The Mechatronic System Design Of Ultrasonic Scanner
For Inservice Inspection Of Research Reactor

Khairul Handono, Kristedjo K., M. Awwaluddin and Ihsan Shobary.

Center for Nuclear Facilities Engineering, National Nuclear Energy Agency,
PUSTIPTEK Area, South Tangerang, Indonesia 15310

Abstract. The mechatronic system design of ultrasonic scanner for inservices inspection of Research Reactor has been conducted. The requirement designed must be reliable operated, safety to personnel and equipments, ease of maintenance and operation, protection of equipment mechanically, interchangeability of equipments and addition of the several model of probe immersion ultrasonic transducer. In order to achieve the above goals and obtain the desired results, a mechatronic design based on mechanical and electronic practical experiences will be needed. In this paper consist of the mechanical design and the system mechanical movement using stepper motor control. The criteria and the methods of designs of mechanical and electronic equipments of the system have been discussed and investigated. A mechanical and instrumentation control system drawing and requirement of design will be presented as the outcome of the design. The designed of mechanical system is consequently simulated by solidwork software. The intention of the above research is to create solutions in different ways of inservice inspection of integrity of Reactor.

Keywords : mechatronic, ultrasonic scanner, inservice inspection and research reactor

1. Introduction

Indonesia has operated three research reactors. The first is Triga Mark 2000 kWth which has been operated since January 1965 and located in Bandung, West Java. The second is Kartini Reactor 450 kWth which has been managed since 1979 and the reactor is located in Yogyakarta, Centre of Java. The last and largest one is the Multipurpose Reactor G.A. Siwabessy (RSG-GAS) 30 MWth, located in Serpong, Banten and it has been operated since August 1987. In fact, Reactor GA Siwa Bessy is now 30 years old so there has been a reactor component aging. Due to the aging management becomes an important issue in the operation of old reactors. Nuclear Energy Regulatory Agency as a regulatory body utilization of nuclear energy in 2015 issued Regulation No. 2 Bapeten on Aging Management Systems, Structures and Components (SSCs) for Research Reactors [1].

The Regulation contains the obligation of every owner of non-power nuclear reactors required to publish and implement aging management program or the data of related periodic degradation of the material in the reactor components such as fuel, the reactor tank, cooling pipes, and more. In the internal scope of RSG-GAS operating license will soon expire. As an extension of the operating license requirements, Perka BAPETEN No. 7 in 2015 requires the results of the study of aging research reactors and have to report data component aging RSG-GAS reactor area [1]. At higher regulations contained in the IAEA safety standards for standardization in the management of aging research reactors contained in the IAEA Safety Series No. Standard SSG-10.[2].

To realize the SSCs aging management at the research reactor, construction manipulator ultrasonic scanner system to retrieve the data integrity of the research reactor components should be done. This paper presents the design of an ultrasonic scanner manipulator system in mechatronics (mechanical design and control, and electronics). In the mechanical system
is a manipulator arm, where the sensors, actuators support in the form of stepper motors and mechanical systems support [3].

Mechanical system design requirements of ultrasonic scanners for the research reactor in adjusted to actual conditions and SAR research reactor consists of: ultrasonic manipulator can be used for data retrieval radially and vertically on the walls of the reactor GA Siwabessy [3]. Then, the equipment can be used for sampling data on the reactor core, containment structure. Mechanical materials used have a composition similar to the material that is installed in the reactor GA Siwabessy. Other requirements should be flexible in terms of easy assembly, the enhanced mobility so easily moved out of the reactor and is easy to operate [2,4].

Electronic design and control requirements also refer to the requirements of the SARs and Safety Standard Series includes : the control system must be able to control all the mechanical system components safely. Electronic components must have the reliability to radiation and waterproof and equipment instrumentation and control systems must be calibrated.

2. System Description
A research reactor GA Siwabessy technical specifications is an open-pool type reactor cooled, among others : 5000 mm diameter reactor pool with a depth of 13,750 m. Components inside the reactor, among others : the rack element fuel, spent fuel racks, piping systems, support fuel rack, reinforcing the walls of the reactor. The in-service inspection of SSCs were carried out by using an ultrasonic scanner system. This ultrasonic system is important, because the complexity of the components in the reactor tank, as of the main component inspection need consistent with the requirements and guaranteed to be safe in operation. The design of ultrasonic scanner system as shown in Figure 1.

![Figure 1. Ultrasonic Scanner System](image)

The main component of mechanical system is manipulator arm as shown in Figure 1 the component (3), support structur of stepper motor (1), support structure of ultrasonic sensor
cover and set of gopro camera. The material of manipulator arm is selected. The material requirements of mechanical systems is a first priority because in order to comply with Regulation of Bapeten No. 2 of 2015 on the Establishment List Information Design and also Regulation of the Bapeten No. 1 of 2009 on the Provision System of Physical Protection of Installations and Nuclear Material where in the metal material will be at risk of exposure to radiation [1]. So that the mechanical material will be selected is Aluminum 6061 with high purity. While the use of the SS component is permissible under the requirements of pretty no time limit in accordance with radiation safety regulations [5]. Mechanical ultrasonic scanner system to adjust the physical condition of the reactor pool RSG GAS and its contents, in which components are in such number of pipe is an important consideration. Manufacture of these components to be quite complicated so that the required mechanical simulation using the solidwork software. Ultrasonic sensor is emerson type (no 6) has 30 mm of diameter and ultrasonic scanner is operated upright to the object (SSCs, no 4) in scanning with a maximum distance of 1 inch respectively [6]. Generating ultrasonic waves sent by the ultrasonic pulser (component no.7), then the wave came to be measured using a digital oscilloscope (8), stored by the data acquisition computer system until to obtain the condition of the object being observed. Ultrasonic scanner manipulator arm is driven by a stepper motor controlled by an Arduino control system (component no 5) by using HF driver 28 (component no 2) [7,8].

3. Methodology
The step of mechatronic system design for ultrasonic scanner based on the flow chart is shown in Figure 2.

![Flow chart of ultrasonic scanner system design](image-url)
4. Result And Discussion

Mechatronics system design consists of the design of mechanical systems and electronic systems design. The main design priciples are defined to meet the project objective, including technical feasibility, safety and reability, flexibility, and later-upgrade sustainability [3,9].

4.1. Design Characteristic of Mechanical System

The mechanical system is improvement from conseptual design by using solidwork software design [3]. The evaluation detil degn of mechanic system has been conducted by review base on detil design mechanical system . The design mechanical system of ultrasonic scanner as shown in Figure 3, and the design of mechanical support system shown in figure 4.

Based on the results of solidwork design in Figure 3 that the results of the general system design of the mechanical ultrasonic scanner system as a whole consists of mechanical systems for vertical movement, mechanical systems to move radially and the mechanical system holder ultrasonic sensor. Distance retrieval of data for a process based on the design in Figure 3. Directions Recording such as vertically up and down and radially. A maximum of 15 m with the distance between the point of taking 10 cm and radially is maximum 30° respectively.
Figure 5. Design mechanical roller system of ultrasonic scanner

Stepper motors used for vertical movement of the mechanical system in Figure 5. The ultrasonic holder is a stepper motor, torque load calculated a value of 3 Nm. With the torque load of the specification of at least 2 A. Ampere motor is used to drive the wire sling load 20 Kg. From Figure 5, the fix roller A and B only used for the sliding guide wire slings, roller C is used for rolling wire sling and connected by a motor, this roller will be as a drum with grooves so that the wire sling arrangement would be neat. Roller fasteners D can be positioned towards vertical by 60 mm and is used to adjust the tension wire sling as expected by the operator. Figure 5, E is a stepper motor in accordance with the specifications mentioned above and adjustable speed. For determination of the movement distance at the time of data collection vertically then used a rotary encoder that will be affixed to the roller C and given a display that can be read distance.

Figure 6. Design mechanical support of ultrasonic sensor
From Figure 6. It can be explained that: A is the ultrasonic sensor scanner plate holder made from 6061 aluminum plate 1mm thick with a diameter of 30 mm and a length of 50 mm. Sensor ultrasonic scanner is placed inside the front of the sensor surface, then fastened using the screws M4 x 1 mm material SS 316L. B is retaining motion sensor holder made of teflon material and serves as an anchoring plate holder movement sensor holder ultrasonic scanner at the time of data collection and avoid reinforcing walls of the reactor. C is the sensor holder players with a diameter of 10 mm and made of 316L SS which serves as a swivel motion of ultrasonic sensor mounting plate scanner. D is the foundation as well as sliding into a column made of aluminum profile series 6061 and functions as the foundation of vertical motion in the column. From Figure 7, the ultrasonic sensor scanner plate holder made from 6061 series aluminum with a size of 20 x 20 mm and serves as the foundation of the plate holder and the sensor can be moved radially 90°.

From Figure 8 can be explained that the mechanical system holder ultrasonic sensor scanner can be moved vertically up and down using a sling wire diameter of 2 mm made of SS 316L.
and is connected with the stepper motor. The follow of movements in the groove or profile contained in the column.

From Figure 9 can be explained that the movement of the mechanical system (mechanical systems and base column ultrasonic sensor scanner) using a radial direction with sliding movement system using hollow SS 316L 40 x 80 x 1.2 mm. Radial movement can be done as far as 22.50 considering the room space and the number of components in the reactor pool. The mechanical system movements toward radial will be installed on the top surface of the outer side of the pool reactor utilizing the existing screw holes on the surface. The position can move following circle movement in reactor wall [10].

4.2. Design Characteristic of Electronic and Control System

Design of computerized control system and data acquisition system in the format of block diagram shown in Figure 10.

From figure 10, the object of scanning SSCs (1) is wall of reactor pool, primary pipe, and reactor core. The ultrasonic sensor (2) is immersion type. Typical frequency up to 25 MHZ for routine applications, [6,7,11,12]. The ultrasonic wave generator is from subsystem no (3) also as function of ultrasonic pulser receiver system direct send to digital oscilloscope (4). The data ultrasonic scanner from oscilloscope to save using data acquisition computer system
(8). The ultrasonic sensor and gopro camera (2) movement by stepper motor (5). The characteristic of motor stepper is shown in Table 1.

### Table 1. The Stepper motor characteristic

| Switch No. | Resolution | Step Angle |
|------------|------------|------------|
| 0          | 1          | 0.72°      |
| 1          | 2          | 0.36 °     |
| 2          | 4          | 0.18 °     |
| 3          | 5          | 0.144 °    |
| 4          | 8          | 0.09 °     |
| 5          | 10         | 0.072 °    |
| 6          | 16         | 0.045 °    |
| 7          | 20         | 0.036 °    |
| 8          | 25         | 0.0288 °   |
| 9          | 40         | 0.018 °    |
| A          | 50         | 0.0144 °   |
| B          | 80         | 0.009 °    |
| C          | 100        | 0.0072 °   |
| D          | 125        | 0.00576 °  |
| E          | 200        | 0.0036 °   |
| F          | 250        | 0.0288 °   |

From Table 1 shown that switch number from 0 to F is hexadecimal is the characteristic of digital switch of stepper motor. Select the step angle (motor rotation angle) per 1 pulse. The set step angle is dividing basic step angle of stepper motor by setting value. The calculation formula of step angle is basic step angle divided by resolution. The resolution of motor from 1 to maximum resolution 250 produce the step angle from 0.72 ° until smallest step 0.0288 ° respectively. The switch number connecting and conversion and coding using encoding stepper motor to transmit and received using driver and control by Arduino controller (7). The characteristic of motor torque and driver is shown in Figure 11.
From figure 11, the optimum torque of stepper motor using driver MD5-HF 28.
Human Machine Interface (HMI) of ultrasonic scanner design is shown in Figure 12

From Figure 12 shown that for monitor ultrasonic sensor by using gopro camera, result of this monitor is shown from few camera (1) and to monitor ultrasonic signal from ultrasonic scanning (2), t is the thickness of SSCs material testing. All of the data to save using the data acquisition computer system by using Labview.

5. Conclusion
The mechatronic system design of ultrasonic scanner for inservices inspection of Research Reactor has been conducted. The criteria and the methods of designs of mechanical and electronic equipments of the system have been discussed and investigated. A mechanical and
instrumentation control system drawing and requirement of design has been presented as the outcome of the design. The designed of mechanical system is drawing by solidwork software. The electronic and control system adjust to the design of mechanical systems. The mechanical system components can be controlled by electronic system. Electronically using computerized data acquisition system, a data of ultrasonic scanner can be loaded.

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7. Reference

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