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Flowformed Ti-6Al-4V AMS 4929 Seamless Tubular Parts

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Flowforming is an advanced, cold metalworking process for manufacturing seamless, dimensionally precise, tubular and rotationally symmetrical products. In this process, a cylindrical work piece (preform) is attached to a rotating mandrel. Compression is applied by a set of three CNC-controlled rollers that are moved along the length of the preform. This causes the metal to be plastically deformed in the axial direction along the rotating mandrel. The result is a seamless, cylindrical or tubular-shaped product with increased mechanical properties, superior surface finish, all with repeatable accuracy, on a part-to-part and a lot-to-lot basis. Flowforming readily produces features difficult to achieve by other forming methods, i.e. increasing and/or decreasing wall thickness, tapers, radii and steps.

Titanium pipe 8" schedule 10

Flowformed Ti-6Al-4V Production Parts

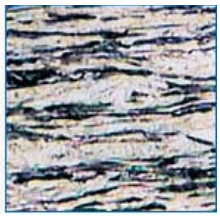
Dynamic Flowform Corporation of Billerica, Massachusetts, USA, an internationally recognized leader in the production of high-quality flowformed products, continues to expand its wide-ranging material-specific flowforming know-how. For example, tubular shapes in the popular Ti-6Al-4V alpha-beta alloy are now in regular production in commercial quantities in both conventional and extra-low-interstitial (ELI) composition grades.

Ring sections from production flowformed Ti-6Al-4V (conventional chemistry) tubular parts were tensile tested in a longitudinal direction (parallel to the axis of the tube). Pieces from two different mill lots were tested in the as-flowformed condition and after vacuum annealing at 1300 F for one hour followed by argon cooling. Tensile properties are shown below.

Lot	Spec. Id.	YS, (ksi)	TS, (ksi)	EL, %
Flowformed				
5	1	165.9	195.5	14.2
5	2	168.0	194.6	14.0
5	3	169.2	194.6	13.5
5	4	164.7	194.1	14.3
Flowformed + 1300 F anneal – argon cooled				
5	1	146.9	153.0	19.1
5	2	147.3	153.3	19.4
5	3	147.5	154.6	19.4
Flowformed				
6	1	165.7	198.3	13.1
6	2	165.8	194.1	13.7
6	3	165.5	195.2	13.0
6	4	162.7	192.0	13.3
Flowformed + 1300 F anneal – argon cooled				
6	1	145.3	153.3	19.9
6	2	146.8	154.1	19.9
6	3	146.7	153.8	19.5

Metallurgical Examination

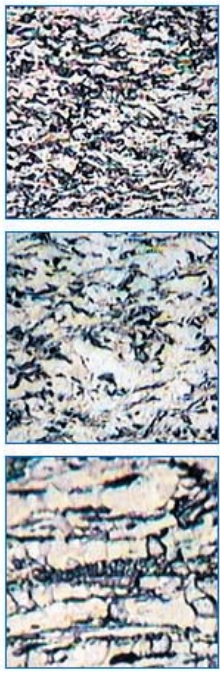
61L 400x



61L 800x

Specimens were cut from Lot 5 tensile test specimen 1 in the as-flowformed condition for micro examination in both the longitudinal and transverse direction – identified as 61L and 61T. Photo micrographs were taken at magnifications of 400X and 800X.

The microstructures show very fine primary alpha grains elongated along the axis of the tube in the direction of the metal flow from the flowforming process. The transformed beta surrounding the primary alpha grains is more clearly visible in the micro taken in the transverse direction 61T.



Top: 61T at 400x
Middle: 61T 800x
Bottom: 64L 800x

The effect of vacuum annealing at 1300 F for one hour followed by argon cooling (to simulate annealing of a flowformed finished part) is shown in a photomicrograph at 800X magnification from tensile specimen 1 cut from Lot5 identified as 64L (longitudinal direction). As expected, the 1300 F anneal has partially recrystallized the flowformed structure without completely eliminating the axial directionality produced in the flowforming process. The grain size is extremely fine -- ASTM 10 or finer.

No internal cracking has been observed in any of the specimens examined to date. This fact, coupled with absence of any surface cracking on the flowformed parts, demonstrates that the plastic deformation of flowforming processes at Dynamic Machine Works Inc. was accomplished well within the limits of the ductility of the metal.

Hardness Testing

Rockwell C hardness test data for the two conditions (average of three readings) show HRC 35.7 for the as-flowformed state and HRC 33.6 for the flowformed + 1300 F vacuum anneal – argon cooled state.

Conclusion

Conventional chemistry Ti-6Al-4V joins the wide-range of currently available alloys in regular commercial production in flowforming a variety of open and closed-end tubular parts at Dynamic Flowform. The plastic deformation of the flowforming process significantly increases the strength while still maintaining good tensile ductility. Furthermore, enhanced yield and tensile strength levels in the mid 140 ksi and mid 150s ksi respectively with elongation in the upper teens is produced by vacuum annealing at 1300 F for 1 – hour – argon cooling. Hence, the flowforming process offers the designer of tubular conventional chemistry Ti-6Al-4V annealed parts an opportunity to incorporate the higher strengths usually associated with a full solution and aging heat treatment at a superior level of tensile elongation.

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