Y-SC-39

MACHINING DEPLETED URANIUM

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Oak Ridge Y-12 Plant

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ABSTRACT

This report summarizes the experience gained by the Oak Ridge Y-12 Plant in machining and handling depleted uranium. Parameters are given for turning, boring and facing, cutting, drilling, gun drilling, reaming, threading, tapping, milling, and grinding. Health and safety hazards involved in the machining of depleted uranium are also discussed.

CONTENTS

SUMMARY

This report summarizes the experience in machining and handling depleted uranium that has been acquired at the Oak Ridge Y-12 Plant.[a] Parameters are given for turning, boring and facing, cutting, drilling, gun drilling, reaming, threading, tapping, milling, and grinding. Uranium metal is somewhat abrasive; consequently, carbide tooling is recommended for nearly all operations. Health and safety hazards, including the handling of chips, are also of major concern. One of the most sensitive properties of this metal, one which requires constant attention, is its pyrophoricity. Without the use of ample coolant, machined chips will ignite and continue to burn to produce an extremely hot fire and a radiological hazard to personnel. Coolants containing chlorides should be avoided, as the chloride ion attacks uranium at the grain boundaries. Carbon dust is a satisfactory fire control material, but uranium will react with carbon dioxide. The finer the turnings, the more care is required in handling to prevent igniting the chips by friction. Adequate respiratory protection must be used in the vicinity of metal fires.

(a) Operated for the U S Atomic Energy Commission by the Union Carbide Corporation's Nuclear Division.

INTRODUCTION

Since little recent information is available outside the AEC concerning the machining and handling of depleted uranium, and since more and more nonnuclear uses for this material are being discovered, there exists a need for publicly available machining and handling guides. The recommendations given in this report are not to be construed as the final machining parameters because too many factors enter into each machining operation to establish a firm, unalterable set of conditions. However, they do represent the parameters which have given the Y-12 Plant the most success in machining this material.

URANIUM MACHINING

MATERIAL PROPERTIES

Uranium is a dense, malleable metal; however, it work hardens easily. It has a hardness of approximately R_A55 and a melting temperature of about 2,070° F. In the freshly machined state, uranium has a bright silver color, but oxidizes rapidly in air. During oxidation it changes color from silver through brownish yellow to black as the oxide forms. The material is pyrophoric, with the degree of pyrophoricity increasing as the particle size decreases. Uranium is very dense, weighing 0.675 pound per cubic inch (~ 19 gms/cc).

Natural uranium, from which depleted uranium is derived, consists of approximately 99.3 percent uranium-238 and 0.7 percent uranium-235 (a small percent of uranium-234 is also present). For most uses in the atomic energy field, natural uranium is processed through a separation plant where as much of the U-235 is removed and collected as is economically feasible. The product remaining, which still contains a small amount of U-235, is known as depleted uranium; the separated uranium-235 is called enriched uranium.

The machining properties of enriched, natural, and depleted uranium are essentially the same. They must be considered differently only in terms of the type of radiological hazard with which they are associated.

PERSONNEL PROTECTION PRACTICES

Experience in the Y-12 Plant has shown that depleted uranium can be processed safely by practicing careful handling techniques, good housekeeping practices, and common sense.

Persons handling raw castings prior to machining should wear gloves, preferably rubber, to prevent contamination from residual oxide which may contain radiologically active daughter products. At Y-12, outer clothing such as coveralls and safety shoes are made available to machining, product inspection, and maintenance personnel. Those working with depleted uranium should follow such normal personal hygiene practices as washing hands thoroughly before eating, not laying cigarettes down on work benches, and avoiding the inhalation of fumes from metal-cutting operations or burning chips. During machining operations, chips and swarf should be kept submerged in cutting fluid to minimize the possibility of fires and the spread of minute particulate matter in the air. Much has been written concerning proper health practices in handling depleted uranium. (Documents 2, 6, 7, 9, 11, and 14 in the Reference Section of this report provide detailed information concerning this phase of the problem.)

MACHINING METHODS

Cutting Fluids

Water with a rust inhibitor such as Rustlick "BX" or a soluble oil such as Dasco-900 or Irmco-330 is used freely in large quantities during metal-removal operations. In addition to the need for normal cooling and, in some instances, lubricating, there is the added necessity for preventing fires and controlling the spread of particulate matter. Fluids containing chlorides should be avoided because the chloride ion attacks uranium at the grain boundaries. Chlorinated organics must also be avoided as cutting fluids, since chip fires in the presence of such materials can produce phosgene gas.

Each machine can contain its own cutting-fluid supply or, if conditions justify, a central cutting-fluid system can be used to supply several machines. The machine sumps must be cleaned periodically to remove uranium oxide and finely divided metal. Care must be exercised in handling and disposing of this material from the standpoint of both safety and environmental pollution.

The pan of each machine used in machining uranium should contain fluid of sufficient depth to cover a reasonable accumulation of chips. Without this precaution, the machined chips may ignite and continue to burn, producing an extremely hot fire and a radiological hazard to personnel. The specific cutting fluid used at Y-12 for each machining operation is given in the Machining Guide section of this report.

Cutting Tools

It is noted in the Machining Guide that carbide tooling is necessary for nearly all operations since uranium metal is somewhat abrasive. The general type or composition of tool given for each machining operation is a result of the experience acquired to date. New carbide grades and tool materials are constantly being developed as a possible help for improving future uranium fabrication operations. Recommended specific tool geometry is presented in the Machining Guide.

Machining Operations

Probably the most critical property of depleted uranium that must be considered in planning machining operations is its pyrophoricity. Failure to provide adequate protection against this characteristic of the metal can lead to serious consequences. Fortunately, there are ways to control it. To prevent the occurrence of chip fires, copious quantities of a water-base coolant are used, and the cutting speed is adjusted to a rate that will be just under that which causes fires in a specific operation.

Good machining practices such as maintaining a minimum tool overhang and maximum machine and setup rigidity must be followed. In addition, heavy-duty machines are required that possess adequate horsepower to machine this easily work-hardened and dense material.

After machining, finished parts should be dried and coated with a light coat of thin oil and wrapped in plastic to guard against oxidation. Paper should not be used because of its hygroscopic nature. Humid conditions will accelerate the corrosion of uranium parts.

The recommendations listed in the Machining Guide are not to be construed as final machining parameters. Too many factors enter into each machining operation to give a firm, unalterable set of conditions. However, they do represent the parameters which have given Y-12 machinists the most success in machining depleted uranium.

Surface finishes obtained from the turning parameters listed in the Guide reach levels in the range of 64 - 250 microinches for roughing, 32 microinches for finishing, and 15 microinches for fine finishing. Milling operations achieve essentially the same quality of finishes as turning. The parameters given for grinding result in surface finishes in the range of 20 - 30 microinches. By varying the parameters, finer finishes may be obtained, but the resulting fine swarf must be handled with extreme caution since it is very pyrophoric. This form of uranium has been known to ignite under water.

Y-12's experience in applying some of the nontraditional metal-removal processes to depleted uranium has been rather limited. Most electrolytes used in electrochemical machining are corrosive to uranium. Stephens(15) reports that if this process is used, caution must be exercised. Electric discharge machining has been tried with varying degrees of success. In general, the results have been unpredictable. Use of ultrasonic machining methods for metal-removal purposes is limited because of the degree of ductility which uranium exhibits.

Chip Handling

During all machining operations, the machinist must keep the chips submerged in coolant. When chip accumulation in the pan becomes too great to be adequately covered with fluid, the machinist must transfer them to a covered container. (At Y-12 a 55-gallon drum is stationed at each machine.) It is not necessary that this drum contain water or coolant, but at no time should there be more than one drum of turnings at a machine. The drum cover should have an overhang or apron to prevent any sparks which might occur at the point of cutting from dropping into the drum and igniting the wet chips. The lids should remain closed when the drums are in transit so that ample protection is available at any and all locations. There is no fixed length of time that chips may remain in a drum at a machine. The time can vary from an hour to a week, depending on the machining load. However, uranium chips must not be stored in a closed container for long periods of time because hydrogen can be produced by the action of uranium with water, providing the conditions for a possible explosion.

At Y-12, full drums of chips are moved to an outside dock where they are emptied into a water-filled truck-transportable container. Chips thus collected are disposed of at a suitable burial site or sent to another building where they are crushed and pressed into briquettes for reuse.

Fires are practically nonexistent when the chips are kept submerged in coolant and the containers are kept covered. Occasionally, however, when procedures are not followed, fires will occur at a machine or in a storage drum. A fire at a machine is extinguished best by submerging the burning mass in coolant; fire in a storage drum is smothered or controlled by applying carbon dust. (Carbon dioxide foam must not be used because hot uranium will react with the gas.)

Plastic bags of powdered graphite (10 to 30-pound sizes) are kept in metal drums on dollies in the Y-12 machining areas. The bags can be removed from the drum and tossed on top of a chip fire. In most cases, bagged graphite can be used without the accompanying waste and scattering that increases the cleanup problem that occurs when shoveling loose powder from a drum to a fire. Other extinguishing agents, such as Met-L-X powder and dry sand, have also been found to be satisfactory.

Due to the extreme heat that is created during a chip fire in a drum, water must not be used inside a building to control a drum fire. Once the fire is controlled with carbon dust, the drum should be removed to an outside area and flooded with water.

It must be kept in mind that the finer the turnings, the more care is required in handling the chips to prevent ignition by friction. Also, adequate respiratory protection must be used in the vicinity of metal fires.

MACHINING GUIDE

Turning	Rough:	Speed	150 - 200 ft/min
		Feed	0.012 - 0.018 in/rev
		Depth of Cut	0.050 - 0.100 inch
		Tool Geometry	5° negative or neutral rake, 0.047 inch radius, 5° clearance
		Tool Type	Carbide (72% WC, 8% TiC, 11% TaC, 9% Co)
		Coolant	2% rust inhibitor and water
	Finish:	Speed	275 - 325 ft/min
		Feed	0.002 - 0.003 in/rev
		Depth of Cut	0.002 - 0.005 inch
		Tool Geometry	Neutral or 5° positive rake, 0.020 - 0.025 inch radius, 7° clearance
		Tool Type	Carbide (74% WC, 20% TaC, 6% Co)
		Coolant	2% rust inhibitor and water
	Fine Finish:	Speed	425 - 450 ft/min
		Feed	0.001 - 0.002 in/rev
		Depth of Cut	0.0001 - 0.0005 inch
		Tool Geometry	Neutral rake, 0.020 - 0.025 inch radius, 7° clearance
		Tool Type	Carbide (57% TaC, 37% WC, 6% Co)
		Coolant	2% rust inhibitor and water
Boring and Facing		Same specifications as for turning except that the specified surface speed should be decreased by 10%	
Cutting Off		Speed	100 - 150 ft/min
		Feed	0.008 - 0.010 in/rev
		Tool Geometry	Flat nose - hone corners slightly
		Tool Material	Carbide (73% WC, 11% TaC, 6% TiC, 1% NbC, 9% Co)
		Coolant	2% rust inhibitor and water or 10% soluble oil and water
Drilling		Speed	20 - 25 ft/min
		Feed	0.001 - 0.0015 in/rev
		Tool Geometry	Standard 118°
		Tool Material	Carbide (C-2 grade)
		Coolant	10% soluble oil and water

Gun Drilling		Speed	20 - 25 ft/min
		Feed	0.0005 - 0.001 in/rev
		Tool Geometry	Standard
		Tool Material	Carbide (73% WC, 21% TaC, 6% Co)
		Coolant	10% soluble oil and water
Reaming		Speed	5 - 10 ft/min
		Feed	0.001 - 0.0015 in/rev
		Tool Geometry	Reduce land width to 0.002 inch
		Tool Material	Carbide (73% WC, 21% TaC, 6% Co)
		Coolant	10% soluble oil and water
Threading		Speed	20 - 30 ft/min
		Tool Geometry	Neutral rake
		Tool Type	Carbide (74% WC, 20% TaC, 6% Co)
		Coolant	2% rust inhibitor and water
Tapping		Speed	12 - 15 ft/min
		Tool Geometry	2-flute spiral point (chip drive)
		Tool Material	Nitrided high-speed steel
		Coolant	Molybdenum disulfide base

No grind burrs are allowed; use 65% thread height; machine tap wherever possible.

Milling	Rough:	Cutter Speed	150 ft/min
		Table Feed	2 1/2 - 3 in/min
		Depth of Cut	0.050 inch
		Tool Geometry	0.030 - 0.050 inch nose radius, 5^{o} positive rake or less, 7^{o} clearance
		Tool Material	Carbide (C-2 grade)
		Coolant	5% soluble oil and water

Adjust the cutting conditions to obtain a 0.002-inch feed per tooth (approximately).

Finish:

Cutter Speed	200 - 250 ft/min
Table Feed	1 1/2 - 2 in/min
Depth of Cut	0.005 inch or less
Tool Geometry	0.020 - 0.040 inch nose radius, 5^{o} positive rake or less, 10^{o} clearance
Tool Material	Carbide (74% WC, 20% TaC, 6% Co)
Coolant	5% soluble oil and water

Adjust the cutting conditions to obtain a 0.001-inch feed per tooth (approximately).

Grinding

Speed	3000 - 5000 ft/min
Downfeed	0.002 - 0.005 in/pass
Wheel	Silicon carbide 46 - 80 grit "G" or "H" hardness 11 - 13 open structure vitrified bond
Coolant	2 - 5% grinding fluid inhibitor and water

Cross feed, table feed, or rotating speed must be kept slow enough to prevent burning of work.

Caution: Grinding swarf is extremely pyrophoric. Exercise great caution in handling or disposing of this material.

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