L.2: Computerized inspection system for PHWR fuel pellets

A prototype machine vision based computerized inspection system was 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) and was sent to NFC for initial trials (RRCAT Newsletter, Issue 1, 2009). The prototype system was able to carry out inspection of a single pellet in ~ 20-24 seconds, with the inspection accuracy of ~ 75%.

It was observed that the image acquisition in this system was not satisfactory, primarily because of pneumatic drive, which was not able to provide repeatability. Hence, the pellet angular rotation mechanism was redesigned using a stepper motor based actuator. A standalone 3A/phase, 8-bit micro stepping stepper motor drive was developed to provide the angular motion to the pellet. This motorized actuator enabled a smooth, precise and faster angular rotation of the pellet which replaced the earlier pneumatic rotary system.

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 was used to generate pellet motion event followed by trigger event for the frame grabber PCI card. The image acquisition software collected the image data and re initialized the frame grabber for the next event. The time synchronization unit relieved the image acquisition software module from the handshaking and polling activities which were required in the earlier setup. Moreover the motion and image acquisition activities could be overlapped to the extent possible; thus further reducing the overall surface image acquisition time.

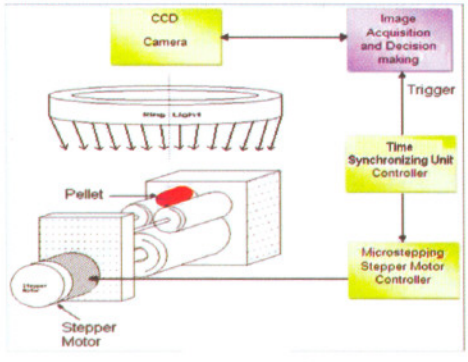
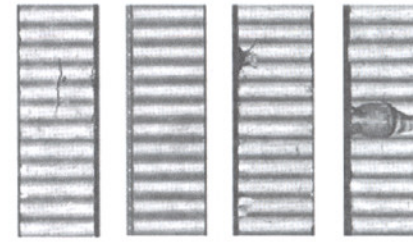


Fig.L.2.1: Schematic diagram of the revised pellet inspection station.

This revised machine vision system (refer Fig.L.2.1) is now able to complete the inspection of a single pellet within ~ 8 seconds, with high accuracy; (±50μm feature size) and repeatability. The system has to accept these pellets from special trays (20 rows x 30 pellets/row) which impose strict space constraints. An LED based illumination system was re-designed and developed to suit the above production line setup.

The Labview based software on PC was also revised to supervise the overall surface image acquisition and reconstruction of the pellet surface image within stipulated time frame. Fig.L2.2 shows acquired surface images of the PHWR pellets using the above mentioned modified setup.

The image processing software delivered earlier was not able to correctly identify the pellet ends; especially if it had long edge cracks. The identification was also dependent on the precise position of the pellet on the rotary mechanism. This was impractical since the loading of the pellet would be carried out by automated pellet handling system. In few cases, the narrow chip defects were wrongly identified as cracks and vice versa. This was producing wrong result due to difference in acceptance criteria for the chip and the crack defect. The



FigL.2.2: Scanned surface images of different pellets.

algorithms for the pellet end detection were improved to correctly identify both the ends, irrespective of the loaded pellet position or in presence of a long edge crack. New algorithms were developed to identify and classify the smaller defects. These modifications resulted in improved inspection accuracy.

The inspection system was tested at NFC with assorted 100 samples that represented good and bad pellets. The system performance was satisfactory with 90% accuracy. The inspection cycle time was observed to be ~ 8-10 seconds depending on the number and type of the defects. The inspection system will now be installed at NFC along with an automated pellet handling system. This will completely eliminate the human inspector and it will be tightly integrated in the fuel production line. The throughput of the computerized inspection system is expected to yield one pellet/second.

Reported by:
P. P. Deshpande (ppd@rrcat.gov.in), M. J. Joshi, A. Valecha and C. P. Navathe