IMPROVEMENT OF PWR FUEL FABRICATION

Hitoshi Inada
Mitsubishi Nuclear Fuel Co., Ltd., Japan

ABSTRACT

Mitsubishi Nuclear Fuel Co., Ltd. (MNF) has supplied PWR nuclear fuels to PWR power plants in Japan. MNF has been also promoting the development of new processes and automatic fabrication equipment by using the latest technology for accomplishing higher quality and lower cost nuclear fuel.

This paper describes three examples of equipment by using unique technology. These are UO_2 pellet visual inspection system by using image data processing technology, non-destructive plenum length and pellet gap measurement system by using the principle of eddy current and a new Mitsubishi designed fuel assembly fabrication process.

These system runs effectively for labor-saving and improving fuel reliability.

INTRODUCTION

MNF is the only integrated PWR nuclear fuel manufacturer that covers the processes from the conversion of uranium hexafluoride to assembling of PWR nuclear fuel in Japan. We have been fabricating PWR fuel assemblies since 1971. Up to the end of April 1998, a total number of approximately 12,000 fuel assemblies were manufactured and supplied to 23 PWRs in Japan.

In the meantime, MNF has been developing new technology in various process, and going ahead with application of automated and high-performance equipment for improving reliability of fuel and labor-saving. And such automated equipment system have also run effectively for being stable in quality and reducing human exposure.

This paper describes three examples of fabrication equipment system as below.

- Pellet visual inspection system: Using image data processing, the capacity is 18,000 pellets/hour
- Non-destructive plenum length and pellet gap measurement system: Using ECT technology. High-precision and compact.
- New Mitsubishi designed fuel assembly fabrication process: Establish of a combination of scratch-less fuel rod loading process and maintaining fuel assembly fabrication time.

These equipment system are developed by using unique technology of MNF especially.

PELLET VISUAL INSPECTION SYSTEM

Background and Outline

UO_2 powder is formed into cylindrical green pellets in a rotary press. Then the green pellets are sintered at a temperature higher than 1700C. Sintered pellets are ground to the specified dimensions and over 200,000 pellet are produced per day is. MNF has applied 100% visual inspection of the pellets and human inspection is labour-intensive and time-consuming. Therefore MNF developed a pellet visual inspection system to substitute for human eyes. This system utilizes image processing technology and has been in production use since 1991.

system to substitute for human eyes. This system utilizes image processing technology and has been in production use since 1991.

2.2 Features and Method of Inspection

The system configuration of the pellet visual inspection system is shown in Fig. 1.

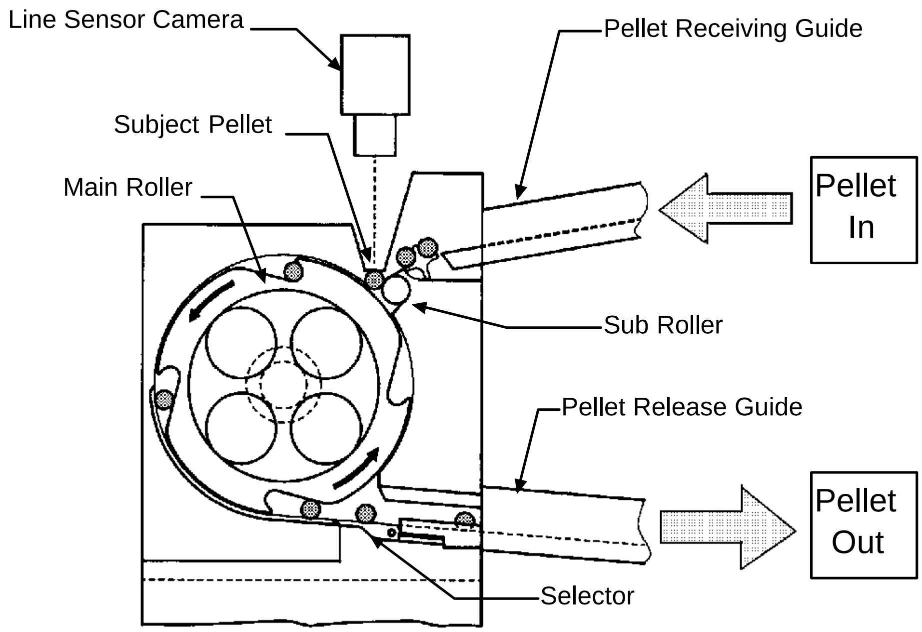

Figure 1 System Configuration of Pellet Visual Inspection System

The main unit of the system is compact – about 50 cm square – and consists of pellet receiving guide, main roller, sub roller, line sensor camera, laser distance sensor, selector, and pellet release guide.

Each pellet is delivered between main roller and sub roller from the pellet receiving guide. The pellet rotates on the rollers until latching with the bezel opening in the main roller. The line sensor camera receives axial direction images and they are laid out while the pellet is rotates on the rollers. The developed image is digitized to a monochrome image and any detected defect is compared against stored criteria. Fig. 2 shows a sample of an original developed image and, after digitized about one pellet circumferential surface, a laser distance sensor reads the end faces surface configuration while the pellet rotates on the rollers. Defects in the end face surfaces are detected by variations in the measuring signal from laser distance sensors. Fig. 2 shows an example of detection of chips on the end faces surface.

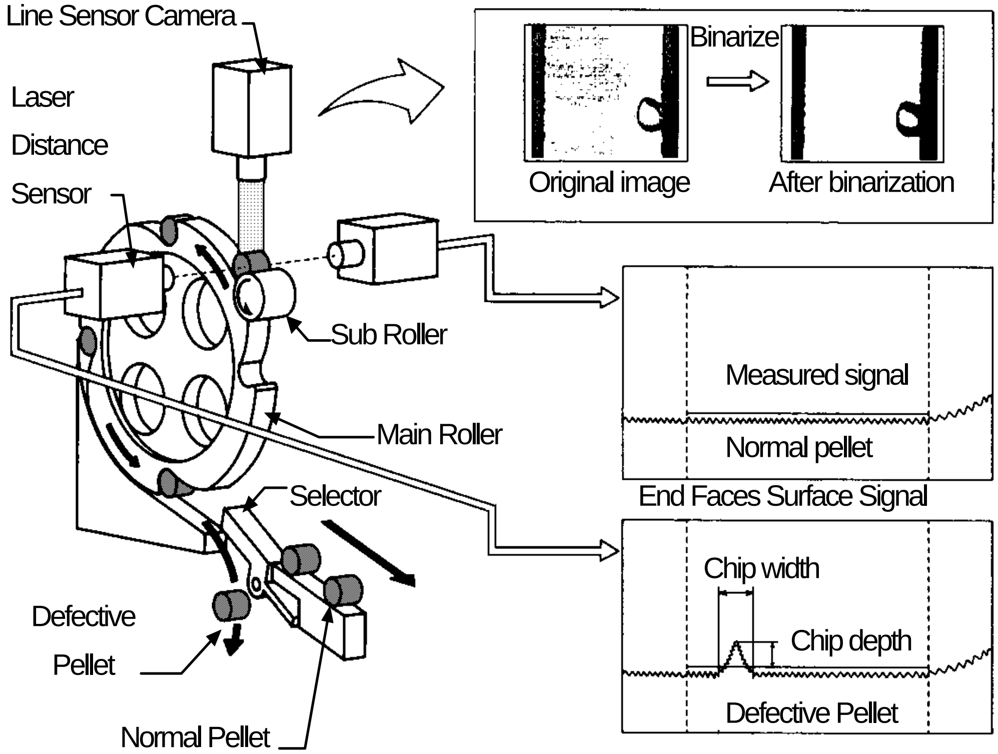

Figure 2 Analyzed Image and Method of Pellet Visual Inspection

If the system detects defect such as chips, cracks and pore on the pellet surface, a selector operates and puts it out of the line. Normal pellets come out via the pellet release guide toward the next process.

2.3 Performance

This system has a high level inspection capacity of 5 pellets per second (18,000 pellets per hour).

MNF has established a fully automatic process system from pellet grinding to arrangement of pellets on a tray including visual inspection.

Another benefit of this system is a major reduction of human exposure.

3. NON-DESTRUCTIVE PLENUM LENGTH AND PELLET GAP MEASUREMENT SYSTEM

3.1 Background and Outline

UO_2 pellets and a pellet-holddown spring are loaded into a zircaloy-tube. Then end plugs are pressed into place at both ends. The end plugs are welded to the tube. Helium gas is pressurized through a vent hole of the top end plug and then the vent hole is seal-welded. Fuel rod has checked by non-destructive inspection method to verify the pellets are located correctly and the plenum length is enough for storing fission product gas. An X-ray fluorescence method is used for this non-destructive measurement in general.

MNF developed an original equipment for this non-destructive inspection for fuel rod by using Eddy Current Test (ECT) technology instead of the X-ray method. This system realizes high resolution, space saving and low cost equipment and shows a good result in cost saving.

3.2 Feature and Method of Inspection

ECT technology finds defects in metallic materials in general. MNF has developed the application of ECT technology for fuel rods by utilizing the difference of electromagnetic induction sensitivity for each part of fuel rod. Table 1 shows the rank of electromagnetic induction sensitivity of each part of the fuel rod.

Table 1 Rank of Electromagnetic Induction Sensibility

Part	Material	Sensitivity Rank	
Tube	Zr-4	S	VS: Very Strong
End plug	Zr-4	S	S: Strong
Holddown spring	SUS 302	VS	M: Medium
Pellet	UO_2	M	W: Weak
Gas	Helium	VW	VW: Very Weak

The configuration of the system for non-destructive plenum length and pellet gap measurement is shown in Fig. 3.

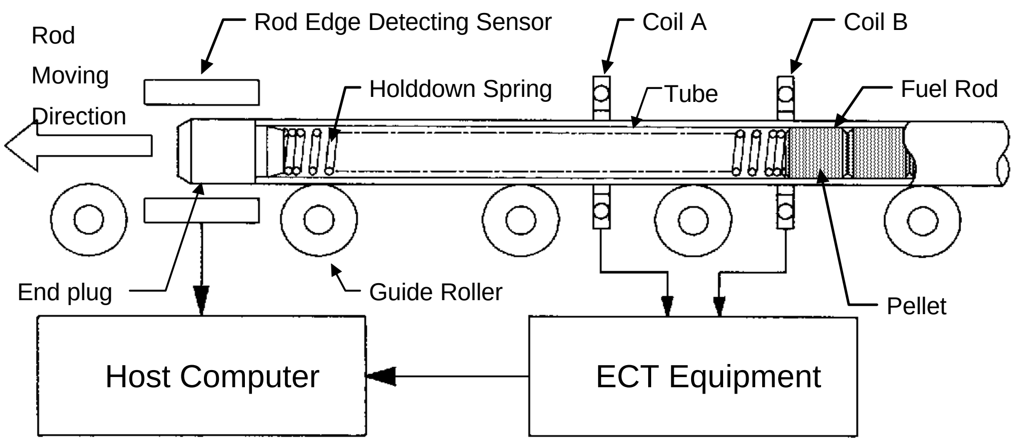

Figure 3 Non-destructive Plenum Length and Pellet Gap Measurement System

The equipment consists of a probe unit and an analysis/decision unit. The probe unit has a rod end location detective sensor and two eddy current detection coils. Coil A detects the boundary position between pellet and plenum, and coil B detects the gap between pellets. The analysis/decision unit consists of an ECT equipment and host computer that stores signals and makes decisions by comparison with design specifications.

Boundary locations are detected by eddy currents generated due to the difference in electromagnetic induction sensitivity between spring and pellet when the boundary between pellet and plenum is passing through coil A. Fig. 4 shows a sample chart of this system.

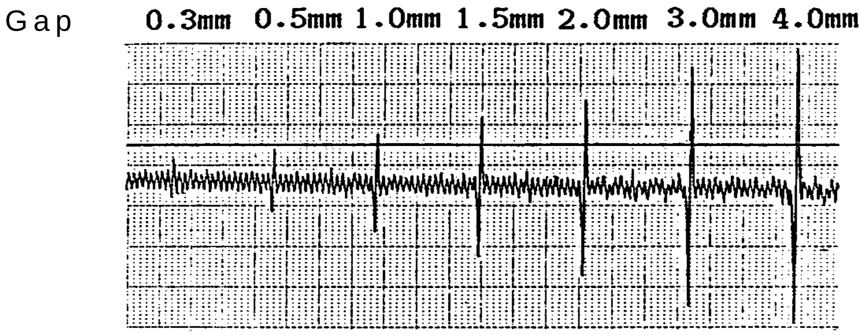

Figure 4 Sample Chart of Plenum Length and Pellet Measurement System

The gap between pellets is measured by eddy currents generated due to the difference in electromagnetic induction sensitivity between pellet and gap (helium gas) when the gap between pellets is passing through coil B. This eddy current signal is proportional to gap length.

The eddy current signals from a gap calibration dummy rod is shown in Fig. 5.

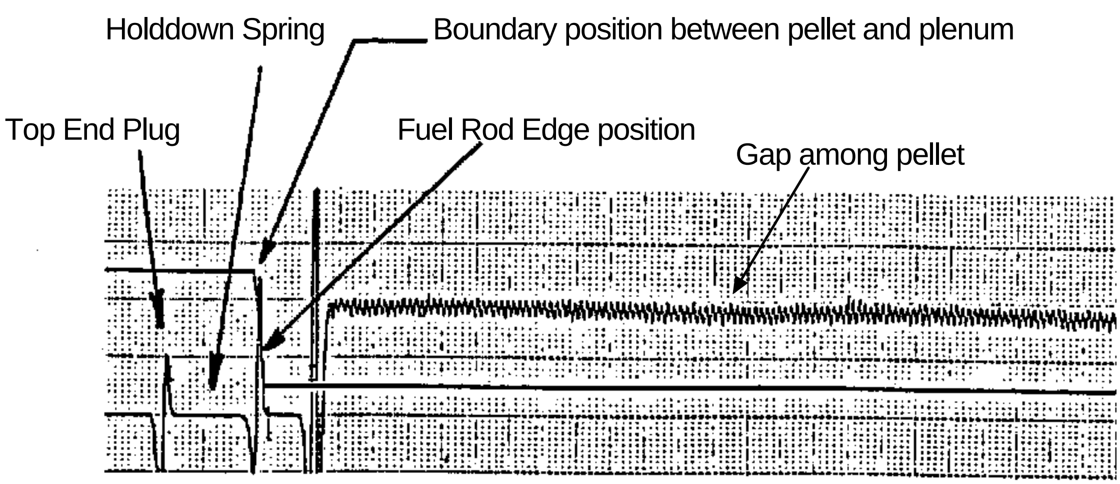

Figure 5 Pellet Gap Calibration Signal Chart

3.3 Performance

Previous X-ray fluoroscopy equipment required a minimum space of about 3 m square to provide protection from X-ray radiation. For the new ECT system, the probe unit is very compact – only 40 cm square - and the total required space, which includes equipment for fuel rod transport, is only 1/10th of that of conventional X-ray fluoroscopy equipment.

The repeatability is 0.01 mm, 10 times better than the X-ray method.

Furthermore the speed of the inspection is 250mm/sec (15 seconds per fuel rod). And this rate is an order of magnitude faster than the X-ray method.

4. MITSUBISHI NEW DESIGNED FUEL ASSEMBLY FABRICATION PROCESS

4.1 Background and Outline

MNF makes three kinds of PWR fuel assembly in Japan, identified by their arrangement of fuel rods as types 1414, 1515, and 1717. There are 179 fuel rods in the 1414 type, 204 fuel rods in the 1515 type, and 264 fuel rods in the 1717 type.

Fuel rods are inserted into grid assemblies that hold fuel rods in a consistent lattice. Then, guide thimble tubes are mechanically joined to the grids and the top and bottom nozzles are attached, completing fuel assembly fabrication.

In the past fuel assembly fabrication procedure, fuel rod are loaded into a skeleton assembly composed of control rod guide thimbles and grids. However scratches were generated on the fuel rods by hard contact with the spring and dimples of the grid during rod loading. The scratches themselves were considered to be no problem for fuel performance, but it required much time to remove chips.

MNF and MHI (Mitsubishi Heavy Industries, Ltd.) which has responsibility for design, cooperated with each other and developed newly designed grid (I-type grid) and a new process for fuel assembly. MNF established a scratch-less fuel rod loading process. We call the new type fuel as MZIP (Mitsubishi Zero-defect I-type grid Progress) [Process ??].

4.2 Feature and Method of Fabrication

Fig. 6 shows the configuration of MZIP fuel assembly and typical I-type grid.

I-type grids are set with spring supports as special tools which give a enough space during fuel rod loading and located to assembly bed. All fuel rods are loaded into grids at the same time. After the spring supports are removed from the grids, guide thimble tubes are loaded into the grids and the top nozzle is located on the sub-assembly. Then bulging tools make bulges for connecting grids, top nozzle and thimble tubes. By this fabrication process, the grid cell has enough space to load fuel rod and no scratches occur during load loading.

Fig. 7 shows equipment for fuel assembly fabrication.

4.3 Performance

This process has produced some advantage such as elimination of process steps and decrease of cycle time for fuel assembly fabrication. Cycle time is further reduced by reduction of visual inspection effort as a result of improved surface condition of fuel rods in the assembly. These reduced cycle times also reduce of human exposure during fuel rod assembly.

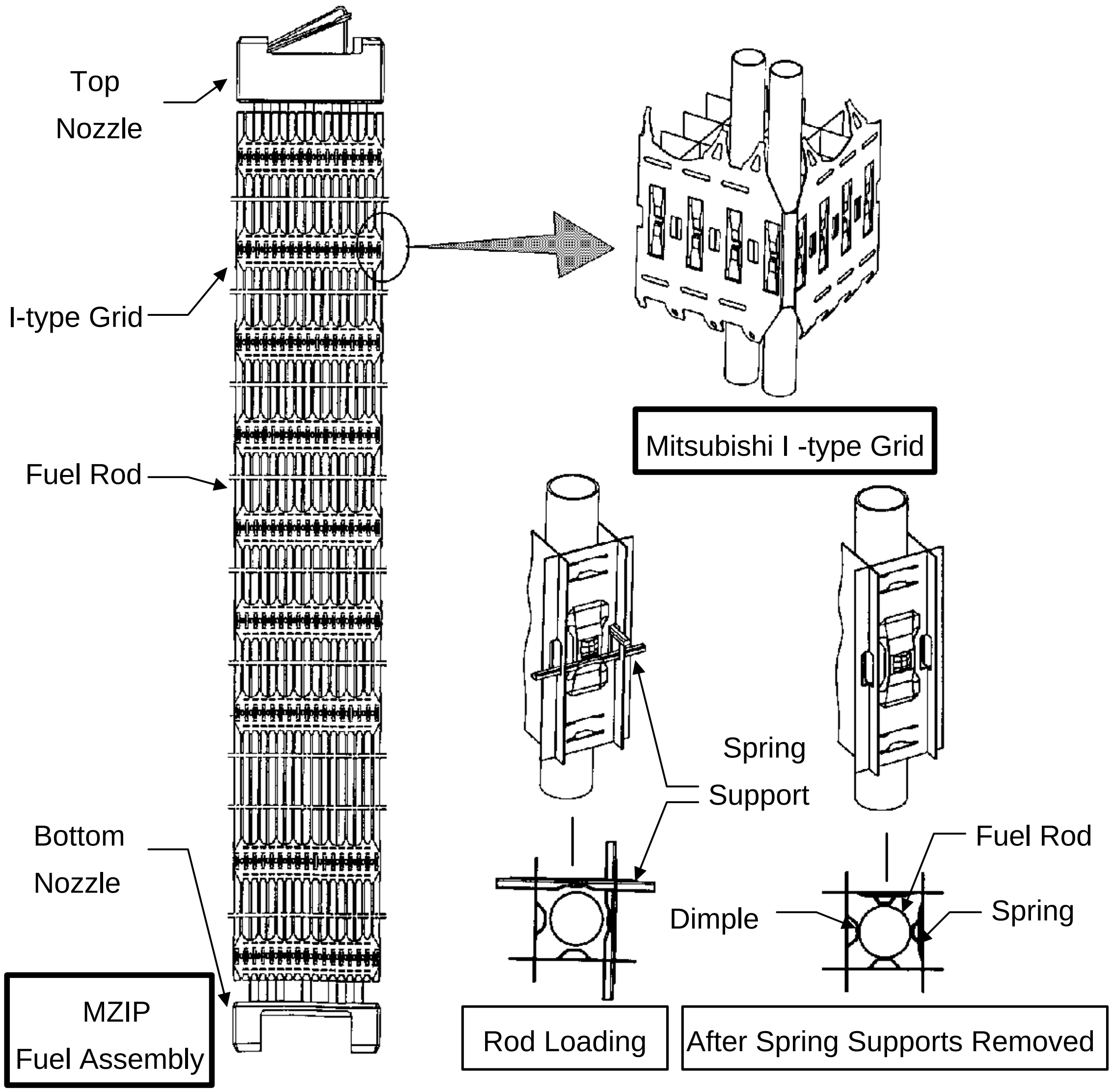

Figure 6 MZIP Fuel Assembly and I-type Grid

Figure 7 Equipment of MZIP Fuel Assembly Fabrication

5. CONCLUSION AND FUTURE

By using high-technology, MNF developed automatic manufacturing systems. These system are effective for labor-saving, improvement inspection reliability and reduction of radiation exposure.

This paper focused on three example of fabrication equipment on mechanical area. MNF also has unique technology on chemical area. In particular, a radioactive liquid waste treatment system using insoluble tannin (trade mark “TANNIX”) is attracting attention in various institutions.

MNF has pushed forward the research and development activities of new technology to keep high quality, high reliable fuel and to improve productivity. And we would like to supply our technology not only to PWR fuel fabrication but also for wide application in other industrial fields.

MNF will supply not only PWR fuel but also custom-order systems which could give customer satisfaction.

6. REFERENCES

1. Yaginuma “Pellet visual inspection” Journal of image applied technology Vol. **9** *No. 3* pp 18-19, 1994
2. Abeta, K. Yoshigai “Non-destructive eddy current test on using nuclear field” NIKKEI MATERIALS 1991, may, 20 P148-153, 1991
3. Abeta, R. Fukuda, K. Kita “Design and performance of Mitsubishi PWR fuel for increased reliability” International Topical Meeting on Light Water Reactor Fuel Performance Portland, Oregon March 1997 pp 309-317, 1997

KEY WORDS

MNF, PWR, nuclear fuel, pellet, visual inspection, image processing, ECT, fuel rod, MZIP.