L.5.: PHWR Nuclear Fuel Pellets Inspection System for NFC Fuel Fabrication Facility

A prototype machine vision based computerized inspection system has been designed and developed at Laser Electronics Support Division (LESD) in collaboration with NFC, Hyderabad, for quality assurance of the fuel pellets used in Pressurized Heavy Water Reactor (PHWR). The prototype system had a single inspection head and was able to carry out inspection of a single pellet in ~ 8 seconds (RRCAT Newsletter, Issue 1, 2010). The inspection accuracy of ~ 90% was achieved.

In order to make it suitable for use at the fuel fabrication facility at NFC; with a desired inspection throughput requirement of one pellet tray (consisting of 600 pellets) in ~ 20 minutes, a completely new system was designed. This system consists of a pellet transport mechanism to automatically move the pellets; one by one; from an input tray to the inspection head, rotate them during inspection and further move and place them in the output (accept or reject) tray. In order to meet the inspection throughput rate of 1 pellet tray/20 minute, four parallel inspection heads have been employed.

An Ethernet based master - slave distributed architecture (Fig. L.5.1) has been developed for networking of the four inspection heads with a master PC which also serves as an operator console. Each inspection head is controlled by its own PC (slave PC). The slave PC performs the task of actual inspection. A Programmable Logic Controller (PLC) controls the pellet transport mechanism. The slave PCs and the PLC communicate with each other using proprietary hardwired I/O bus. An Ethernet link is used for data communication between the four slave PCs and the master PC.

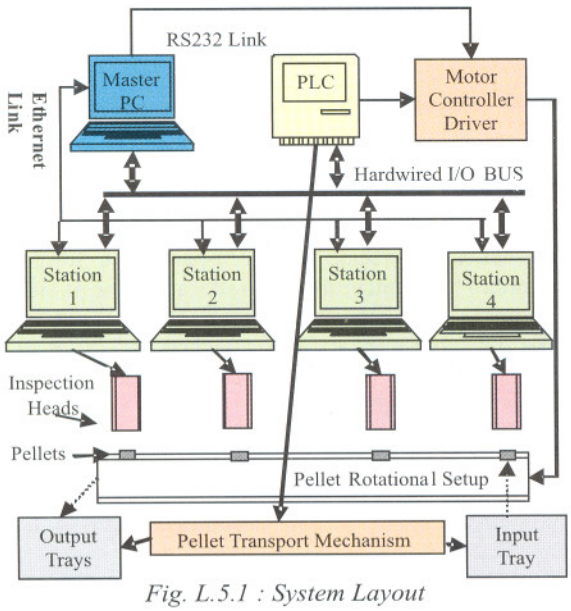

Fig. L.5.1 : System Layout

The system accepts these pellets from special input trays (20 rows x 30 pellets/row). The PLC control system loads the pellets serially from the input tray and places them under each of the four inspection stations. The master PC instructs the slaves PCs to start the inspection. Each slave PC then inspects a pellet and generates an accept/reject result. These results are communicated to the PLC and to the master PC. The PLC control system removes the pellets from each of the inspection stations and places them in Accept or Reject output tray depending upon the inspection result. The master PC displays the above the result and stores it in 'excel' format file.

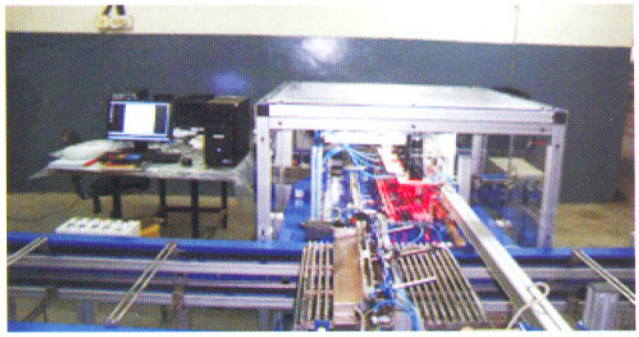

Fig.L.5.2: Photograph of the inspection system installed at NFC.

A standalone 3A/phase, 8-bit micro stepping stepper motor drive was developed to provide the angular motion to the pellet. An 8051 micro-controller based time synchronization unit was also developed to synchronize the pellet motion and pellet surface image acquisition activities. The synchronizing unit generates time synchronized events for pellet rotary motion and trigged image acquisition. The pellet rotation and image acquisition activities have been overlapped to the extent possible; to optimize the image acquisition time.

The inspection software provides a facility for calibration of individual inspection stations. It is a four step process that involves adjustment of the camera position, adjusting the focus for sharp image, selection of uniformly illuminated ROI and calculating the effective pixel resolution (in μm) for the adjusted system. This computer assisted calibration procedure of inspection station helps a trained supervisor to calibrate the inspection stations.

This machine vision system (see Figure L.5.1 and L.5.2) has been developed, installed, commissioned and inaugurated on 1st November 2011; at NFC, Hyderabad. The performance of the system was satisfactory and inspection throughput of one tray in typically 20-23 minutes has been achieved with high accuracy; (±50μm feature size) and repeatability.

Reported by:
P. P. Deshpande (ppd@rrcat.gov.in)
M. J. Joshi & C. P. Navathe