Alpha Beta Extrusion of Titanium Alloys

George Legate
Nu-Tech Precision Metals
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- Extrude titanium, zirconium copper alloys, niobium, steels, Ni based alloys,
- Custom seamless pipe 1” to 8” NPS and custom sizes
- Pipe/ tube finishing (cold drawing, honing grinding)
- Cylinders to 15” OD X 54” long
Nu-Tech ... cont

- Structural shapes, flats and bars to 10” dia circle size
- Clad materials (eg: Ti clad copper) for anodes and buss bars
- Parts and appurtenances
- ISO 9001, AS 9100, NPT Stamp, ASME Material Organization,
Goals of this Presentation

- Alpha beta processed extrusions are very different from beta extrusions we want to show the differences.
- Dispel the “less than” mentality surrounding titanium extrusions
- Industry specs for alpha beta titanium don’t prevent the supply of extrusions
Goals - Cont

- Alpha Beta Extrusions can provide a competitive solution in some cases – we will define where those are
- Alpha Beta processed titanium extrusions have unique asymmetrical properties that may have potential applications for critical components
Titanium Extrusion History – What Caused the Misconception

- Titanium shaped extrusions developed in the mid to late 50’s for aircraft
- Certain shapes could only be produced using flat dies
- The use of flat dies and the relatively small size of presses available dictated the need to use hot extrusion temperatures
- A separate spec. was created for beta extrusions separating extrusions from rolled and forged products
Only the Beta Extrusions are different!
Beta vs. Alpha Beta

Annealed Beta

- Yield and UTS same
- Toughness better than alpha - beta
- Can’t be strengthened
- Issues with transverse ductility and core properties (die design)

Annealed Alpha Beta

- Yield and UTS same
- High cycle fatigue life better than beta
- Can be strengthened
Market for Alpha Beta Extrusions

- Users currently machining aircraft parts from AMS 4928 or 4967 bars or open die or closed die forgings or AMS 4911 heavy plate looking for near net in the annealed condition

- Users currently rough machining parts from bars or forgings or heavy plate and then heat treating we have substituted near net extrusions in the STA condition

- Low volume users of flat or round bars

- Users wanting Ti 6-4 (possibly 6-6-2) hollows for pilgering to hydraulic tube or flow forming to larger thin walled tube
Case Study

- Was... AMS 4928 Forged block saw cut – 60 lb
- Became Near Net Shape – 17 lb.
- Even though the extrusion is 2X the price of bar there was still a 45% cost savings
- 43 lb less metal to machine.
- Mechanical property and design reliability benefits
Applications for 6-4 extrusions (to date)

- **Input Hollows (6-4 ELI)** for pilgered hydraulic tube (fatigue resistance)
- **Input hollows for flow forming and cold drawing** (6” OD x 0.250 wall)
Shapes

- Replacement of AMS 4928 forged block (bar), annealed and STA condition (AMS 4934)
- Replacement of part machined from AMS 4967 Closed Die Forging
AMS 4928 Input Material for Closed Die forging

100 Sq in

19 Sq in

George Legate, President
Alpha Beta Extrusions

- Potential direct replacement for AMS 4928 or AMS 4911 products
- Improved fatigue resistance to beta processed products
- AMS 4928 input material for cold working, rolling or forging,
- Asymmetric and perhaps enhanced mechanical properties

George Legate, President
The Specs

- Most titanium specs AMS, MIL, and ASTM address the product form (bar, shape, wire, etc) they do not restrict the hot working method used to make it.
Why are most extrusions made in the beta range?

- Allows use of flat dies which are: cheaper to make, allow for more complex shapes, give better size control.

- Flat dies (used for titanium) fill best and have best size control with high ram speeds, strain rates of about 10. Presses are the water hydraulic.
Flat Dies

- Flat dies have high friction
- High strain rates increase material flow stress
Ram Speed (Strain Rate) Vs. Flow Stress for Ti 6-4

- Most titanium extrusion presses are water hydraulic which have comparatively high strain rates
To make flat die extrusions at high speeds one needs to lower the material flow stress.

Lower flow stress also leads to bigger billets, better yields and lower costs.
Flow Stress of 6-4 Vs. Temperature
Press Pressure Vs Billet Size
13 Sq Inch T Section
Flow in a Flat Die
Alpha Beta Extrusion

- Alpha beta extrusion is conducted at temperatures 200F to 300F below beta extrusions... thus the material flow strength is 2 to 2.5 X higher

- As such the opposite strategy is needed to compensate for the material strength: slow ram speeds, different lubricants, conical dies (lower friction), assured heating below the transus
Ingredients for Alpha – Beta Extrusion

- Oil hydraulic press capable of producing slower ram speeds (keeps the flow stress down)
Heating

- Heating that permits prolonged and controlled soak temperatures below the transus (also protection from material oxidation and hydrogen pick up during soak)
The use of lubricants and conical dies (sometimes complex) to reduce friction and flow stress
Flow in Conical Dies
Comparison of Conical Die Extrusion to Other Hot Forming Methods

- Flow in open die forging approx. 1.2 – 2 to 1 reduction per pass – overall (4 - 10 to 1)

- Flow in rolling plate or bar reduction of 1.15 to 1.2 per pass (10 - 40 to 1)
Comparison of Hot Forming Methods

- Flow in conical die
- Typical reduction 10 - 30 to 1
- Resolved stresses in conical dies are similar to forging and rolling (turn this photo on end and it’s a pot forging)
Typical Strain Rates of Hot Working Processes (in/in/sec)

- Normal Extrusion (water hyd) - 10 or more
- Finish Rolling - up to 10
- Rough rolling (plate rolling) - .1 to 2
- Press Forging – 0.01 to 1
- Extrusion (oil hyd ) – 0.01 to 2
Conical Die – Closed Die Forging
## Mechanical Properties – Annealed (Mid Extrusion)

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Mechanical Properties – STA (Mid Extrusion)

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Texture

XRD# CB83 Nutech Ti Extrusion Position 1
Basal Pole Figure
Fr Fo Ff
.342 .321 .338

XRD# CB83 Nutech Ti Extrusion Position 2
Basal Pole Figure
Fr Fo Ff
.302 .372 .326

XRD# CB83 Nutech Ti Extrusion Position 3
Basal Pole Figure
Fr Fo Ff
.258 .361 .341
Microstructure
There is such a thing as an alpha beta extrusion extrusion that meets AMS 4928, 4967 or 4911.

Not all extrusions are alike and that alpha beta processed extrusions using conical dies are part of the forged and rolled product family.

Alpha beta extrusions can be designed with exceptional mechanical properties and be used to solve unique problems, such as making 6-4 tubing.