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Density of Plutonium Turnings Generated from Machining Activities

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Problem Statement and Objective

Determine the density of plutonium (Pu) turnings generated from the range of machining activities, using both surrogate material and machined Pu turnings. Verify that 500 grams (g) of plutonium will fit in a one quart container using a surrogate equivalent volume and that 100 grams of Pu will fit in a one quart Savy container.

Experimental

Plutonium is machined in the Plutonium Facility on a variety of different machine tools (lathes and mills). For this report two machines have been used to generate turnings: T-base 2 lathe which generates the most turnings and the Precitech lathe which generates the least amount of turnings. T-base 2 has a relatively large depth of cut and feed rate while the Precitech is used with a shallow depth of cut with relatively slow feed rates. These machines were chosen because they produce turnings at the upper and lower ends of the density range.

For T-base 2, a hemishell surrogate was machined on a Mazak Nexus 150 CNC lathe utilizing the same cutting insert used to machine on the T-base 2 lathe. Surrogate materials with similar mechanical properties to plutonium were chosen. A cardboard platform was placed underneath the hemishell surrogate to capture turnings. Multiple cuts with similar depths of cut, as taken on T-base 2, were taken on the hemishell surrogate. A similar amount of turnings, as from the T-base 2 process, were produced creating a bird nest turnings pile. The bird nest volume was measured/ estimated in place. The outline of the bird nest turnings had a height ranging from 1 5/8 inch to 2 1/8 inch, see Figure 1. After the volume measurements were complete, the turnings within the outline were collected and weighed. The remaining turnings (those outside the defined volume) were measured to have an average height of 3/16 inch and were also weighed, no volume was calculated of these turnings, see Figure 2.

For Precitech, actual plutonium 40 millimeter samples were machined to generate the turnings using a 0.001 inch depth of cut and a 0.008 inch radius cutting tool. The Precitech machine generated turnings with a similar aspect ratio but much thinner than the turnings generated in the T-base 2 operations. The turnings were weighed and measured to calculate a volume to determine the density. These calculations are shown in the Data and Results section.

Figure 1: T-base 2 machined turnings (bird nest turnings pile)

Figure 2: Bird nest turnings pictured on right and the remaining turnings on the left.

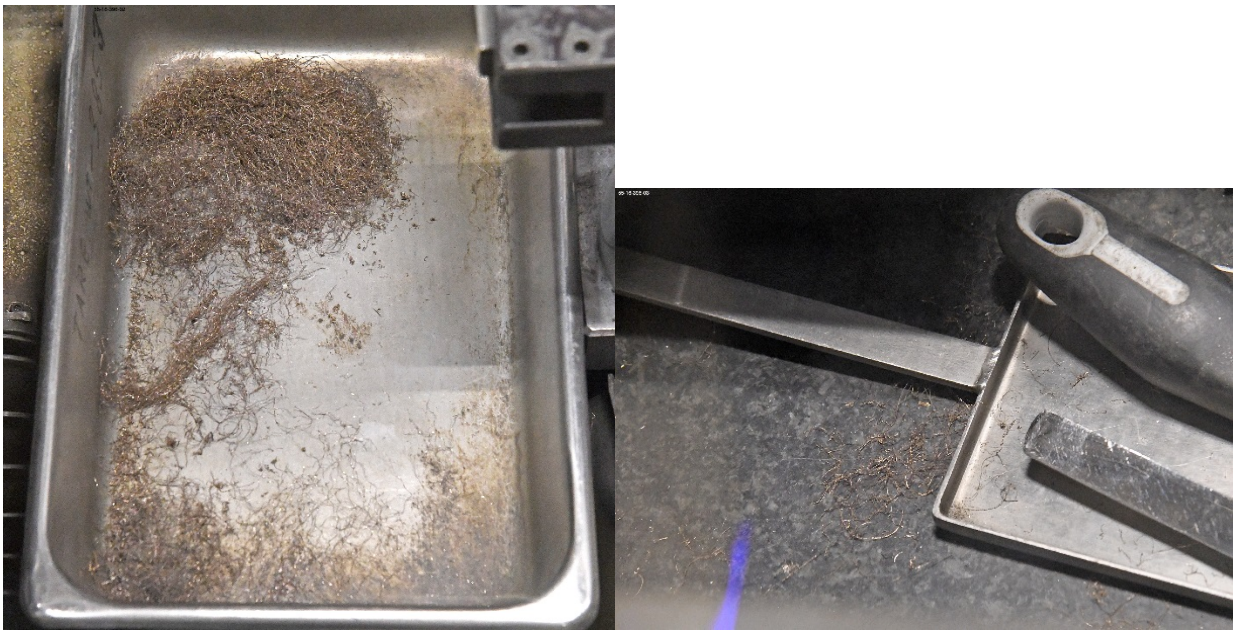

Figure 3: Precitech turnings

Data and Results

T-base 2

Approximate volume of the bird-nest turnings	1281.3 cubic centimeters (cc)
Bird-nesting turnings equivalent weight of Pu	322.83 grams
Remainder of turnings equivalent weight of Pu	366.02 grams

Surrogate turnings density 322.83 g /1281.3 cc = **0.252 g/ cc** = 0.252 kg/ liter

Precitech

Approximate volume of Pu turnings	232.86 cubic centimeters (cc)
Mass of Pu turnings	97 grams

Pu turnings density 97 g/232.86 cc = **0.42 g/ cc** = 0.42 kg/ liter

A wide range of turnings characteristics are obtained from machining plutonium shells and other parts, see Figures 3 through 5. The form of the turnings is influenced by machining parameters such as depth of cut, rotational speed, geometry of cutting tool, as well as the metallurgy of the plutonium. During production of shells for the W88 program a wide range of turning forms were obtained from shells while using the same machining parameters as well as casting parameters. The typical turnings that are machined during the Precitech operations result in a thinner type of turning form, see Figure 3. Turnings that are stringy, curled, or a fine bird nest are examples of what can be generated during lathe operations. An example of turnings produced on a waistband lathe results in yet another type of turning form, see Figure 5. Clearly a wide variety of turnings forms are produced in plutonium machining processes.

Figure 4: T-base 2 Pu turnings are hanging off the tool post (left); turnings on lathe surfaces (right).

Figure 5: Pu turnings produced on the waist band lathe.

T-base 2 Pu surrogate turnings and the Precitech Pu turnings, are a good representation of the range of turnings produced in PF-4 machining operations. In normal part machining processes multiple machining passes occur during the fabrication of one part, cleanup of turnings takes place several times and may accumulate 300 grams to 600 grams on the surface of the machine. Cleanup of the turnings implies that the turnings are swept-up and placed in the containers. Historically, part machining processes have produced anywhere from 1 gram to 3000 grams of turnings when producing one final machined plutonium part. Recent production changes have reduced this to less than 2000 grams of turnings in one complete part evolution. For Precitech machining operations the amount of turnings generated are between 1 gram and 500 grams per part. This is based on the fact that the Precitech is a finish machining operation and takes cuts on the order of 0.001 inch per pass. This produces turnings that have a similar aspect ratio to those machined on T-Base 2, however, they tend to be thinner. Based on the Pu turnings piles shown Figures 3, 4 and 5 one can conclude that the bird nests will have a range of bulk densities based on the metal consistency and depth of cut. Machining operations produced with a larger depth of cut, such as on the T-base 2, produce stiffer turnings resulting in a lower birds nest density. Machining operations with a shallow depth of cut, such as the Precitech, will produce finer turnings which naturally compact into a higher bird nest density.

This study has shown that we can expect all plutonium machining operations to produce turnings with densities ranging from 0.25 to 0.42 g/cc.

Turnings Compaction upon Containerization

Two separate surrogate materials were machined to 500 grams of plutonium equivalent volume. The machined turnings were machined at various depths of cuts to simulate multiple machining processes. Therefore, these turnings had different mechanical properties than those obtained from the typical hemishell machining process. Specifically they were thicker and more rigid than hemishell machining turnings, see Figure 6. These turnings were then compacted to fit into a one quart Savy container, see Figure 7. A 100 gram bird nest of Precitech Pu turnings was also compacted to fit into a one quart Savy container, see Figure 8.

Figure 6: 500 grams of Pu equivalent volume next to one quart Savy container.

Figure 7: 500 grams of Pu equivalent volume compacted into one quart Savy containers.

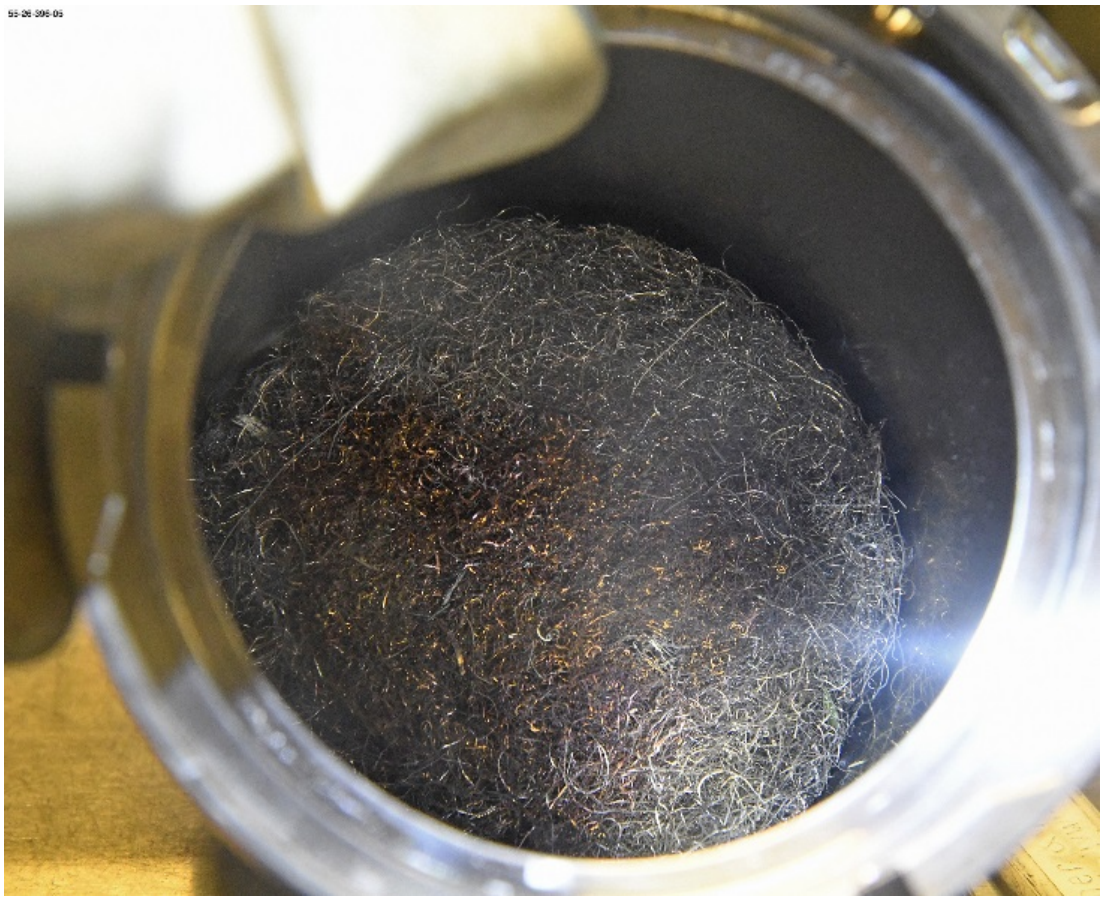

Figure 8: 100 grams of Pu turnings produced on the Precitech in a one quart Savy container

Results

It was confirmed that 500g of Pu can be compacted to fill a one liter container (0.5g/cc). Since the turnings do not accumulate into a nice cylindrical, round or cubic shape, placing the turnings into the shape of the Savy container required change in the shape of the turnings bird nest. There was certainly compaction of the bird nest resulting in an increased density of the turnings. Therefore, the density of the turnings prior to containerizing is less than 0.5 g/cc. Compaction of the finer 100 grams of turnings produced on the Precitech lathe fit into a one quart Savy container.