Laser Size Reduction of Contaminated Magnox Pond Skips – 15166

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ABSTRACT

The Magnox Pond Program Team at Hinkley Point A Power Station have successfully demonstrated the use of an automated Computer Numeric Controlled (CNC) dry milling process to efficiently decontaminate radioactive pond skips that were once used to store and transport Magnox spent fuel assemblies between reactor sites and Sellafield for reprocessing. This decontamination process has ensured ILW skips meet metal melt recycling criteria, and even Out of Scope levels, while at the same time producing dry swarf that is easily disposed of as ILW. However, the dry milling method requires the skips to be size reduced to a very simple flat geometry to simplify the milling operation. Several size reduction techniques (mechanical and thermal) have been evaluated. Based on the advantages of remote handling, high cutting speed, flexibility with complex geometries, reduced secondary waste production and significantly reduced worker exposure, robotically operated fibre delivered laser cutting was chosen. This paper describes the development, installation and operation of an automated laser cutting system commissioned at Hinkley Point A to size reduce contaminated skips in to five flat sections. It was demonstrated that a complete skip can be remotely size reduced in less than 60 minutes. This successful demonstration, coupled with CNC milling, has the potential to save an estimated £30 million across the Magnox sites alone, with much higher saving potentials for skips stored at Sellafield, enabling this new size reduction process to meet cost reduction objectives of the UK's Nuclear Decommissioning Authority

INTRODUCTION

First Generation Magnox Storage Pond skips (FGMPS) have been the workhorse for storing and moving spend nuclear fuel from the 10 Magnox sites to Sellafield site for reprocessing. The skips are coated with an epoxy based paint (system 6 or a stove enamel material with the trade name of Calvanac), and are of welded construction with reinforced sections and flanges, fabricated using 6mm thickness C-Mn steel in various configurations, weighing between 400 to 450kg each, Figure 1.

Figure 1 Magnox pond skips. Sketch of a Magnox pond skip (left), stored skips in Magnox plant (right)

Over the years Magnox have processed thousands of skips at several sites using various decontamination methods to reduce skips from Intermediate Level Waste >12 GBq/te Beta Gamma and >4 GBq/te Alpha (ILW) to Low Level Waste (LLW) disposal limits. The decontamination methods used were effective in reducing the population of skips from ILW to LLW, however, all of these methods generated significant amount of secondary ILW waste streams, e.g. concentrated ILW acid solutions, wet ILW waste streams of paint, metal oxides and sludge from Ultra High Pressure (UHP) water jetting. Because of the aforementioned reasons the baseline method for treatment and disposal of ILW skips was to manually size reduce them and place them into Ductile Cast Iron Containers for storage and ultimately disposal. This approach proved to be costly as underwater characterization revealed a much larger percentage of the remaining Magnox skip population would be ILW. It also introduces the issue of double handling where an approach to process the skips to final disposal would be more beneficial from both an ALARP and a cost perspective.

All of the standard Magnox skips have been moved between Sellafield and the 10 Magnox sites for decades and now that the Magnox sites are being decommissioned and the reactors are being defueled. There are now thousands of redundant fuel cooling skips remaining that needs to be processed for disposal and to free up space within the Fuel Handling Plant at Sellafield site. Therefore, this is a UK‘s Nuclear Decommissioning Authority (NDA) priority project in support of the goals to provide management options for processing the large remaining redundant skip population.

This has driven the program to seek new size reduction and decontamination methods. The Magnox Pond Program Team at Hinkley Point A (HPA) Power Station have successfully demonstrated the use of an automated Computer Numeric Controlled (CNC) dry milling process to efficiently decontaminate radioactive pond skips [1]. This decontamination process has ensured ILW skips can meet LLW metal melt recycling criteria, and even Out of Scope levels, while at the same time producing a dry swarf that is easily disposed of as ILW. However, this cost effective and efficient dry milling method requires the skips to be size reduced to a very simple flat geometry to simplify the milling operation, and at the same time the skip size reduction technology needs to meet the Technical, Safety, Environmental and Economic criteria. This paper describes the process for selecting fibre delivered laser technology for skip size reduction, installation of Magnox skip size reduction system at HPA and evaluates the potential of robotically operated fibre delivered laser for remote size reduction of redundant fuel cooling skips in to five flat sections.

Potential of fibre delivered laser technology for decontamination of concrete surfaces, size reduction of variety of materials and geometries (including concrete), and in-air and underwater has been successfully demonstrated by TWI in laboratory conditions [2-7]. This is the first time in UK this technology has been deployed for active decommissioning in a production like environment.

SKIP SIZE REDUCTION TECHNOLOGY SELECTION

Initially twelve size reduction technologies were considered (mechanical and thermal) and their performance were evaluated by conducting feasibility studies. Following the initial stakeholder review workshop and performance assessment of size reduction technlogies, five size reduction technologies were down selected for further evaluation.

1. Diamond Wire
2. Reciprocating Saw
3. Diamond Coated Disc
4. Plasma Arc
5. Fibre Delivered Laser Beam

Based on key attributes, that reognise the NDA's value framework, the final workshop utilized weighting factors and sensitivity analysis to choose fibre delivered laser beam cutting as the best option for meeting the project requirements and NDA's objectives for size reducing skips.

The final conclusion of the technology scoring process highlighted following key advantages of laser technology.

- The laser cutting technology generates no reaction forces, is able to cut with large standoff distance and therefore the skip does not need to be clamped in place which eliminates the need for frequent nozzle change and minimizing human intervention.
- The laser cutting process was fastest producing smallest kerf, which generates the smallest amount of secondary arising.
- The laser cutting is already proven to be a reliable and robust cutting technology that is deployed across all major manufacturing industries.
- The cutting head weighs less than 5kg, requiring minimum deployment efforts.
- The high value asset laser source can be located in clean area nearly 100m away from the size reduction station; thus can be used for other size reduction activities.
- Remote operation with minimum routine maintenance in the contaminated area.
- Precision repeatability of cutting operations, with the ability to intervene manually if required.
- Deploying the laser from a robotic arm allows a skip to be cut without having to make multiple movement of the skip position.
- The amount of airborne contamination can be minimized with the potential to tune laser focusing conditions, power and assist compressed air pressure during cutting to minimize the kerf size.

DESCRIPTION OF LASER SKIP SIZE REDUCTION FACILITY AND OPERATION

The Laser Skip Size Reduction Facility (LSSRF) is an automated fully integrated laser-robots system, designed to cut redundant Magnox skips into a five flat sections with minimum amount of manual handling, before decontaminating these skips by dry milling operation to reduce ILW to LLW for final disposal.

The LSSRF is encapsulated inside a ventilated Modular Containment (Moducon) unit which was installed inside a dry skip store with its own ventilation system. The dry skip store at HPA originally used to store redundant used fuel skips was previously decontaminated, de-cabled and de-planted and made available as a skip size reduction facility. This dry skip store with its heavily shielded walls, decontamible surface finishes and installed ventilation made the facility suitable for radiation and contamination level 4 operations. In addition the limited access route allowed personnel access to be controlled and restricted via an interlock system and was ideally suited for deployment of laser technology. This is shown as a graphic plan view in Figure 2. The Magnox LSSRF consists of three sub-systems:

1. **A skip drive system (SDS**) – A drive roller conveyor system used to move the skip from load/unload position before and after completion of the size reduction operation.
2. **A skip cut-part handling system (SCHS)** – A handling robot used to hold, remove and place the laser cut skip pieces from the cutting station onto the "toast rack" designed to hold five cut pieces from an individual skip for transfer to the CNC Milling Station.
3. **A laser cutting module (LCM) –** An integrated laser robot system used to cut the skip.

The SDS is a four stage conveyor track, each stage powered individually. The first stage conveyor was positioned outside the Moducon used for loading whole skips placed on the lidded container base as well as the empty toast rack. This was also used for unloading cut skip pieces placed in the toast rack loaded on a base and lidded for transport. The lid was designed to fit both the container base enclosing whole skip and the toast rack, which was designed to house size reduced skip sections back out of the Moducon unit to the CNC Milling Station.

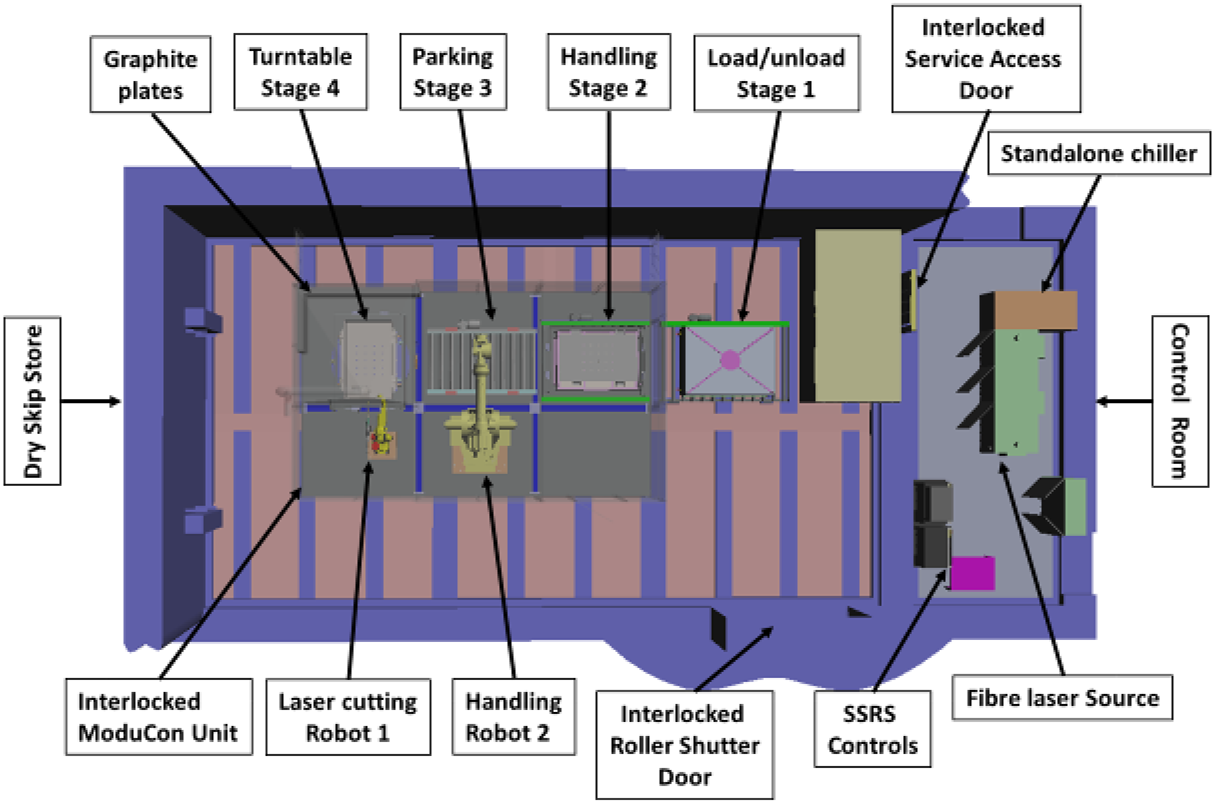


Figure 2 Graphical plan view of LSSRF installation inside a dry skip store at HPA

The enclosed contaminated skip with the empty toast rack are brought in to the dry skip store via the roller shutter door and placed on the stage 1 conveyor. Personnel then vacate the area and all access doors, including the Moducon are interlocked shut.within the system. The skip size reduction process is then initiated by the operator positioned inside the clean control room. The complete size reduction process was controlled and monitored from the control room using three CCTV cameras. Once the Magnox LSSRF was activated, the Moducon door was opened and the stage 1 conveyor moves the enclosed skip with empty toast rack to the stage 2 position.

The stage 2 and 3 conveyors have a locking mechanism which holds the enclosed skip and the empty toast rack in position respectively. Once in position the automatic sliding Moducon door was closed and SCHS system is automatically activated by indexing the handling robot 2 to pick up the lid from skip base container and hold it positioned over the skip and the toast rack with sufficient clearance. Both stage 2 and 3 are then unlocked and the skip base moves on the turntable located at stage 4 while the empty toast rack positioned at stage 3. Once this procedure was completed, stage 2 and 3 are locked again and the handling robot 2 places the lid on stage 2 conveyor. At this point the Moducon sliding door is opened and the stage 2 and 3 are activated to position the lid at stage 1 and empty toast at stage 2. On completion the Moducon door was closed and stage 2 and 3 are locked again, and the skip size reduction process was set on standby to activate LCM for size reduction process to begin.

The Magnox LSSRF was designed and programmed to remotely cut any of four skip faces/sides in any sequence from the control room. The normal cutting process begins by selectively removing the two skip sides without lifting trunions first followed by the two sides that have lifting trunions and finally the base of the skip is removed. The laser cutting procedure and programme were developed to leave selected parts of the skip side uncut (stitches) to keep the laser cut skip side held in position. For the majority of the cutting operation the handling robot 2 is safely parked in secure position. Only when the skip sides have to be separated from the main skip body, the handling robot 2 is activated to move in position to grip the side using magnets and the stitched cut to release free the skip side. The handling robot 2 picks up the freely released skip side and precisely places it inside the toast rack. After all four skip sides and the skip base were successfully placed inside the toast rack, the stage 2 and 3 conveyors were unlocked and the loaded toast rack indexed to stage 3.

At this stage the Magnox LSSRF was set on standby for prescribed period to vent the Moducon before opening the Moducon door and to index stage 1 and 2 conveyors in order to position the loaded toast rack on stage 3 and the lid from stage 1 to 2. This is followed by activating the handling robot 2 to pick up the clean lid and place it over the loaded toast rack. Finally the securely loaded and lidded toast rack was indexed to stage 1, from where it was transported out of the dry skip store to the CNC Milling Station.

LASER CUTTING PROCEDURE DEVELOPMENT

Overview

Prior to installation of Magnox LSSRF at HPA, laser cutting procedures on off-cut epoxy coated skips were developed at TWI. Based on the developed laser cutting parameters, the laser cutting head was specifically designed and manufactured for Magnox LSSFs operations. Combination of newly designed cutting head and developed cutting parameters, the Magnox LSSRF was integrated and programmed to perform full inactive demonstration to stakeholder and Factory Acceptance Test (FAT) at TWI. As this was necessary to ensure that deployment, commissioning and operation of Magnox LSSRF at HPA complies with local site rules and operational safety requirements.

Equipment, Material and Approach

The laser cutting head for procedure development consisted of a 5kW beam from an Yb-fibre laser delivered down a 40m long, 150 micron core diameter optical fibre connected to the laser cutting head. A laser cutting nozzle tip was specifically designed to operate at 8bar compressed air pressure. Through the nozzle tip the laser beam was coaxially aligned to position minimum laser beam diameter (i.e. the focus position) approximately 15mm below the nozzle tip. The complete system was mounted and integrated with FANUC Arcmate 120iC robot. The cutting gas pressure was measured immediately before the cutting nozzle and monitored on a control panel digitally located in safe operating area. The materials used for the laser cutting procedure development were off-cuts of inactive epoxy coated Magnox skip plate with thickness of approximately 6 and 12mm. The skip size reduction procedure development consisted of two tasks:

1. Determination of maximum linear cutting speeds for each skip plate thicknesses
2. Experiments to examine the cutting sequence for skip reinforced sections

Task 1 - Determination of maximum linear cutting speeds
To determine the maximum linear laser cutting speed, a series of laser cutting trials was carried out for the two thicknesses of skip plates. For these trials the requested laser power was kept constant at 5kW and the maximum cutting speed was established by incrementally increasing the cutting speed till the material could not be separated cleanly.

This incremental cutting speed assessment was performed using three compressed air gas pressures of 2, 5 and 8 bar, for two nozzle tips to material surface Stand-off Distance (SD) of 15 and 50mm. (The corresponding laser beam diameter on the material surface was 0.4 and 4.1mm). This is shown schematically in Figure 3. The SDs were chosen as:

- 15mm offered the highest power density available at the workpiece surface.
- 50mm offered a degree of tolerance in positioning of the laser beam.

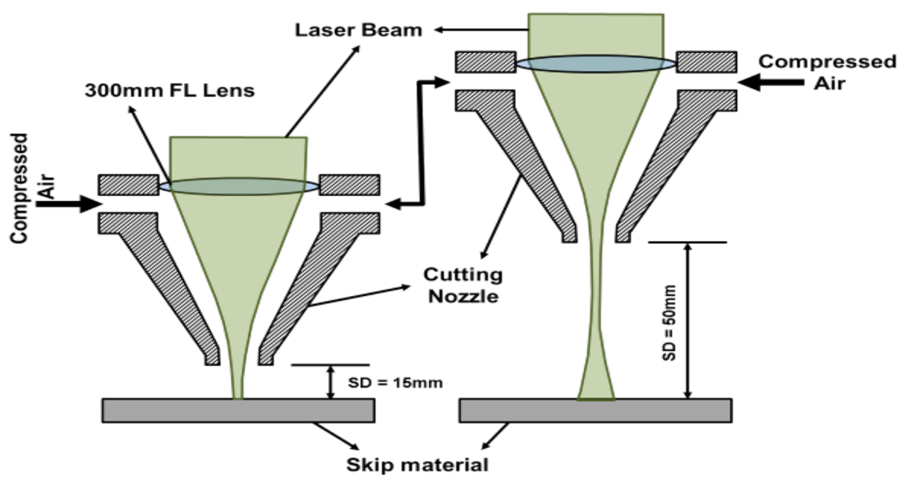


Figure 3 Experimental set in linear laser cutting of skip material

Task 2 - Experiments to examine the cutting sequences for skip reinforced section
To determine clean separation of skip reinforced sections, with minimum programming points for cutting and highest possible cutting speed achievable, a series of laser cutting trials were carried out. The skip reinforced sections described here has a 12mm thickness u-channel section, with a ~80mm flange protruding from its surface. The estimated variation of the material thickness at the flange corner was between 12 and 25mm. This was dependent on the relative angles of 90 and 45^{o} between the laser beam axis and the skip material surface. All cutting sequences started from right to left in order to minimize laser heating of epoxy paint on the opposite side of the skip reinforced section.

At all times the requested laser power, cutting compressed air pressure and SD was maintained constant at 5kW, 8bar and 50mm respectively. Due to the geometry of the flange section it was difficult to position the cutting in and around T-joint corners with DS of 15mm; hence no cutting trial with this setup was performed. For flange cutting, the variables cutting parameters adjusted were cutting speeds and cutting head orientations. The cutting speed was varied between 0.2 and 0.35m/min and with respect to the flange section the cutting head orientations were varied between +45 and -45°. All together four set of cutting trials were performed from single pass to multiple passes targeted towards the T-joint section of the flange. The first three cutting sequences required 14 robot programming points, and for the optimized fourth cutting sequence only 8 points were needed to achieve clean skip reinforced section separation, which is schematically shown in Figure 4.

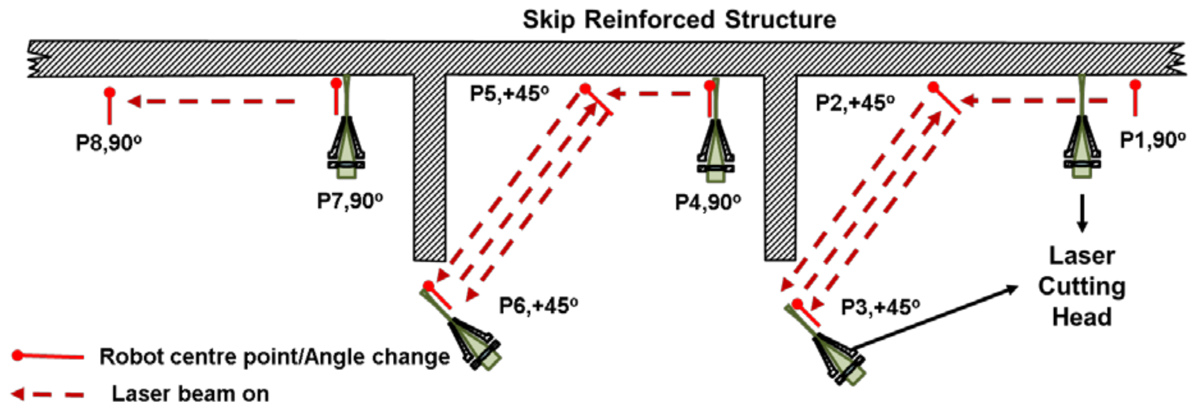


Figure 4 Optimized laser cutting sequence for the Skip Reinforced Structure

ACTIVE MAGNOX SKIP SIZE REDUCTION DEMONSTRATION

Cutting Head Re-design

Based on the results from the laser cutting procedure development, the cutting head was modified to ensure highest power density as well as effective compressed air pressure was available for cutting of Magnox skip. This was achieved by shortening the nozzle housing to provide nozzle to laser focus position at 30mm. The modified nozzle was tested and used in inactive demonstration at TWI for Factory Acceptance Test (FAT).

Active Skip Size Reduction Demonstration

After successfully completing the FAT assessment and inactive skip size reduction demonstration to stakeholder at TWI, the MSSRS described earlier were successfully installed and commissioning at HPA. For the active demonstration, modified cutting head with the laser cutting parameters developed were used to program the laser cut path. The MSSRS operating and size reduction sequence described were followed. The skip was laser cut in the following sequence (as shown in Figure 5).

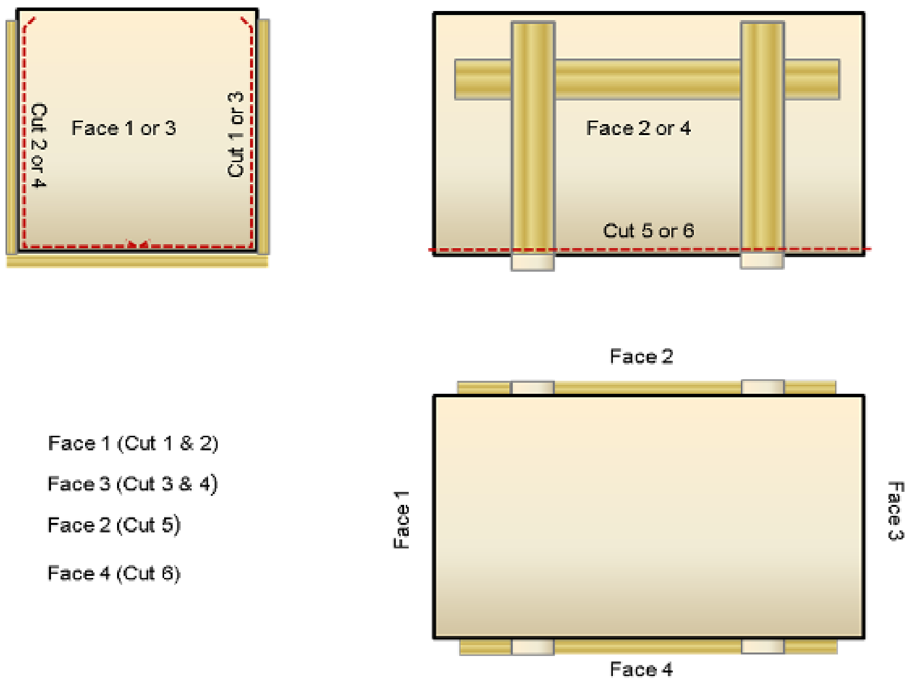


Figure 5 Sequence of laser cutting paths used to separate each skip face with cut paths highlighted in red by a dashed line

Face 1: Cut numbers 1 and 2 were made leaving small stiches intact at the top of the skip, which were subsequently cut when the handling robot was in position.

Face 3: The skip was rotated 180^{o} and nominally identical cut paths to those used for face 1 were repeated; these were cut numbers 3 and 4.

Face 2: The skip was rotated 90^{o} in clockwise direction and mixture of linear and profile cut paths were used for cut number 5.

Face 4: The skip was rotated 180° and a mixture of linear and profile cut paths were used for cut number 6.

RESULTS AND DISCUSSION

Determination of Maximum Linear Cutting Speeds

The results of maximum linear cutting speeds for 6 and 12mm thickness skip plate are shown in Figure 6. Figure 6 indicates that higher compressed air pressures allow the skip plates to be cut with higher cutting speeds. However, this relationship is non-linear and appears to saturate as the compressed air pressure approaches 8bar for both SDs. The smaller SD results in higher cutting speeds, particularly when cutting smaller thickness. This is to be expected because the laser power density on the plate surface at SD of 15mm is approximately 40kW/mm^2. In contrast, the laser power density on the plate surface is approximately 0.76kW/mm^2 at a SD of 50mm, which explains the reduction in cutting speed at higher SD for a fixed optical setup.

Typical kerfs produced in 6mm skip plate at the two SDs are shown in Figure 7. This clearly indicates that laser cutting of skip plate with the smaller laser beam diameter, and hence highest possible cutting speed, produces a narrower kerf and is most likely to produce a smaller quantity of dross and fume. However, simply trying to achieve minimum fume and dross production by cutting the skip plate at the highest possible speed is not sufficient. There does have to be clean separation of material and handling of the cut part after it has been cut, therefore, there needs to be sufficient clearance between the two cut sections. In addition, it is highly likely that a gas flow through the narrow kerfs may be reduced and dross attachment near the kerf exit may cause an issue. This may reduce the chances of clean separation. A compromise must be achieved between the cutting speed, tolerance to the SD, location of the laser focus with respect to the material surface and the cutting gas pressure. This was achieved by modifying the nozzle housing to achieve nozzle tip to laser focus position of 30mm.

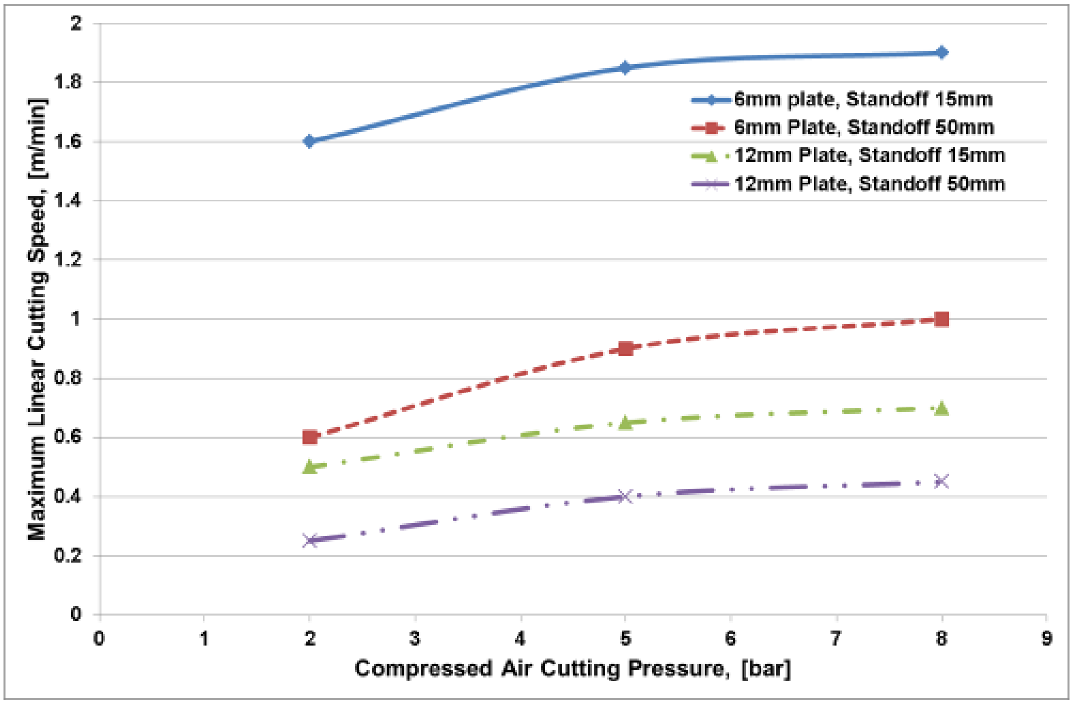


Figure 6 Effect of compressed air cutting pressure on cutting speed in 6 and 12mm thickness skip plates.

Figure 7 Cross-sections of laser cut kerfs produced in a 6mm thickness skip plate using 8bar cutting gas pressure with two SDs; 15mm (left), 50mm (right)

Experiments to Examine the Cutting Sequences for Skip Reinforced Section

Linear cutting parameters developed with a SD of 50mm for both 6 and 12mm thickness plates were used as a starting point to assess and optimise laser cutting procedures for the skip reinforced sections. This was because using the existing cutting head configuration, the shape and size of the flange did not permit laser cutting of T-joint corners with SD of 15mm. Therefore, in order to mitigate the risk of not achieving complete separation and/or production of higher secondary arising, TWI redesigned and manufactured the cutting head to increase the relative nozzle tip to focus position to 30mm. The modified cutting head was tested by laser cutting a 6mm thickness skip plate with 5kW requested laser power, a cutting speed of 1.0m/min was achieved with SD of 50mm. The result was clean separation of the plate.

Using the modified cutting head and single pass linear cutting parameters developed in Task 1 for 12mm thickness, it was relatively easy to achieve clean cut across a straight and flat section of the reinforced skip section plate. However, in order to cut the T-joint or flange corner with a single pass cutting technique, the cutting speed was needed to be reduced to 0.2m/min. Although the flange corner appeared to have been cut with the single pass cutting technique, it was noticed that some melt deposit on the front of the cut at select locations were present. At these locations the cut sections of the flange corners appeared to be re-weld, which required some physical force toseprate the cut part free from the parent skip section.

The cutting path was modified to only cut in one direction with three laser beam passes without re-tracing over the original cut. The result of using this optimised cutting sequence shown in Figure 4 was reduction in the cutting coordinate points to 8 from previous cut paths containing 14 points, and at the same time increase in productivity. Figure 8 shows the cleanly separated skip furniture section using the optimised laser cutting sequence.

There are further advantages for using this optimised cutting sequence:

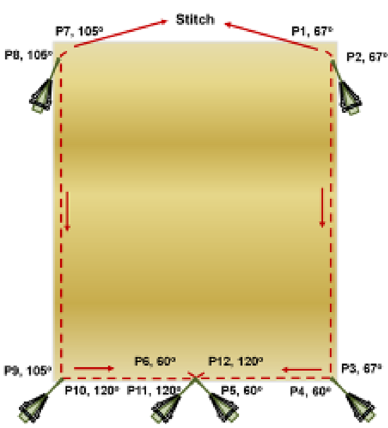
- The cutting process can be monitored for skip face piercing using the camera located inside the Moducon unit. A continuous and directional discharge of melt ejection only from the kerf exit is an indicator for consistent process performance.

- The pierced skip face during flange cutting can also be used as a guide to programme the next position of the laser cutting head correctly. This laser pierced point during the first flange section cutting can be seen as a heavy gouged line in between the u-channel section between P4 and P5 in Figure 8. It is also necessary and important that the next cutting point is located just behind this pierced point, which is location point P4 as shown in Figure 8.

Figure 8 Laser cut edges and skip furniture cut section produced using optimised cutting sequence

ACTIVE SIZE REDUCTION DEMONSTRATION

The active demonstration went as planned, an active skips with activity level just below 40Gb/te was successfully size reduced, and during the demonstration no operator intervention was required. The laser cutting procedure development for the skips in Task 1 and 2 were used. However, the laser cutting speeds for active size reduction was reduced. As highlighted in Task 1 and 2 results, the maximum cutting speed achieved for 6mm thickness skip section was 1.0m/min. Figure 9 shows the laser cutting speeds and cutting head orientations used for separating face 1 and face 3 from a whole skip. The slower cutting speeds are a consequence of different cutting head orientations being used. In the procedure development trials the cutting head was always positioned normal to the skip face (ie at 90°). However, during demonstration the cutting head was oriented between 60° and 120° to the skip face, consequence of this was cutting of a skip plate section with variable thickness, which necessitated a decrease in the cutting speed.



Cutting head location	Material thickness cut, mm	Cutting head orientation	Cutting speed used, mm/min
P1-P2	6.5	67°	600
P2-P3	6.5	67°	600
P3-P4	Variable	(67°) – (60°)	-
P4-P5	7	60°	440
P5-P6	7	60°	600
P7-P8	6.2	105°	600
P8-P9	6.2	105°	600
P9-P10	Variable	(105°)-(120°)	-
P10-P11	7	120°	440
P11-P12	7	120°	600

Figure 9 Laser cutting paths for faces 1 and 3 used during the active demonstration.

The complete demonstration lasted for approximately 60 minutes, which included loading of skip and the toast rack, the laser cutting operation, handling of the cut parts, and positioning of the cut parts inside the toast rack. The total laser 'on-time' was 31 minutes and 55 seconds. Figure 10 shows images of the laser cutting of face 1 and face 2 during the active demonstration.

Visual assessment of laser cut edges of size reduced skip sides showed a significant amount of molten material remained attached to the cut edges. This can be regarded as positive effect as less material was needed to be collected during post demonstration clean-up operation.

Maximum entrance laser kerf width measured was approximately 3.33mm and usually the entrance kerf width was larger than exit. Compared to Figure 7, this large kerf is most likely to be the results of cutting skip face at elevated angle, resulting in cutting of increased material thickness, and coupled this with slower cutting speed used for demonstration may be the cause of increased kerf width.

Figure 10 Laser cutting of an active skip at HPA: Laser cutting of face 1 (left); Laser cutting of stitches on face 2 (right).

Radiological Sampling Plan

A key component of the active trial is to determine the industrial and radiological hazards associated with laser cutting of surface contaminated components. In order to accomplish this, a sampling plan was developed to determine the elemental constituents, radioactivity content and time averaged concentration of the off gasses produced during the laser size reduction.

Industrial Hazard Assessment

Elemental analysis was performed on the air sampling papers to determine area time averaged heavy metal concentrations. Further static sampling was also performed inside and outside the Moducon to determine the time averaged concentration of Volatile Organic Compounds (VOC's) and heavy metals. Finally operator Personal Air Samplers (PAS) were used to assess worse case time averaged exposures for comparison with industrial safety concentration limits.

Radioactivity Assessment

The total radioactivity along the cut line was determined by performing a collimated gamma survey along the cut line and then calculating the average cut line dose rate. The skip was then surveyed along its surface to identify a spot on the skip that correlates to the average cut line dose rate. A skip coupon was taken from this area and then submitted for radiochem analysis to determine the average Cs-137 inventory of the cut path. The Cs-137 data was then used to scale in the other radionuclides based of the established Magnox skip finger print to establish the total average activity along the cut line.

The coated steel ventilation hood was assessed for removable surface contamination following the cutting of the each skip. Radiological surveys were taken of the Moducon external and internal surface areas following the cutting of each skip including the installed ventilation ducting.

An approximate activity balance was determined by comparing an initial estimate of activity released based on sampling and surveys to the calculated release of activity based on the cut kerf size and the average radioactivity along the cut line.

The system commissioning was successfully completed with area classifications demonstrated to be lower than the anticipated (worst Case) in the safety case and supporting assessments. The time averaged activity concentrations were C3 for both alpha and Beta. The sample was counted by gamma spectroscopy and gave the following results.

Alpha = 0.48 Bq/m3
Beta = 9.2 Bq/m3

There are however 45 air changes per hour within the Moducon, which equates to 3600m3/h. If we consider that the activity is only produced during the cutting process which takes approximately 30 minutes per skip then without ventilation the activity concentrations would have been high C4 for alpha. Without vent the results is anticipated to be approximately as follows.

Alpha = 11 Bq/m3 (54 DAC)
Beta = 276 Bq/m3 (86 DAC)

Air sampling was performed inside and outside the Moducon to determine the time averaged mixed alpha and beta activity concentrations. In addition, a cascade impactor was used to determine particulate size and activity partitioning within the Moducon area. This determined the potential internal dose burden associated with the respirable particulate.

Airborne particulate sampling within the Moducon using a cascade impactor showed the particulate being produced are relatively fine (<10 micron). Figure 11 shows typical measured particle size distributions collected using a cascade impactor, indicating approximately 21% of collected particles by volume are less than 10 micron in diameter. This has built up on the LEV HEPA filters resulting in full loading of one filter and partial loading on the second filter after cutting of 3 skips.

Loose contamination surveys and L60 air sample taken during cutting within the Moducon indicate that the fine particulate contains significant beta activity, however gamma dose rate surveys of both the Moducon and LEV's are relatively low (1 microSv/h on LEVs) indicating that the beta activity being measured may be dominated by Sr-90.

There was no measurable airborne contamination outside of the Moducon or spread of contamination during access to the Moducon, which indicated that the skip store area outside can clearly and easily be maintained as C2 during future operations.

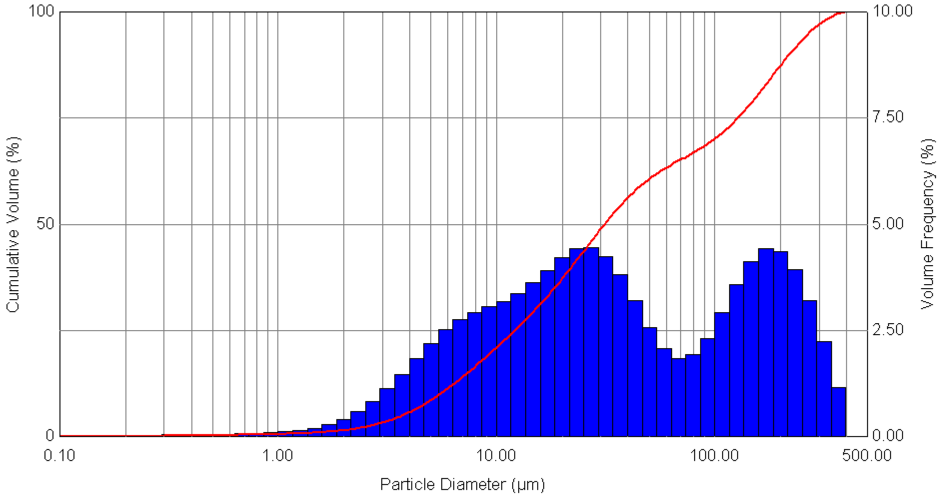


Figure 11 Particle size distribution from laser cutting of an active skip collected using a cascade impactor

Although at least one of the skips contained relatively high levels of loose surface alpha contamination on receipt (1200 cps by 541), Moducon surveys have found relatively low alpha contamination levels post cutting, indicating that the pre-fixing of skips has aided in containing such activity.

CONCLUSIONS

This work has allowed the following conclusions to be drawn:

1. Laser cutting of a 6mm thickness skip plate can be achieved by using 5kW requested laser power, compressed air pressure of 8bar, standoff distances between 15 and 50mm, cutting speeds between 0.9 and 1m/min.

2. For similar laser power, compressed air pressure and standoff distance, a 12mm thickness skip plate can be laser cut with cutting speeds between 0.35 and 0.4m/min

3. An optimised procedure using three passes, with a cutting speed between 0.2 to 0.25m/min, without cutting the opposite flange face, was found to be most effective method of separation for the skip reinforced flange section.

4. Compared to the initial laser cutting trials reported in Task 1 and 2, the laser cutting speeds used for active laser cutting demonstration were lower. In addition the amount of dross and smoke produced were higher than anticipated. These are most likely related to changes in the cutting head orientation and slower cutting speed used.

5. The demonstration was successfully delivered. No ‘operator-in-cell’ intervention was required during the demonstration and the complete demonstration was delivered within 60 minutes, with less than 50% of this time being laser beam on-time.

6. The Moducon facility provided robust containment of airborne and surface contamination. Radiological real time air sampling and radiation surveys demonstrated that the facility can be operated in C3/R3 conditions rather that the C4/R4 conditions established from theoretical assessment. However, improvement in the cutting path, refined optical path and a better method of pre-filtration may be required to further reduce the loading of LEV HEPA filters.

7. Fibre laser cutting process has easily shown to meet NDA objective for size reducing one Magnox Pond Skip per day. If used in a production like environment and only considering size reducing these skips, it is possible to size reduce 4 skips per day; thus exceeding NDA’s original objective.

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