Hot Extrusion of Heavy Wall Seamless Tube for Platinum Jewelry Applications

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After nearly four decades, Platinum resurfaced in the North American jewelry market in the mid 1980's on the coattails of surging Japanese popularity. Early marketing directed at younger, less conservative consumers suggested that wedding bands would be a base from which to expand Platinum alloys into the North American jewelry markets. At that time, Johnson Matthey's predominant method of manufacture for wedding hands was to stamp ring blanks from cold rolled sheet, followed by various forming and machining operations to produce final product. There were several advantages to this manufacturing technology including fine equiaxed grain structure resulting in excellent ductility, hence the ability to expand / reshape inventories of fewer base sizes to a multitude of I.D. sizes, band widths and band thicknesses.

Commercially it was the manufacturing method of choice world wide. However, there were significant issues with manufacturing costs such as labor sensitivities (numerous manufacturing step procedures) and overall metal utilization, as sheet webbing and center discs outweighed finished product ring washers.

Realizing the potential market pressures for projected industry growth, JM took a critical look at this "Industry Standard Practice", and concluded that a significant improvement in manufacturing efficiency would be paramount to our future success. Therefore in 1989 we began exploring alternate manufacturing technologies within the global Johnson Matthey family that would be:

1) Technically equivalent to rings stamped from sheet
2) Substantially more efficient to produce

This paper will share the Johnson Matthey assessment of several alternate manufacturing techniques, circa 1989, that led to the selection of Hot Extrusion of Seamless Tube as our primary method of manufacture resulting in the production of over 1/2 million T.O. of heavy wall platinum tube that the North American jewelry industry has converted into over 2 1/2 million wedding bands from 1991 through 2002.

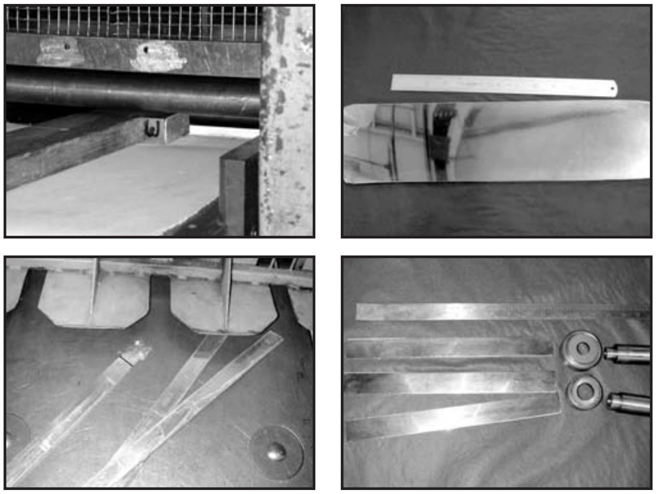
Table I
Stamped Ring Blank

- Cast Ingot
- Machine ingot to remove surface distress
- Anneal if necessary (homogenization alloys prone to segregation)
- Roll to desired thickness (reduction / anneal schedule appropriate for work-hardening rate of alloy)
- Blank washers in as-rolled condition
- Machine to remove disturbed micro-structure (alloy & size dependent)
- Anneal washers to ductile condition
- Press washer to pre-form geometry (potentially multi-stage)
- Anneal pressed washer
- Draw back pre-form to desired ring blank height (band width)
- Anneal to restore ductility
- Ring roll cylinder to finished OD / ID ring blank dimensions

The Manufacturing Methods

I. Stamped Ring Blanks

Production of Platinum ring blanks by stamping rings / washers from sheet was the most popular manufacturing method worldwide in 1989 and the Johnson Matthey method of choice. Characterized by excellent dimensional control, and a fine, uniform equiaxed grain structure in the annealed condition, these blanks



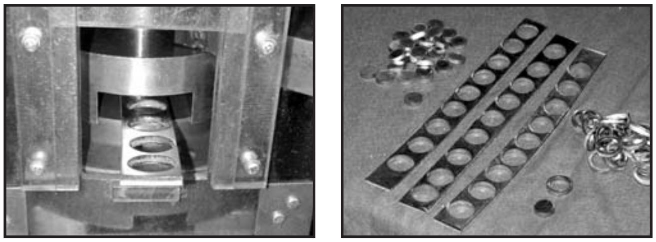


Figure 2

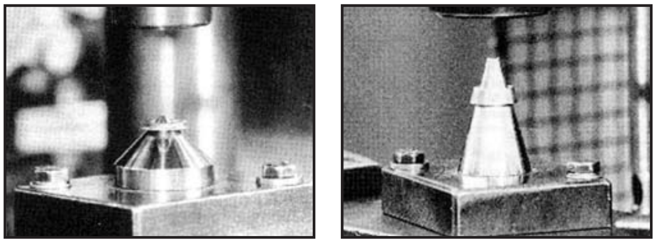


Figure 3

were readily expanded 5 - 8 ring sizes and therefore permitted consolidations of several ring sizes at few intermediate stocking sizes. The manufacturing process, however, was lengthy and carried a substantial quantity of metal to nearly the end of the manufacturing process where the rings / washers were actually stamped, leaving sheet webbing and center disc portions to be returned to the melt stage.

A typical process for manufacturing “stamped ring blanks” is shown in Table I to require as many as 12 manufacturing steps or sequences. Considering also that the rolling and annealing schedule from all initial ingot thickness of 1.5" down to 0.100 -0.125" thickness might require as many as four intermediate anneals, it is apparent that this procedure is indeed labor sensitive. Figures 1 & 2 summarize the procedure photographically – Cast / machined ingot - Roll to plate and shear to strips - Stamp rings (single or multi-stage) and then Forming (Figure 3(2)) pre-finish rings by a method such as inversion forming where a washer web width is redistributed to form band width - Applying a final anneal to restore ductility and this pre-finished form is ready for sizing (expansion) followed by machining to the desired finished geometric design.

There are several advantages to this methodology:

- It was the most widely accepted and mature manufacturing process and therefore an industry standard.
- Dimensional control was excellent, reflecting the ability of most manufacturers to control sheet thickness to + 0.001” and the fact that the stamping tools are machined also to stringent tolerances.
- The resulting microstructure (after removal of distressed material from sheared edges) was observed to be uniform fine grained (ASTM 4-5) equiaxed after re-crystallization annealing, establishing the desired mechanical properties, forming and machining characteristics.

However, the disadvantages are equally obvious:

- The method is lengthy and therefore labor intensive.
- There is poor ingot to finish product yield with much of the Platinum alloy weight carried throughout the majority of process steps.
- There is a propensity for micro-structural distortion at the sheared surface (Figure 4) both ID and OD which require rectification by mechanical metal removal processes.
- Punch and die sets wear quickly and require significant maintenance / eventual replacement.
  Therefore, our overall assessment was that although stamping ring blanks was a well established method producing technically acceptable parts, there needed to be substantially improved material utilization and / or a more streamlined manufacturing process.

II. Cast To Size Ring Blanks

Potentially the least labor intense manufacturing method for near net shape production is to cast ring blanks as close as possible to finished size. Certainly as Table II suggests, pre-finished rings requiring only final machining to desired geometry / designs could be produced in as few as 5 manufacturing steps. However, as many have learned and reported (a topic of nearly one third of all Pt Day Symposiums Presentations since

Table II
Cast-To-Size Rings

- Cast to desired pre-form shapes
- Cut shapes from casting tree
- Machine / grind sprues smooth
- Homogenization heat treatment to obtain chemical equilibrium (alloy dependent)
- Ring roll cylinder to finished OD / ID ring blank dimensions

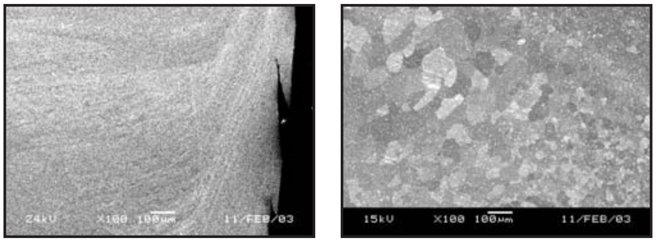


Figure 4

Table III
Cast-To-Size Rings

Gold Alloys	880 – 1100°C
Ni-Base Super Alloys	1250 – 1500°C
Platinum Alloys	1700 – 1800°C

1995) casting of platinum alloys is not the same as casting the karat gold alloys.

Among the unique properties and characteristics of platinum and the 950 platinum alloys is high melting point. Although this might be an attribute for extreme temperature applications where strength can be maintained at temperatures where many glass / ceramic compositions melt, one must also consider the distress on casting tools such as crucibles, flasks, and molds. The 1700° - 1800°C M.P. range of several 950 Pt alloys is shown by comparison to typical melting ranges for karat gold alloys and Ni-base Super Alloys in Table III. Add 75° - 150°C super heat to facilitate complete fill of sprues, gates, risers and ring shapes, and it is readily apparent that casting Pt is a significant technical challenge.

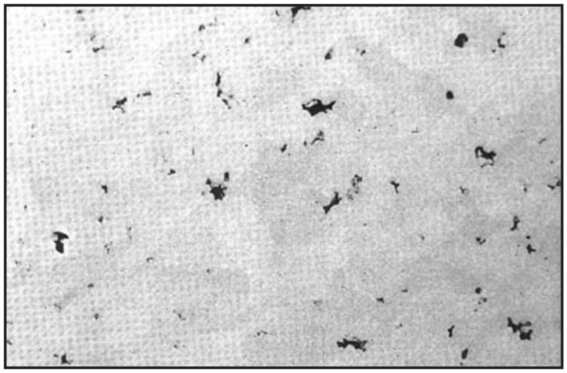


Figure 5

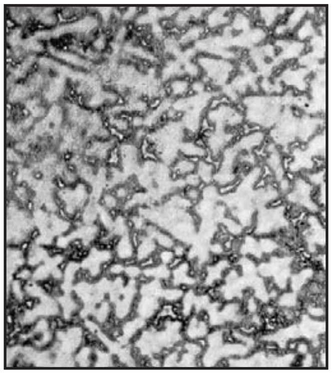


Figure 6

Gold alloys flow and fill readily at temperatures compatible with mold / flask materials. This lower temperature range also represents a smaller liquid to solid volume change and therefore reduced propensity for shrinkage and corresponding micro porosity compared to Pt alloys. (Figure 5) Even when considering the Ni-base super alloys used primarily in jet engine applications, they have reasonable M.P. and superheat temperatures. This industry has also been a leader in the development of crucible and mold compositions which unfortunately stops 200°C short of Pt alloy casting conditions. Techniques to improve fill and reduce shrinkage such as insulating smaller cross sections, raising mold preheat temperatures are impractical due to the small part geometries and limited temperature capabilities of mold material. Increasing the cross-section and number of gates and risers to accommodate fill is counterproductive to metal utilization efficiencies. Finally, raising super heat temperature for pour to improve fill increases shrinkage porosity, and also produces undesirable metal / crucible / and metal / mold reactions that induce and / or trap contaminating vapors and inclusions.

Table IV
Hardness Comparison

Alloy	As Cast (Hv)	Cold Worked (Hv)
Pt-10	120	155 – 175
Pt-5 Ru	126	160 – 185
Pt-5 Co	128	155 – 175

In addition to the technical concerns centered around high melt temperatures, complete fill and porosity, as-cast structures can also adversely affect mechanical properties, and therefore formability and machinability. Further, in the case of the age hardenable compositions, uncontrolled cooling / solidification rates can result in significant primary and secondary dendrite arm spacing (Figure 6(3)) that promotes chemical and micro structural inhomogeneities that can lead to poor ductility and therefore little or no sizing by expansion / reforming compared to rings produced by wrought manufacturing methods.

Consider also a comparison of important physical / mechanical properties between as-cast and cold worked wrought versions of the same alloy compositions as shown in Table IV. For the popular Pt – 10% Ir, Pt - 5% Ru and Pt – 5% Co compositions, the cold worked wrought versions are generally 35 - 40% harder and therefore generally more machinable and superior in wear resistance compared to the as-cast versions.

Our assessment of cast-to-size wedding ring blanks, although promising in regard to minimal processing steps and near net shape capabilities significantly lowering manufacturing costs, was overshadowed by the

Table V
Deep Draw

- Cast Ingot
- Machine ingot to remove surface distress
- Homogenization heat-treatment (as required)
- Roll to thickness (reduction / anneal schedule appropriate for work-hardening rate of alloy)
- Blank / cut disk to required dimensions
- Anneal to optimum ductility for deep forming operations
- Press into cup
- Repeat cupping and annealing operations to desired tube hollow dimensions
- Cut off cupped end
- Draw tube to desired OD / ID dimensions (reduction / anneal schedule appropriate for work-hardening rate of alloy)
- Part ring blanks
- Secondary operations for sizing as required

technical disadvantages of non-uniform cast microstructure, shrinkage porosity and inferior mechanical properties compared to ring blanks stamped from sheet.

III. Deep Draw Ring Blanks

Another mature and widely accepted seamless tube manufacturing method, popular primarily for smaller / thinner wall tube products, is the cupping and forming of a sheet disc to form a tube hollow for subsequent mandrel or plug drawing of seamless tube (Figure 7). However, as shown in Table V, this manufacturing route, like stamped ring blanks, is long and therefore labor sensitive as well as geometry limited. Similar to ring blanks stamped from sheet, deep draws start from the production of sheets and subsequent cutting of discs, (for Johnson Matthey = 6” diameter by approximately 0. 100” - 0. 125” thickness). As the resulting cupping – deep draw – and tube draw processes generally result in simultaneous reduction in OD and ID dimensions, the resulting wall thicknesses produce only the smaller ring blanks desired by many of the ring designers / manufacturers, and due to the diameter restriction of 6”, limited overall length.

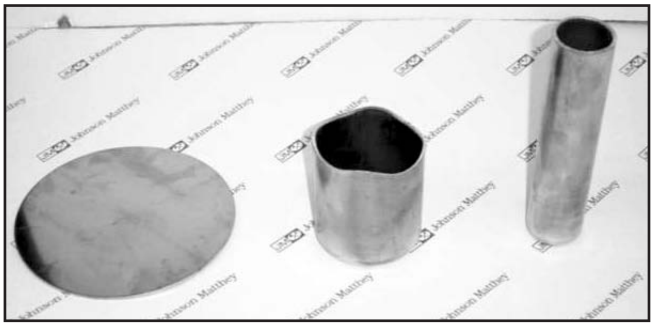


Figure 7

Here again, the advantages are maturity / acceptance of practice, and uniform fine-grained microstructures with mechanical properties equal to that of stamped ring blanks. However, the manufacturing process is extensive and therefore labor intensive. Working margin is not adequately reduced as round deep draw discs cut from rectangular sheet, as well as removal of the cupped end, substantially inhibit yield. In addition, depending upon equipment capabilities, there can be significant limitations on OD / ID Wall and overall length dimensions.

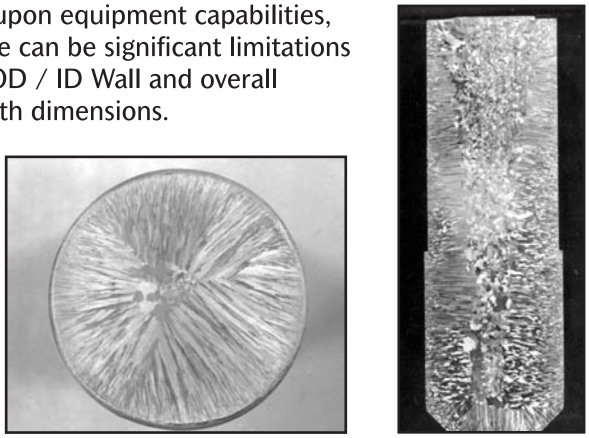


Figure 8

IV. Machined From Solid Bar Ring Blanks

In the late 1980's, Johnson Matthey began a major capital improvement plan to upgrade our machining capabilities with the acquisition of Computer Numerical Control (CNC) equipment including center hole boring capabilities. With this capability we examined the potential for center drilling solid rod to form heavy wall tube hollows.

Boring as-cast rods was rejected for many of the same difficulties presented by casting ring blanks directly, such as porosity and undesirable as-cast microsructures. The larger cross-sections exacerbated the micro structural inhomogeneities between center and surface regions as

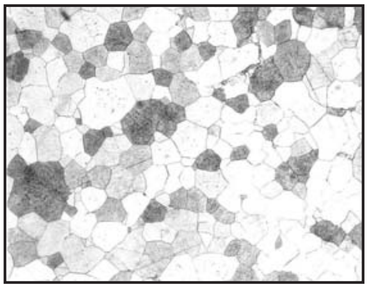


Figure 9

Table VI
Machine from Rod

- Cast round
- Forge / hot roll on falling heat or Extrude
- Cold roll / draw to desired OD dimension (reduction / anneal schedule appropriate for work-hardening rate of alloy)
- Straighten bar
- Machine OD / ID dimensions
- Part ring blanks
- Micro-structure and mechanical properties of blanks suitable for direct machining or optionally annealed for sizing from 1 – 9 ring sizes depending on alloy and method of sizing

shown in Figure 8. The surface or first region to freeze was extremely fine-grained equiaxed, followed quickly by highly directional elongated grains that followed the cooling / freezing gradients to a point in the center where grains once again nucleated in all directions, resulting in an equiaxed structure - albeit of a much coarser nature than the rapidly-frozen surface grains. In addition, on a microscopic basis, casting dendrites continued to be predominant throughout the cross-section. Although OD and ID could be readily machined to produce a heavy wall tube, resulting ring blanks could not be readily sized by tile predominant expanding techniques at the time.

This as-cast ingot structure is not unfamiliar to the primarily PGM manufacturers, and like many other metals industries, is generally converted by a hot-working operation such as forging, rolling or extrusion, to tile final equiaxed grain structure of Figure 9. Hence, the manufacturing method described in Table VI.

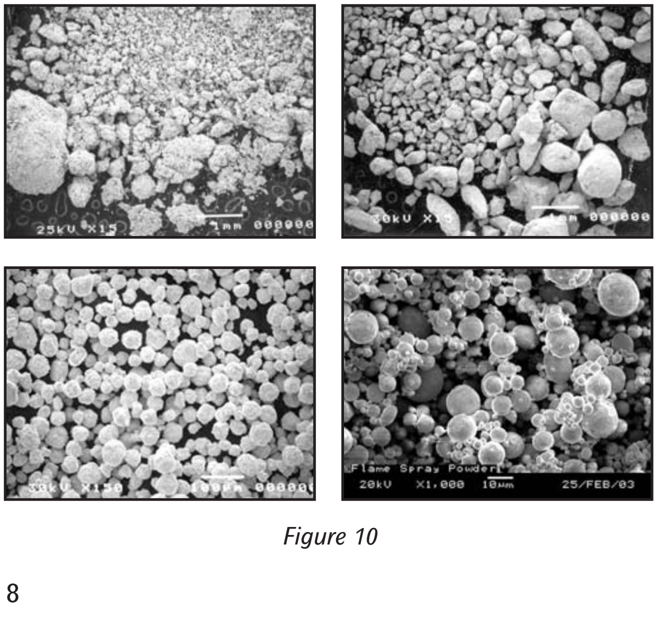


Figure 10

The advantages are straight forward - a significant reduction in operations from melt to finished ring blanks compared to stamping ring blanks from sheet, while achieving the desirable porosity-free, fine-grained microstructures with mechanical properties suitable for machining. The disadvantages are primarily related to working margin and physical limitations that restrict overall tube length. Machining of bar OD and ID to desired tolerance for wall thickness and concentricity is performed immediately prior to parting of individual ring blanks late in the process. This means carrying working margin well into the process before it can be cleaned and returned to melt, and from a length-to-volume consideration it represents a significant percentage of the material weight. However, with JM's reclamation and refinery capabilities, this metal recycling issue alone is not the only limiting factor.

Throughout the late 80's and early 90's Johnson Matthey was not the only one to enhance machining capabilities for speed and efficiencies. CNC equipment can run unmanned but still requires initial set-up time. Therefore, it is essential to maximize run time between set-ups which in turn creates a demand for longer length tubes feeding the process. These machines are also capable of precise dimensions with less “error tolerance” built-in to feed stock dimensions, providing of course that the feed stock can also be supplied with close tolerance control for bend, bow, and concentricity of wall.

Drilling long lengths of rod with cantilevered tooling to desired concentricity requirements was found extremely difficult beyond 8 - 10 inches, therefore, longer tubes suffered from increased variation in wall thickness. Further, ring machining houses complained of low yields on short bars due to the working margin taken by grips / collets. Four 10" bars require 4X the

Table VII
Powder Metallurgy

- Produce Powder (water/ gas atomize / other)
- Dry powder / de-gas (alloy geometry)
- Sieve powder to desired geometry characteristics
- Press powder to desired cylinder geometry
- Sinter in non-oxidizing / reducing atmosphere (alloy dependent)
- Coin cylinder to desired height (band width)
- Ring roll to finished OD / ID ring blank dimension
- Anneal as required to permit further sizing operations

working margin of one 40” bar that can be gripped in a collet only once for machining and parting.

Table VIII
Extrusion of Tube

- Melt and cast round ingot
- Machine OD & ID to extrusion cylinder (remove metal returned directly to melt and cast early in overall manufacturing process)
- Pre-heat extrusion billet
- * Extrude to desired OD / ID dimensions (1.50” OD x 1.00” ID x 24” L)
- Abrasive clean OD & ID
- Anneal (alloy dependent)
- Draw the tube to desired OD / ID dimensions (reduction / anneal schedule appropriate for work-hardening rate of alloy)
- Part ring blanks
- Machine OD / ID
- Micro-structure and mechanical properties of blanks suitable for direct finish machine or optionally annealed for sizing

Figure 11

Figure 12

Figure 13

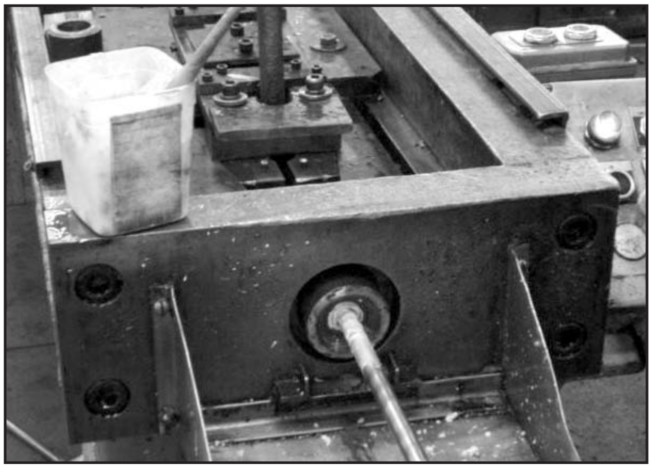


Figure 14

V. Powder Metallurgy Ring Blanks

By 1989 Johnson Matthey had considerable experience with PGM powders ranging from our flame spray, zirconia grain stabilized (ZGS) production of creep resistance platinum alloys for high temperature applications to compacted and sintered manufacture of Ru, Rh, and Ir sputtering targets. Although most other metal industries forming components by PM processing were producing closely controlled powder particle geometries by processes such as inert gas atomization, we were unable to find any vendors capable of dealing with the high Pt alloy melting points, and consequential excessive orifice wear of bottom feed crucibles.

However, since the process as described in Table VII is straight forward, less labor intense than stamping ring from sheet, and metal efficient due to near net shape manufacture, we felt this technology warranted further evaluations. Figure 10 represents a small sample of powder particle geometries - representing precipitated sponge, calcined sponge, flame spray and are spray powders. As can be readily observed, precipitated powders, whether calcined or not, were extremely variable in both size and geometry.

Further, there was as much variation from batch to batch of one sponge supplier as there was from supplier to supplier. The sponge frequently contained undesirable moisture content and could range from free flowing to agglomerated lumps. Flame spray and arc sprayed powders were significantly more consistent in regard to shape (generally spherical). However, standard distribution of particle sizes generally resulted in distributions with less than 10% of the particles in the desired range.

Attempts to use less desirable powder geometries resulted in reduced "as compacted" densities, and therefore, fragile green compacts prior to sintering creating significant handling problems. In addition, residual porosity after sintering resulted in unacceptable finished part mechanical properties, most notably catastrophic fracture while expanding the ring blanks to larger sizes.

Manufacturing blanks with sorted powder and applying post-sintering secondary operations such as Hot Isostatic Pressing (HIP) or a significant hot working process that would apply sufficient temperature and shear to close arid heal porosity such as "Gatorizing(4)", fluid die forging or hot ring rolling made significant improvements. However, the additional operations were cost prohibitive.

Although, we observed significant advantages in the:

- Reduction of process steps required, and therefore reduced labor sensitivities
- Near-net-shape capability and therefore improved material yield
- Potential for a wider range of alloys
- A very fine-grained microstructure with improved ductility

We were unable to develop a reliable source of consistent and cost effective powder. Further, compromises on the integrity of powder source were unacceptable in regard to product quality and / or too costly to rectify by additional secondary operations.

Hot Extrusion of Heavy Wall Seamless Tube

With the 1989 purchase of a 400 ton extrusion press intended primarily for the production of high volume Pt alloy rod / wire products, Johnson Matthey was in a unique position to investigate the extrusion of cored Pt alloy billets over a mandrel to produce heavy wall seamless jewelry tube that up until that point had been demonstrated only for karat Au alloys. The manufacturing process as demonstrated in Table IV was successfully reduced from 16 – 18 steps for stamped ring blanks to 8 – 10 for tube extrusion, as shown in Table VIII. In addition, the bulk of working margin was removed from the process after step two, permitting

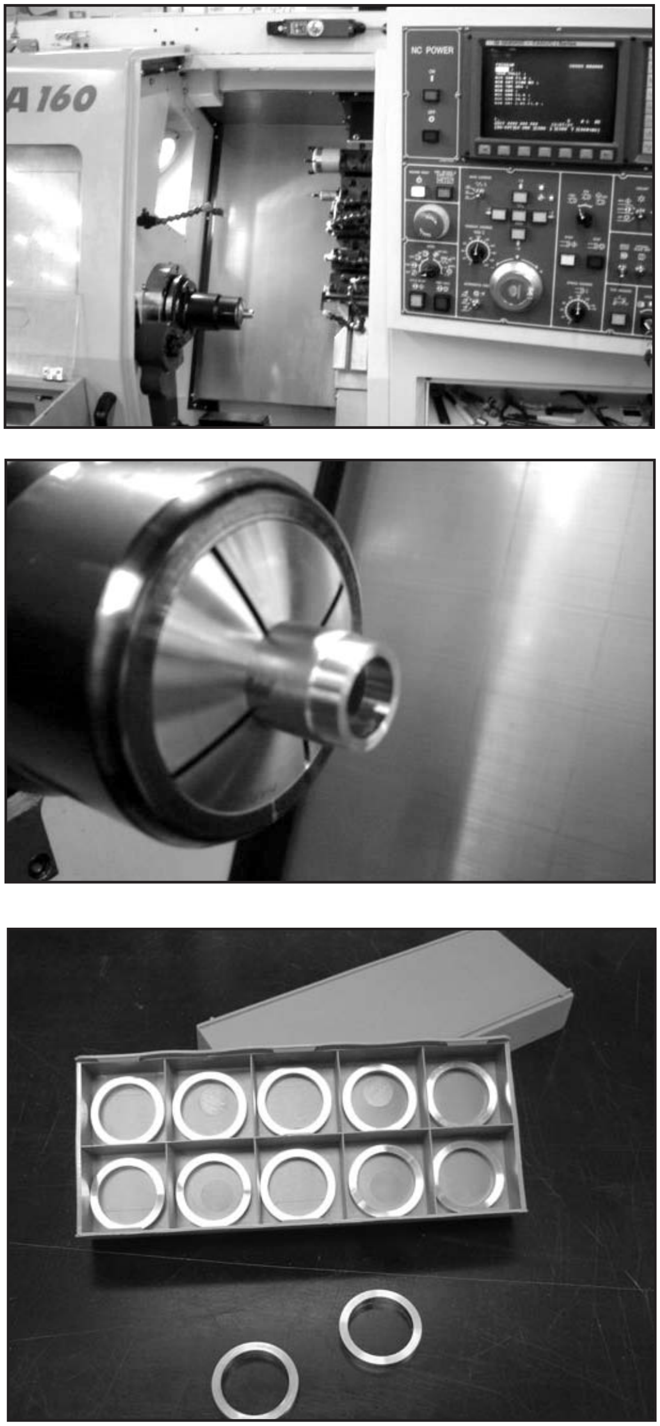


Figure 15

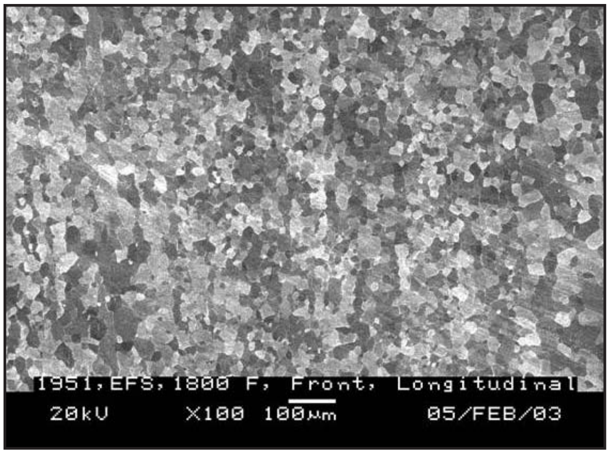


Figure 16

rapid return to the initial melt stage. The sequence of stages are shown in Figure 11 - (melt through billet machining), Figure 12 - the stacking of extrusion tooling and Figure 13 - removal of a hot extrusion billet in preparation for loading into the extrusion press. These processes are followed by batch annealing of extrusions, drawing tube on hydraulic benches and machining into ring blanks - Figures 14 & 15. The advantages include:

- The attainment of porosity free fine-grain microstructure - Figure 16 - and the associated desirable mechanical properties.
- Excellent dimensional control
- Material utilization superior to stamping ring blanks from sheet.

The only disadvantages we were able to identify initially included:

- Shallow OD / ID surface distress from frictional interactions between the die, tube and mandrel rectified by secondary operations such as centerless grinding of OD and ID honing.
- Tool wear at high Pt alloy hot working temperatures.

Overall, however, the assessment as compared to all of the other ring blank manufacturing methods was very positive. This process represented a reduction in processing steps and increased material yields by 100% while delivering finished ring blank quality equal to or better than that produced by the stamp from sheet process, thus meeting our original objectives and preparing Johnson Matthey For the demand in commercial ring blanks that was to follow over the next ten years.

Table IX
Conclusions

Stamped Ring Blanks			Extrusion of Tube	
Weight (g)	Labor		Weight (g)	Labor
13,900	X	Melt	11,900	X
12,500	X	Hot Top Removed	10,500	X
11,500	X	Machine	7,700	1.25 X
9,500	X	Roll / Extrude	7,700	0.50 X
1,700	X	Blank / Draw	5,500	X
1,500	X	Machine / Blanks	4,500	2.5 X
10%		Material Yield	37%	
6 X		labor	7.25 X	
80		Number Blanks	230	
x3				
240 Blanks				
18 x Labor				

The Final Analysis “Stamped Ring Blanks” versus Extruded Tube

A comparison of the manufacturing yields and labor sensitivities for stamped ring blanks and extrusion of tube is presented in Table IX. Typical weights from a single melt are shown for each of the six major manufacturing process steps in each method. Due to economies of scale that are realized by batch processing of several melts, the associated labor times for each step have been normalized and are shown relative to the labor for the “stamped from sheet” method.

Several key material yield advantages of the extrusion method were highlighted by this analysis. At only 10%, the material yield of the stamping process is well below that or the extrusion method at nearly 40%. Additionally, metal employment is lowered by 2000 grams per melt; representing one extra extrusion melt for every six sheet melts for stamped ring blanks. Looking at the incremental yield for each method, it is seen that nearly half of the working margin scrap is returned to melt by the mid-point of the extrusion process; whereas for the sheet method, nearly the entire working margin is carried through the process to the stamping stage.

At first glance it would appear that these improvements in material yield come at the expense of labor hours, as evidenced by the 20% increase in labor time per melt for the extrusion method relative to the stamping method. However, when the overall material yield is factored in, it is evident that for a given size ring blank, the extrusion method will yield approximately three times the number of blanks that can be stamped from one sheet melt. Therefore, with the necessity of processing three melts by the stamping method, the labor time increases to more than double that of the extrusion method for a comparable number of finished blanks. Additionally, with the need to process three times the number of melts, metal employment and working margin become even larger issues than initially indicated.

Taking the material yield and labor sensitivities into consideration, it is evident that the extrusion method represented significant improvements in process efficiency without sacrificing product quality.

The Last Ten Years

There have been a number of improvements to the manufacturing procedures evaluated by Johnson Matthey since 1989 / 1990. Technically advanced stamping equipment and tooling now permit the simultaneous stamping of ring and center disc in a single operation, saving time and further insuring OD / ID concentricity. Improved tooling materials require reduced maintenance. However, excessive webbing and disc working margins, plus secondary machining operations to clean up damage material at sheared edges remain as undesirable by products of this technology.

We have also come a long way in casting Pt alloys, both in the development or flask / mold materials(5) and casting equipment / techniques(6). Casting trees with reasonable gating systems can produce significant yields as demonstrated by Jurgen Maerz and Michael Epstein(7) for "Friendship Rings". Unfortunately, as-cast grain and dendrite structures still prohibit expansion / sizing, an essential requirement to minimize stocking volumes for wedding band application.

Much of the manufacturing improvements for the manufacture of tubing by the deep draw method has centered on the very small geometries. Tubing as small as 0.008" OD with a 0.002" wall is standard. However, the more popular heavy wall wedding band configurations remain outside the range of PGM manufacturing, and the process remains both labor and working margin sensitive.

There have also been advancements in the ability to produce longer length center-bored wrought rod stock. There are a limited number of vendors with highly proprietary processes who will quote heavy wall drilling capabilities up to 8 ft. in length. However, the tolerances beyond 12 inches remain undesirable (± 0.010" concentricity) and the processing at $40 - $90 / ft adds significant cost. Further, recovery and refining issues with tile center-bore machine scrap by subcontract vendors remains a significant and costly security issue when dealing with platinum alloys.

There have been exciting technical improvements for the production of near net shape wedding bands for 950 Hallmark Pt alloys(8). A combination of water and gas atomized powders has substantially improved green compact strength, eliminating many of the handling problems previously experienced. High density fine-grain microstructures are attainable and the need for expensive secondary operations (HIP, hot ring rolling, etc.) are no longer required for densities at 98% Plus. Unfortunately, the process continues to be related to a reliable source of powder within defined geometric parameters. Although powder for gold alloys is readily available, it remains extremely difficult to attain such powders in 950 Pt alloys.(9)(10)

Over the last ten years Johnson Matthey has continued to improve the extrusion manufacturing methods and resulting tube quality. Extensive development of die geometry / materials, mandrel materials, and high temperature lubricants has significantly extended tooling life. In addition, the early 0.005" to 0.007" ID surface defects have been reduced to an infrequent 0.00 1" ID defect. Lengths of 72 inches with straightness / bow tolerances of 0.030" and concentricity of ± 0.005" are now standard.

The Next Ten Years

Observing how much progress has been made in the platinum jewelry industry in the past ten years leaves no doubt that there will be more technological developments to come. We are developing and learning how to work with increasingly difficult alloy compositions such as the age hardenable grades that permit the restoration of hardness and wear resistance by heat treatment after forming and fabricating operations. At Johnson Matthey, we fully anticipate that such alloys will be available as long length heavy wall extruded tube.

What else might our industry develop over the next 10 years? Perhaps the momentum behind casting improvements will continue and techniques such as "GX"(11) or "MX"(11) that promote extensive nucleation of fine grain equiaxed microstructures in aero space alloys, may be incorporated into jewelry applications. Perhaps we will overcome current tooling deficiencies for the high inching point Pt alloys and continuous casting of Pt alloys will follow karat Au alloys to commercialization. If tooling for continuous casting is on the horizon, so must orifice tooling for crucibles used in water / gas atomization of platinum alloy powders. Perhaps such a breakthrough will also lead to the development of 950 Pt alloy compositions that would otherwise be unworkable / unmanufacturable.

If not the enhancement of one of the technologies discussed, perhaps we will develop a hybrid technology that combines the desirable attributes of two or more methodologies. This may include casting a net shape cored extrusion billet that when subsequently hot extruded will heal casting porosity and convert the as-cast microstructure to a fine grain equiaxed tube suitable for redraw and extensive sizing (expansion).

Whether a current technology breakthrough, the development of an all new technology or a hybrid of two or more existing manufacturing methods, it will be exciting to see whether or not an emerging technology will surpass Hot Extrusion of Heavy Wall Seamless Tube and become the next standard in ring tube / wedding band manufacturing.

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