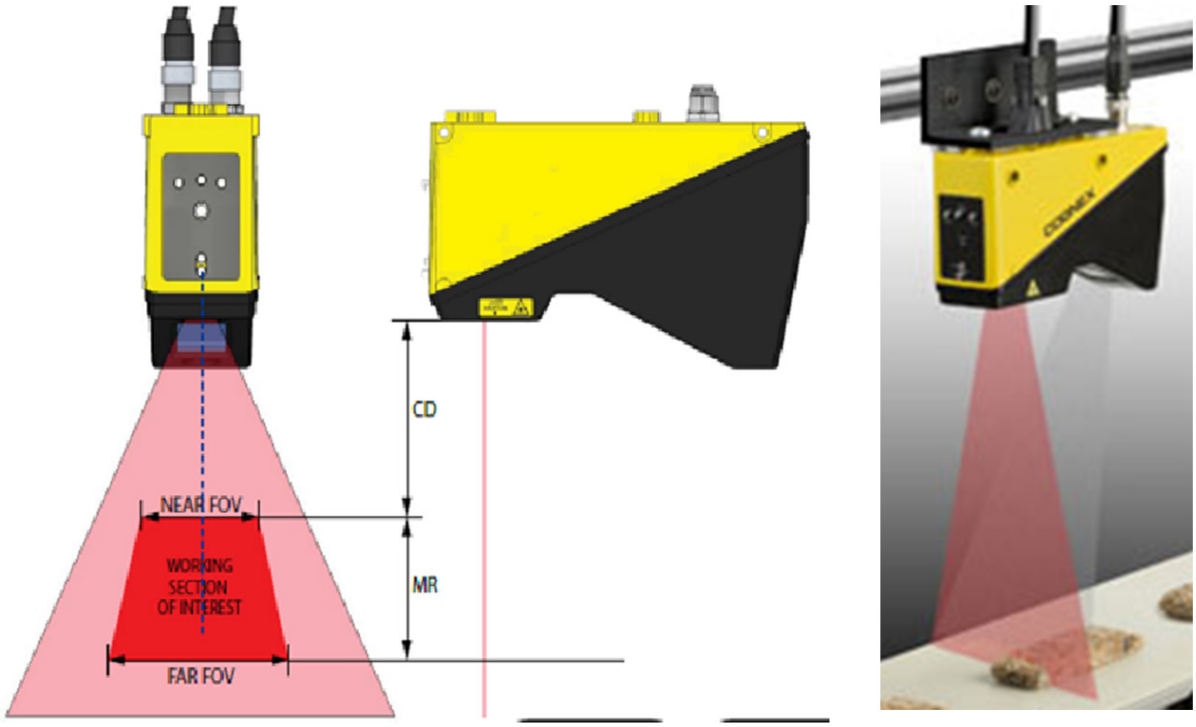

Figure 6 *Picture of Laser Profilometry system - Sensor Head*

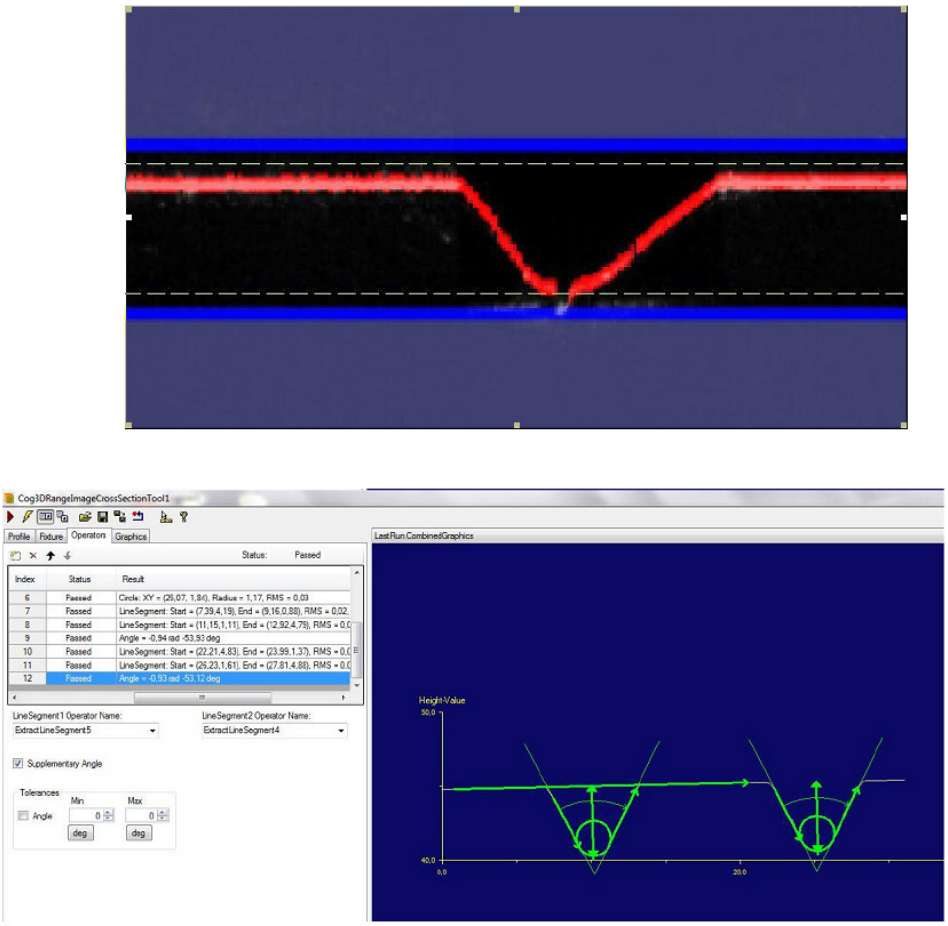

Figure 7 *Selling groove profile determined by laser and software measurements*

Characteristics of Laser 3D software for data acquisition and data analysis:

1. 3D machine vision software used with Laser sensor head delivers accurate, real-time 3D position information to improve vision performance.
2. 3D software delivers accurate, real-time, three-dimensional information about irregularities on RPV sealing surface. Related to any kind of irregularities the software can submit information about size of irregularity (LxWxH in mm), its volume in mm3, and any cross section profile of the irregularity.
3. 3D software tolerate non-uniform lighting
4. Application performance is enhanced by high-precision calibration algorithms that adjust for optical distortion and laser position, and synchronize cameras with moving elements.

7. VIDEO SYSTEM DESIGN

Video system consists of one SCAUT camera si shown in Figure 8 with characteristics given in Table 3.

Table 3 *Characteristics of SCAUT camera*

Resolution horizontal/vertical	2592 pixels x 1944 pixels
Resolution	5 MP
Pixel Size horizontal/vertical	2.20 µm x 2.20 µm
Frame Rate	14.0 fps
Mono/Color	Color

Figure 8 *Video camera*

SCAUT cameras are running by HRID HDVIEW software which allows running camera, recording of data (.wmv, or .mov formats), measuring defects etc. only by computer.

8. EDDY CURRENT INSPECTION SYSTEM

Eddy current inspection system consists of eddy current instrument OMNI 200R with AM 203 module and HRID matrix eddy current probe (custom design for RPV sealing surfaces).

Picture of OMNI 200R eddy current instrument is given in Figure 9.

Custom matrix eddy current probe is made from 16 plus point coils with radius of 6 mm, which are examining with one pass the complete sealing surface. For groove inspection two pancake coils are used because for grooves pancake probes demonstrated greater sensitivity. The picture of this probe is given in Figure 10.

9. CONCLUSIONS

Developed inspection system gave excellent multi method inspection possibilities which obtain all necessary information about defects as well gradual changes of sealing surface. Use of this system raise the safety level of nuclear power plant operation and practically exclude any possibility of leakage between RPV and RPVH.

Figure 9 *OMNI 200R eddy current instrument*

Figure 10 *HRID matrix eddy current probe for inspection of sealing surfaces*