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AUTOMATED INSPECTION SYSTEMS FOR PHWR FUEL AT NUCLEAR FUEL COMPLEX

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ABSTRACT - Nuclear Fuel Complex (NFC), Hyderabad is the sole manufacturer of fuel for Pressurized Heavy Water Reactor (PHWR) in India. The fuel production was progressively increased due to commissioning of new nuclear power plants and operating the existing ones at design load factors. In order to carry out inspection of millions of components to meet the increasing fuel production requirements, NFC has indigenously developed several automatic and semi-automatic inspection systems.

These include systems for fuel pellet density measurement, pellet visual inspection, ultrasonic testing for PHWR end closure welds, PHWR fuel bundle backfilling and leak testing with Helium recirculation and bulk metallographic sample preparation. Introduction of these systems have enhanced inspection throughput with higher reliability while reducing human fatigue and monotony. The paper brings out various details of the various systems and their benefits.

1.0 Introduction

Nuclear Fuel Complex, is a constituent unit of Department of Atomic Energy, India is responsible for supplying fuel and structural components for Indian nuclear power reactors. Since its establishment in early 70's, NFC has produced more than 0.8 million Pressurized Heavy Water Reactor (PHWR) fuel bundles. India has a very ambitious nuclear power program, the increasing number of nuclear reactors and their operational efficiency has lead to enhanced fuel production at NFC. The increasing production level was achieved with automation.

2.0 Automated Inspection systems

Inspection activities related to fuel production has been man- intensive and requires large number of skilled operators. Automation has been introduced for various inspection activities to overcome cumbersome and monotonous inspection in large numbers in manual mode. As systems required for inspection of fuel and its components are highly specific in nature and not readily available, several systems were developed indigenously. This facilitated easy maintenance and permit up gradation of the systems with the advancement in technology.

2.1 Fuel Pellet density Measurement system.

Fuel pellet density is a critical parameter in PHWR fuel. Automated fuel pellet density measurement system measures the pellet density using Archimedes principle. It has an edge over systems based geometric measurements in terms of accuracy and permits density measurement of un ground pellets also. The fully automated system measures density of pellets with an accuracy of 0.005 g/cc at rate of

4 pellets/ minute. The system facilitates seamless measurement of density for pellets of both 500 & 220 MWe PHWR.

The system consists of a in-feed with electric driven pellet pusher, out feed trays and two weighing scales, first being for weighing in air and second for weighing in water. The system is equipped with a three position pneumatic linear drive which has twin grippers mounted on it. The operations of the system are controlled by a PLC. The system is equipped with SCADA system which provides a user friendly interface for easy operations. The system also maintains with a database which facilitates statistical analysis of pellet density data generated.

During continuous cycle, pellet pusher brings every pellet to a designated location. At the first position of the linear drive, the first gripper picks the pellet from the designated location and second gripper picks pellet from the first weighing scale . At the second position of the linear drive, the first gripper places the pellet on the first weighing scale and the second gripper places the pellet on the second weighing scale . At third position the first gripper places next pellet on second weighing scale and second gripper places the pellet in out feed tray.

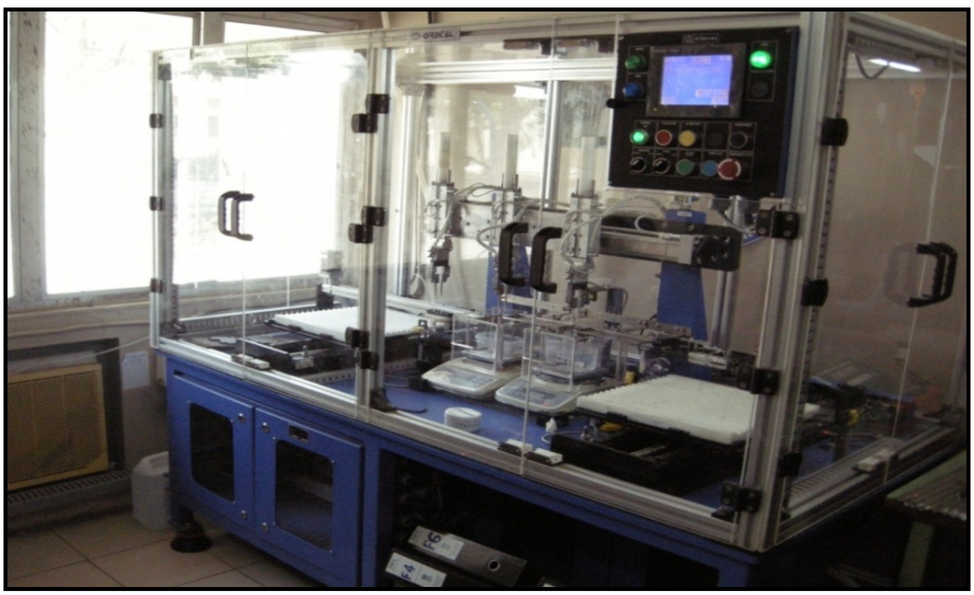

Fig. -1 Fuel Pellet density Measurement system.

2.2 Fuel pellet visual inspection

PHWR fuel pellets are subjected to 100 % visual inspection prior to loading in the fuel tubes. Every year few million pellets have to be subjected to visual inspection at NFC. Manual inspection of these pellets is a cumbersome operation. A Programmable Logic Controller based machine vision system has been developed indigenously and put into use.

A tray with uninspected pellets forms in feed to the system. A mechanical system transfers the pellets from the tray to the imaging station. The imaging station consists of a pair of specially designed rollers. These rollers are driven by using a stepper motor. The pellets to be inspected are placed over the rollers. A series of CCD cameras are placed vertically above the rollers. The entire cylindrical surface of the pellet is imaged by rotating the pellet in steps of 30 ^{o} degrees. Specifically designed software carries out image processing and pellets are transferred to the sorting station. The defective pellets are removed and accepted pellets are finally transferred to tray for further processing. Advanced version of pellet inspection system is under fabrication.

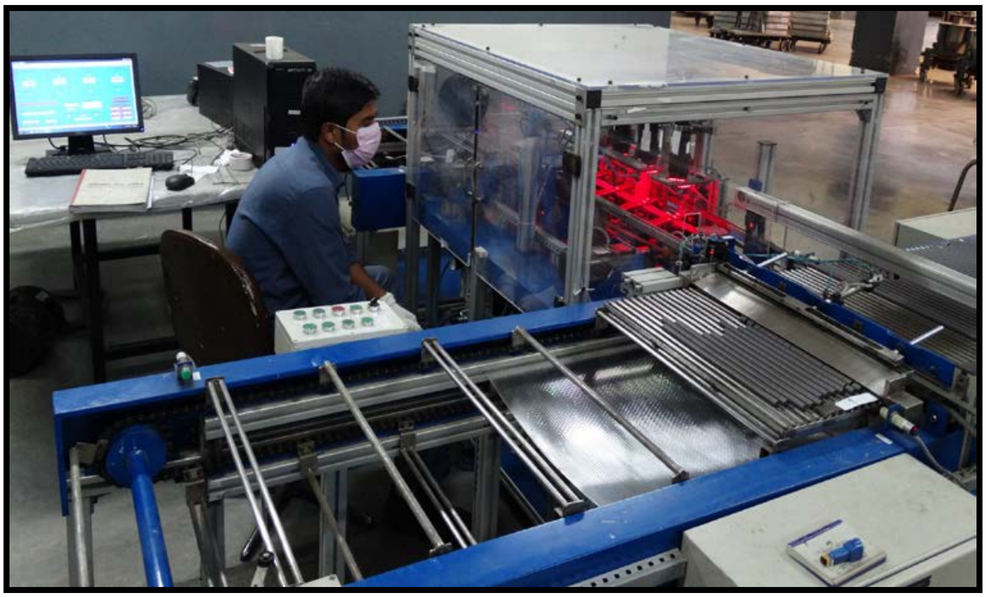

Fig. - 2 Fuel Pellet visual inspection system

2.3 Ultrasonic testing of PHWR end cap welds

End-closure weld is the most critical operation during the fabrication of PHWR fuel bundles. Ultrasonic testing is one of the non destructive tests carried out to evaluate the endcap weld integrity. Ultrasonic testing of end cap welds is carried out by immersion pulse echo shear wave technique. Manual testing of these welds is cumbersome and human intensive. In order to overcome this problem, semi-automatic ultrasonic system has been developed which inspects 1 element per minute.

The system consists of two probes mounted at a fixed distance on a three axis servo controlled slide. The probes are connected to a two channel high frequency ultrasonic flaw detector. The fuel pin under test is rotated on a pair of precisely machined rollers which is placed in a Stainless Steel tank to facilitate the weld scanning. These rollers are driven by a servo motor in conjunction with suitable gears. After each rotation of fuel pin, the probes are moved by a distance of 150 microns. This operation is repeated five times to ensure complete coverage of weld. The entire operations are controlled by a PC along with proprietary software ware.

Fig. 3 Ultrasonic testing of PHWR end cap welds.

2.4 Metallographic sample preparation system

In addition to ultrasonic testing of end closure welds, metallographic evaluation is carried out to check weld shape and microstructure for qualifying welding machines at the start of shift and process monitoring during production. For this, weld sample is prepared by cutting the weld area radially and axially and further polished using belt grinders manually. In order to make sample preparation less tedious a combined cutting, slitting and polishing machine was designed, manufactured and developed from scratch[Fig4] . The concept of Polishing on clamped long tubes with slit surface was adopted. . Cutting and slitting tools are mounted on one lead screw where as Polishing heads on other lead screw. The machine simultaneously carries out slitting at one end and polishing at other end under flood of coolant. This facilitates simultaneous processing 11 elements of 19/37E in compact place for continuous operation. This not only saved 80% man hours but also increased productivity.

Fig.4 Metallographic sample preparation system

2.5 Automatic PHWR fuel bundle inspection system

All the fuel bundles produced are subjected to 100 % dimension inspection, Helium back filling, leak testing and visual inspection prior to their dispatch. This involves extensive of lifting and manipulation of fuel bundles for which an automatic system has been installed [Fig-5] and integrated to the fuel bundle production equipment. The system seamlessly transfers fuel bundles from production station to Helium backfilling station and air washing station. A six axis robot facilitates Helium leak testing of the fuel bundles and subsequent manipulation of bundle to facilitate dimension inspection. The entire system is PLC controlled and the SCADA system records the operating parameters and test data at various stations.

Fig. 5 Automatic PHWR fuel bundle inspection system

3.0 Conclusions

3.1 Density measurement system has facilitated accurate and fast measurement of density for as sintered pellets.
3.2 Pellet visual inspection has reduced the monotony of manual visual inspection in large numbers.
3.3 Ultrasonic testing system for PHWR endcap welds have enhanced inspection throughput and reduced operator dependency.
3.4 Metallographic sample preparation system has enhanced throughput immensely.
3.5 Automatic bundle inspection system has reduced human effort required for lifting heavy PHWR fuel bundles at various final inspection stations.
3.6 The automation of various inspection equipments has enhanced productivity and manpower utilization which helped NFC immensely to produce more fuel.

4.0 Acknowledgment

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5.0 References

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