Research and Application of Radiation Resistant Robot for Nuclear Reactor

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Abstract. With the development of national economy, science and technology, called upon by “generation” in the country, a great development of nuclear power, along with more and more into business shipments, overhaul units, nissan production, maintenance, testing of the necessity of using radiation resistant robot is more and more high, can largely improve the work efficiency, and reduce plant site staff received doses of radiation. Now, the plant's daily maintenance, test failure of operation and the development of robot technology has become a hot spot, robot technology has been popular in the nuclear power plant work. Plant work itself has complex structure, the characteristics of the running process cumbersome, moreover because of the particularity of their work, the plant will produce large amounts of radiation, in the process of work brings to the staff's life and health threats. The robot technology into the plant maintenance, strong radiation detection, treatment of waste, from a certain extent can improve the work efficiency, reduce work error cost savings, reduce the man-made accidents caused due to special reasons, to ensure the safety of employees. Developed in recent years the industry has been the research focus on job skills, complete functions, advanced technology, higher strength of the robot. In recent years, our country established on plant long-term development planning, the development of nuclear power plant in the cultivating place. The robot developed can meet the demand of nuclear power plant work has become the common wish of the nuclear industry's hope. This article mainly from the development history of nuclear power station robot technology, and then analysis the current plant robot technology development present situation and the development of the future.

The Current Plant Development Course of the Robot

Robot Research Comparing Foreign and Domestic Nuclear Power Plants

Influenced by the development of science and technology, foreign plant robot technology than domestic started early, development is relatively mature, some high technical level of the developed countries in the 20th century began to "in the work of" robot technology is applied to plant research, and achieved good results, to produce various types of model robot. The level of economic and technological development faster than other countries, developed a remote machine at radiation processing, effectively reduce the staff rate by radiation. After that, the United States and developed a series of robot into the nuclear power plant work. In the late 20th century, Japan developed the world's first independently walking robot, and the inspection should be used in nuclear power plants work link. With the progress of science and technology, robots become more high-end, intelligent, automation. Today, in some European and American countries the progress of robotics has realized the leap. These robots have higher automation level, the function is more complete, is able to adapt to the intense radiation environment.

Scientific and technological level of our country development relatively late start, on the implement technology in nuclear power plant machine box, also need to import some of the key equipment parts. Before hadn't been attached great importance to nuclear power plant development in our country, the development of small, small market, backward technology research and development level. Low level of robotics research about nuclear power plants in China, the results is not obvious. Work in the earlier developed mobile robots and robot in the wall, but are not widely into use. I countries to realize the importance of nuclear power plant in recent years, accelerated the development of nuclear power plant, some of the nuclear industry the company a large number of imports of foreign robot equipment. The price of these devices is high. Robot equipment can be
imported, but the core of the robot technology or in the exporter, lead to later period maintenance
difficult, high cost. With nuclear power plant in promotion within the territory of China, the
growing demand for nuclear power station robot, at present our country has been committed to
invest a lot of manpower material resources plant research and development work of the robot.

The Plant Robot Application Status

The growth process of plant robot witnessed the growth of science and technology. From the plant
since the robot was born, from the earliest state of remote control robot, and now the modern
sensing technology, remote control technology, electronic technology, intelligent technology into
the research of the robot, the plant robot development level has risen to a new height. It owns
advanced technology driven structure, this kind of structure to fulfill the task for robot to normal in
a special environment to provide security, machine can people to overcome the present difficulties,
remove obstacles. From a certain extent, affects the robot's driving structure flexibility, efficiency
and realize the road conditions, the ability to overcome obstacles and so on. The plant robot has a
strong resistance to radiation. Plant robot must have ability to finish the work properly under the
disturbance intensity. The current robot radiation technology joined the camera radiation technology.
Cameras, strong ability to resist radiation of radiation technology, our country in this study has
preliminarily reached the foreign advanced technology level. In addition, the plant layout structure
is more complex, all of the operational space is relatively small, in order to improve the completion
of tasks of robot, reduce the error of the robot work, need to use remote monitoring, on the robot's
forward state, work completion status for remote monitoring.

Plant Robot Application Research Analysis

Plant robot work done is not in the provisions of the production line position has scheduled task, but
to work to accomplish the position uncertainty, various changes. Plant robot is mainly used for
radioactive inaccessible environment field, can be in its nuclear facilities equipment inspection,
maintenance and accident treatment, etc. Plant inspection mainly include inspection during normal
operation of the plant and the detection of high radiation environment after the accident site, as well
as the important equipment during refueling overhaul nondestructive testing, etc. For small range of
radioactive area, need to develop rail type inspection robot, instead of inspection.

In the operation of the personnel in the radiation area of inaccessible equipment for inspection.
Robot configuration irradiation camera and temperature resistance and radiation detection
instrument, automatic or on a regular basis by the staff in the control room remote operation,
through the image processing and checking equipment is normal temperature analysis and judgment.
For larger range and uncertain area, need to develop the ground mobile robot, mobile way for
crawler or four foot type. During the refueling outage need to defect inspection of equipment, to
ensure that equipment is in good condition, need a variety of nondestructive inspection robot. For
example, the reactor pressure vessel inspection need automatic ultrasonic inspection robot, the robot
is mainly on the inner wall of the pressure vessel and nozzle weld ultrasonic and video inspection,
has the waterproof, prevent wheel.

Ability to work, water resistance, and can work under water for a long time. The equipment
adopts the special ultrasonic acquisition system for automatic NDT of multi-channel ultrasonic
detection and data collection. Other nondestructive inspection robot include stabilizer CCTV video
inspection robot, steam generator main line to take over the safety of radiographic inspection robot,
steam generator the pipe eddy current inspection crawling robot, pipe weld ultrasonic inspection
robot, etc. Nuclear power plant maintenance is different the maintenance of the conventional power
plant or other industrial sectors, it is not only huge scale, the equipment complex, and is very
important in nuclear safety and protect the public health. So plant maintenance needs robots replace
maintenance personnel working in some highly radioactive environment, such as fuel pool
underwater inspection, underwater clear foreign body, reactor control rod drive mechanism of weld
defect repair and reactor coolant piping online repair, etc. For the above several aspects, this paper
discusses the application of the robot, specific.
The Fuel Tank Repair Underwater

Nuclear fuel plant made up of stainless steel cladding surface welding pool, the steel cladding surface at the beginning of the construction of the need for liquid penetrant inspection and vacuum after inspection, to ensure the integrity of the structure to be put into use. But in the power station running after a period of time, due to the corrosion phenomena may produce damage to steel cladding panels, so must regularly to test the pool steel cladding surface, if the corrosion is serious, must be carried out on the corrosion surface repair. At the same time accidentally falling object may also breakdown stainless steel, stainless steel cladding surface caused by leakage, need emergency repair. At home and abroad is carried out by trained divers wearing protective clothing on detection and underwater welding. For the personnel safety, because of the large irradiation dose, the operator can't work long hours, because the space is narrow, the region at the same time equipment, workers take extra care when operating, may cut protective clothing, never so little, he must pay attention to body surface and inhalation injury to the personnel, and because some homework very narrow space, in which workers restricted movement. So, the plant is an urgent need to use the corresponding special work in the harsh environment of underwater robot.

Foreign Body Cleaning Underwater

Plant radioactive pools with larger area and there is no reliable measures to prevent foreign body, due to the participation of staff during overhaul, often many kinds cross homework, therefore, foreign bodies fall into the pool the events have taken place. Especially if foreign bodies fall into the narrow environment or at the bottom of the reactor core, ordinary foreign fishing tool often helpless, usually need to hang out of the reactor core components for a thorough check and foreign fishing, this kind of situation will lead to overhaul the critical path delay and great economic losses, and the core of large hoisting often face some unknown risks, improper operation, the maintenance personnel great irradiation damage within the plant. Therefore, nuclear power plants is necessary to develop some more degrees of freedom robot and intelligent system used in reactor core and precise salvage components such as underwater pool environment.

Reactor Control Rod Drive Mechanism of Weld Defect Repair

During the running of nuclear power plant, the reactor control rod drive mechanism due to the operation condition is bad, and the high temperature and high pressure, high radiation, vibration, impact, control rod drive mechanism, in the next three seal weld possible defects such as cracks, leading to a seal leakage. External experience feedback shows that the control rod drive mechanism of seal weld spill in nuclear power plant in a foreign country, once appear this kind of failure, must carry out defects of emergency treatment. The control rod drive mechanism in distribution in the reactor, the upper lid, near the weld environmental radiation is stronger, three position is quite strict, seal weld repair operation space is narrow, and the seal weld welding quality requirement is high, the running accuracy and stability of the welding equipment, welding process requirement is very strict, by artificial maintenance can not be achieved. Against defects in the current international emergency response plan is: the replacement of the defective control rod drive mechanism or to automatic welding repair of defective parts.

No matter what technology application, you need to use special semi-automatic grinding, cutting and welding robot. At present, this technology is a few large companies abroad to master, such problems in our country mostly rely on foreign firms with the power plant equipment and technical personnel for emergency repair, the implementation of the high cost, and tend to overhaul the critical path delay time, a mega kilowatt nuclear power unit, if the critical path of delay one day time will be about 10 million of power loss, therefore, the core equipment once the defect and fault if not handled in time will cause great economic losses to plant owner.

Reactor coolant piping online repair

Reactor coolant piping is one part of the road boundary, containing radioactive material role. These pipes which connect with the pressure vessel in long-term under high temperature and high pressure
fluid, after years of running, because wear and stress corrosion, cause local thinning of the pipe or potential defects. Without timely detection and repair, can cause great economic losses in power plants. The general approach is to replace the pipe or repair welding for defect pipe processing, but due to the complexity of piping layout channel is narrow, the working space is little, so the maintenance period is longer, artificial service reliability is poorer. Therefore, we need to develop a small automatic welding robot, can better handle pressure vessel connected pipeline emergency repair online processing.

Fuel Accident Treatment Robot Technology

Or in the process of the spent fuel disposition of nuclear power plant operation, occasionally fuel components of abnormal deformation or jamming accident, usually in dealing with such high radioactive fuel related equipment in the process, often take conservative scheme is applied underwater cutting robot for fuel unsmooth place underwater cutting processing, fuel release accidents external force, to achieve the safety accident treatment a state. In addition, due to the nuclear fuel components radioactive dose is higher, once the fuel related failure accidents, processing is very difficult, will be faced with the double pressure of nuclear safety and economy, as a result, conditions for these accidents preventive emergency preparedness, tracking the domestic and foreign experience feedback, for the possible fault phenomenon the robot equipment related to adaptive development in has important practical significance.

Core Important Equipment Emergency Repair

Nuclear power plant in the process of running core important equipment local defects may also occur, if not timely detection and the defects of the equipment, will cause harm to the safety of the reactor. Once a major nuclear power plant reactor core important equipment defects, emergency treatment, usually because of core equipment, processing technology and the implementation plan in need of urgent security and feasibility to implement is fully demonstrated. Technology in our country at present, this aspect is still at the stage technology tracking, basically mastered by the United States, France and other western developed countries, it is necessary to apply robotics for emergency maintenance of important equipment in the reactor core technology research and implementation of preventive solution preparation, for the safe operation of the nuclear power units continue provide strong technical support.

Under the Severe Accident of Disaster Relief Work

A serious nuclear power plant accident such as core melt super design basis accident, 1987 and 2011, the Chernobyl nuclear accident and Japan's Fukushima nuclear plant accident were serious accidents. Such accidents urgently need the following three types of robot under the severe accident of disaster relief. The first is strong radiation environment detecting robot, such as after a nuclear accident for detecting ground creeping robot environment, low rotor robot, this kind of robot to pick up a variety of sensors, can quickly and accurately measure the radiation dose rate of nuclear accident environment, temperature, pressure, oxygen concentration, the concentration of harmful gases, and other key parameters, to provide evidence for accident treatment countermeasures and measures. The second category is the emergency channel barricades clearing robot, this kind of robot usually has strong ability of driving, a complete at the end of the actuator and the target recognition automatically. After a nuclear accident roadblocks to clear the robot except must have common roadblocks to clear the characteristics of the robot, must also possess some unique features, such as including high radiation pollution removal technology, high radiation environmental enforcement agencies at the end of the control technology and structure optimization, high load carrying technology, etc. This kind of robot can independently to clear of clutter on the emergency channel, in order to convenient for emergency personnel or other service robots to provide emergency channel. The third class is serious robot, the scene of the accident emergency operation and maintenance for different state of nuclear accident and damage condition of equipment, required function and structure of different site emergency operation and maintenance robot, sort is various, this kind of robot will do some certain tasks, at the same time have some common features,
including high radiation environment drive mechanism and the actuator adaptation technology, complex ring.

Condition of the actuator at the end of the search path planning technology, precise positioning technology, underwater bionic technology, underwater noise sealing technology, real-time video transmission technology, radiation pollution prevention technique of robot and the adaptability of narrow space, etc.

**Conclusion**

I plant technology started late, belong to just stepped into the development track of the time, the development is not mature enough. Robot technology involves a variety of areas, with the needs of the development of the industry, our country the study of plant robot degree increase. Believe that soon the robot technology will be more widely used in nuclear power plant.

**References**
