Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 29-30, 2014

Survey on Dismantling Technologies of Nuclear Power Plants

Poong Eil Juhn[a*], Kune Y. Suh[b]
[a]*Korea Atomic Energy Enterprise Association*
[b]*Seoul National University, 1 Gwanak Ro, Gwanak Gu, Seoul 151-744, Korea*
[*]Corresponding author: *jpe117k@naver.com*

1. Introduction

The Government of Korea announced in November 2012 to develop 21 key technologies to be applied for decommissioning of nuclear power plants (NPPs) in 10 years with a funding of USD 150 M. The dismantling technologies instrumental in decommissioning, but yet to be locally developed, are surveyed in this paper based on the experiences in Europe, USA and Japan.

2. Classification of Dismantling Technologies

In view of wide ranges of decommissioning projects or tasks, numerous dismantling technologies have been applied in Europe, USA and Japan. The dismantling technologies for sheet-metal manufacturing activities have occasionally been adapted for decommissioning of NPPs.

Due to possibility of radiation exposure associated with decommissioning of NPPs like remote-controlled application, high process safety and efficiency, and underwater applicability, only a handful of dismantling technologies can be used in the radiation controlled area.

Dismantling is defined as the removal of equipment or structures typically to allow for the completing of the decommissioning process by use of any of or some combination of thermal, mechanical or electrical cutting and removal methods [1].

Electrochemical cutting technologies and electrical discharge machining are used for specific dismantling tasks. Explosive cutting was used in Germany and USA for the dismantling of activated concrete structures and biological shields.

Arc saw cutting with a rotating disc was developed in USA and used for dismantling of JPDR in Japan. Consumable electrode water jet cutting has been used for dismantling of pressure vessel and steam dryer housing.

3. Thermal Cutting Technologies

3.1 Oxy-fuel Cutting

Oxy-fuel cutting is restricted to mechanized, semi-remote as well as hand-guided dismantling of mild steel or stainless steel plated structures up to thickness of 250 mm. By adding metallic powder the oxy-fuel cutting can cut stainless steel plates, up to 320 mm and concrete structures, up to 1,200 mm, respectively. A major drawback has to do with the bulky amount of aerosols produced during the process.

Collective processes such as combination of oxy-fuel and plasma arc cuttings have recently been developed [2]. R&D currently crack down on the high pressure oxy-fuel cutting and mechanized underwater oxy-fuel cutting, especially for cutting stainless steel plated mild steel structures.

3.2 Plasma Arc Cutting

During decommissioning, plasma arc cutting is the most commonly used thermal cutting technologies for activated components and particularly reactor internals. The main benefit is that the cutting speed is relatively high over a wide range of plate thickness, particularly for cutting the stainless steel plate, applicable up to 150 mm and 100 mm respectively in atmosphere and under water.

Several plasma arc technologies, based on such principles as water injection plasma arc, dual flow plasma arc and contact ignition, have been developed for the dismantling of the highly activated reactor core components [3].

3.3 Laser Beam Cutting

Laser beam cutting is characterized by small cutting kerfs and precise cutting contours, small heat affected zones, small tolerances, a little distortion of the work piece, stress free treatment, and high reproducibility. Laser beam cutting can be used in special areas of dismantling NPPs.

For example, when dismantling tanks or storage basins consisting of concrete walls lined with steel plates, cutting of the steel plate is complicated. The metal sheets lie directly on the concrete and it is fairly tricky to cut them mechanically. Due to the mobility and flexibility, fiber optical hand guided YAG laser is most commonly exercised in dismantling NPPs in Europe and USA [4].

3.4 Contact Arc Metal Cutting, Drilling and Grinding

Contact arc metal cutting, drilling and grinding are electro-thermal cutting technologies that cut conductive materials with Joule and arc heating. Contact arc metal cutting with a sword like graphite electrode and a water curtain for blowing out the molten material is currently used for dismantling NPPs in Europe and USA [5]. By using this technology, such components of complicated systems as tube-in-tube work pieces and components with re-entrant angles can be separated with a single cut. It can cut up to 260 mm thick components.

A special contact arc metal cutting, drilling and grinding tool with a turntable driving unit shown in Fig. 1 has been developed in Germany. It can cut work pieces of 15 mm thickness at 3 m/min [2]. The material for the cutting electrode can be steel or carbon fiber reinforced graphite. The cutting thickness is up to 50 mm.

R&D in Europe and USA are aimed at reducing the electrode wear and increasing the maximum cutting thickness for contact arc metal grinding as well as at comparing the processes of abrasive water jet cutting and contact arc metal cutting.

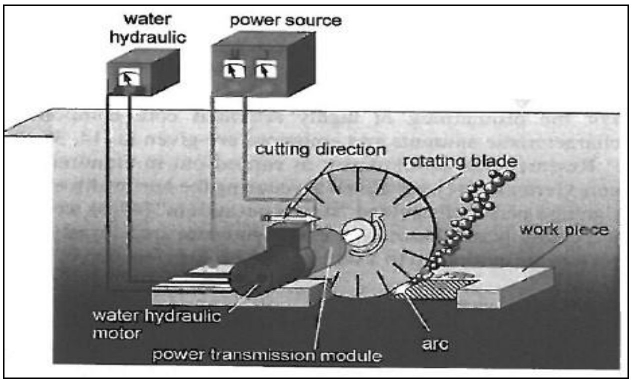

Fig 1: Contact arc metal cutting, drilling and grinding tool

4. Mechanical Cutting Technologies

Mechanical cutting techniques with geometrically defined tool angles, such as sawing and milling, are characterized by collectable residues, high reaction forces, and low cutting speeds. Mechanical cutting technologies with geometrically undefined tool angles, such as grinding and diamond-wire sawing, are characterized by process products consisting of small grained dust in atmosphere or slurry when used under water.

4.1 Grinding

The grinding units are electrically, hydraulically or pneumatically powered discs, apt for the cutting of all types of materials. They may be used in atmosphere as well as underwater.

The maximum cutting thickness for metallic components is limited to 150 mm. Mobile grinders are not suitable for cutting stainless or mild steel thicker than 30 mm. Grinders can be operated remotely using a video equipment.

4.2 Sawing

Sawing is cutting with a multi-teeth tool of small kerfs width. Sawing can be used in atmosphere and underwater. Fret saws are mainly used without coolants and lubricants for cutting depths up to 100 mm. Bow saws are suitable for thin walled components with up to 1 m cutting length. The band saw is used for cutting of large components of up to 3 m, while the circular saw is cutting depths of up to 200 mm for metal and 500 mm for concrete structures. Fig. 2 shows the band saw and the circular saw, which was used for dismantling of BR-3 pressurized water reactor plant in Belgium [3]. Cutting with hack saws is limited to 100 mm because of an undue increase of the cutting time. Diamond wire saws have been used for thick concrete and reinforced concrete structures of up to 1,000 mm and for metal structures of up to 300 mm.

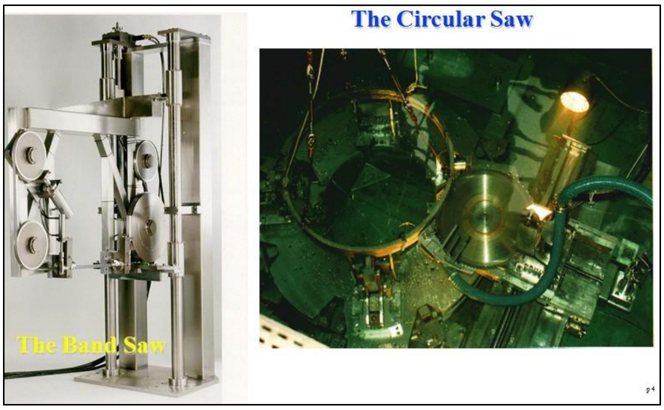

Fig 2: Band saw and circular saw

4.3 Shearing

Shearing is used for cutting metals in the form of sheet steel, pipes, bars, and concrete reinforcement. Shearing processes can be divided into lever shearing, circular shearing, parallel shearing, and nibbling used for plate thicknesses up to 30 mm and cutting lengths of up to 4 m.

5. Hydraulic Cutting Technologies

Hydraulic cutting by abrasive water injection jets was applied for the first time for cutting of biological shield of the JPDR in Japan. Now this technique is commonly used in Europe and USA. At a maximum water pressure of 200 MPa, plate thicknesses of up to 130 mm have been cut.

The advantages of abrasive water jet cutting include the small amount of aerosol, a wide range of plate thickness cut, easy remote handling and low reaction forces [2].

Abrasive water injection jet cutting in atmosphere is used for dismantling the dome of the reactor pressure vessel of the NPPs in Germany.

6. Dismantling of Large Components

Dismantling of large components, such as steam generators and pumps, thermal and mechanical cutting technologies are commonly used in Europe and USA to avoid cross-contamination and to transfer maximal parts to unrestricted reuse by making use of simple decontamination technologies including sand blasting.

When a steam generator was dismantled at MZFR in Germany, as shown in Fig. 3, the jacket was removed first by remote manipulators and then decontamination was carried out by shot blasting. Only the tube bundle had to be dismantled into handy pieces. They were then disposed of as radioactive waste following the high pressure compaction. The jacket was decontaminated for later unrestricted reuse.

Another example of dismantling NPPs in Germany showed that the steam generator was first frozen to fix the tube bundle, while it was cut with a band sawing. The melting ice water was used for cooling the saw blade. Upon the thawing of the cut steam generator discs, the tubes were removed with a boom gripper and subjected to high pressure compaction [2].

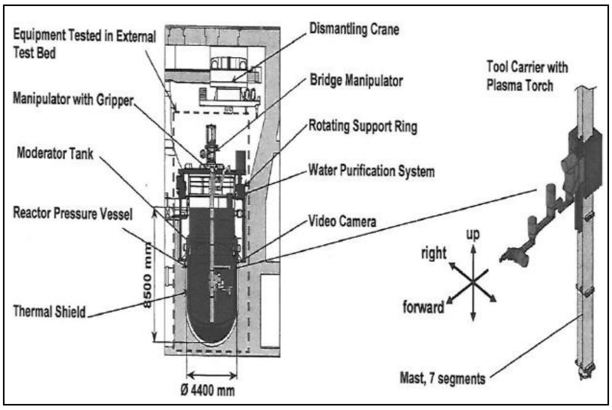

Fig 3: MZFR underwater dismantling in Germany

7. Dismantling of Reactor Core Internals

The activated core internals are dismantled using hydraulic shears, hack saws, milling devices, and plasma arc cutting, handled remotely by manipulators in a shielded cell. The internals are subject to segmentation and high pressure compaction for volume reduction. The advantage of such a cell is that radiation exposure of the workers is minimized and total costs are reduced significantly, as outsourcing segmentation, conditioning and packaging is cheaper than working in the NPPs to be dismantled.

8. Dismantling of Concrete Structures

A major part of dismantling of NPPs is the crushing of concrete structures, which may be contaminated. These structures are equipped with metal linings and/or ducts that aggravate processing. Following the rough dismantling of the concrete walls on site, it is recommended to condition the parts with a view on minimizing the radioactive waste volume.

The metal liners are usually removed from concrete blocks and decontaminated by means of an abrasive dry blasting process. More contaminated parts of a concrete block are cut off by rope sawing and put directly into a steel container. Rope sawing including diamond wire is an efficient dismantling process as it produces smooth cutting surfaces facilitating the surface measurements, as shown in Fig. 4 [3].

Fig 4: Diamond wire cutting of concrete block in USA

Due to water cooling, this process is dust free and no contamination occurs during dismantling. The sawing sludge generated may be dried and compacted at high pressure. For extracting concrete blocks from the NPPs to be dismantled, dry rope sawing with a suction system for removal of chips has turned out to be suitable.

REFERENCES

[1] International Atomic Energy Agency, Status of the decommissioning of nuclear facilities around the world, 2004.
[2] W. Bach, G. Hammer et al, Decommissioning techniques and special features of the dismantling of nuclear research and prototype facilities, Kerntechnik 70, pp. 31- 40, 2005.
[3] L. Boing, Dismantling technologies, Argonne National Laboratory (PPT material), 2013.
[4] International Atomic Energy Agency, Innovative and adaptive technologies in decommissioning of nuclear facilities, IAEA-TECDOC-1602, 2008.
[5] International Atomic Energy Agency, Redevelopment of nuclear facilities after decommissioning, Technical report series No.444, 2006.