L.3: Machine vision system for nuclear reactor fuel pellet inspection

A prototype machine vision based automated inspection system has been designed and developed at Laser Electronics Support Section of RRCAT in collaboration with Nuclear Fuel Complex (NFC), Hyderabad, for quality assurance of the fuel pellets used in Pressurized Heavy Water Reactor (PHWR). The PHWR fuel pellets are cylindrical components with 12 - 15 mm diameter and 15 - 25 mm length. The common surface imperfections that occur on the pellet surface are chips, cracks, pits, and end defects. Since the quantity of pellets manufactured annually is over a million, it is very difficult to inspect each pellet manually. Moreover, the human inspector needs to be protected against radioactivity, and also suffers from monotony and fatigue. The machine vision system (shown in Fig.L.3.1) is designed to inspect 5000 pellets per day to carry out this job with high accuracy and repeatability.

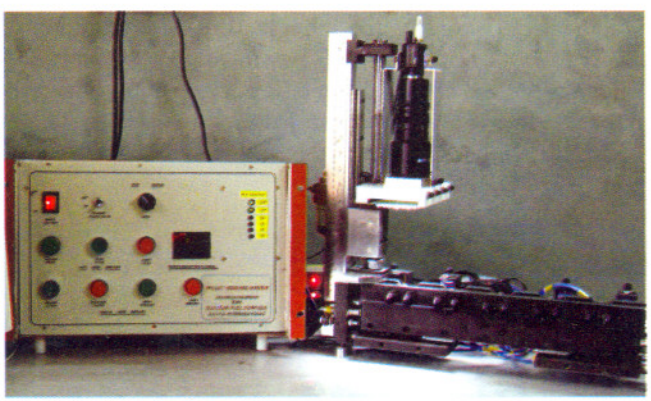

Fig. L.3.1 : Photograph of the pellet inspection station.

A machine vision inspection approach involves acquisition of the pellet image and thereafter digitally processing of the image to identify surface imperfections. A CCD camera with front end optics is used as the imaging device. A LED based lighting panel is specially designed to illuminate the pellet surface uniformly. The use of ultra bright, high efficiency, white LED array, overcomes the effect of ambient light conditions. To obtain the image of the entire pellet surface, it must be rotated through 360°. A pneumatic system to rotate the pellet around its axis was designed and fabricated at NFC.

A PCI monochrome frame grabber (8-bit) card (NI-1407) is used to capture the images from the CCD camera. Though a larger area of the pellet is visible with the camera, a small uniformly illuminated slice (~ 30 degree section of the pellet) out of the complete frame was captured per field, to minimize the errors due to cylindrical nature of the surface. The sequence of image grabbing and angular pellet movement is repeated till complete pellet surface is digitized. The reconstructed un-wrapped pellet surface image from these image slices is used for further analysis to ensure its quality.

A Labview based software has been developed to acquire the image, and process it to identify and classify the defects. A screen shot of the pellet inspection software is shown in Fig. L.3.2. Various image processing algorithms have been developed to identify the pellet ends, shading corrections to compensate illumination non-uniformity, noise filtering, particle filtering, etc. Adaptive thresholding techniques are employed to convert the grey scale image to binary, and pixel connectivity analysis is carried out to identify the defective areas. The defective areas are further processed using defect classification algorithms specially developed to classify them as crack, chip or pit. The software computes the defect parameters such as length, width, area, texture, etc and compares with user defined NFC standards. Based on the extent of the defects the assessment of the pellet is carried out. The software generates an Accept / Reject output signal for the pellet handling system for further processing. A system has been delivered to NFC for inspection of large number of pellets on trial basis.

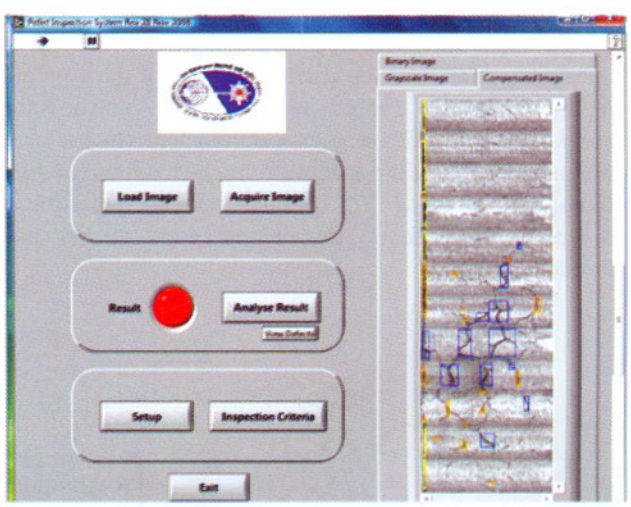

Fig. L.3.2 : A screen shot of the pellet inspection software.

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