MATERION

TECHNICAL REVIEW

Analysis of ToughMet® 3 and Cu-14Ni-3Al

ToughMet 3 and Cu-14Ni-3Al are both high strength copper alloys commonly used in the marine and oil and gas industries, but significant differences are realized when their properties are compared. This Technical Review discusses those distinctions that make ToughMet an advantageous replacement for the nickel bronze alloy in demanding applications and severe environments.

TOUGHMET 3

Materion's ToughMet 3 is a copper nickel tin alloy that is spinodally hardened with a unique combination of mechanical and physical properties. In particular, ToughMet's high strength, excellent corrosion resistance, and non-galling properties make it ideal for use in heavily loaded aerospace bushings, sour oilfield service, and subsea components. It also boasts low magnetic permeability, excellent machinability, and a fine grained and uniform microstructure.

HIDURON 130 & NIBRON SPECIAL[1]

Hiduron® 130 and Nibron® Special are Cu-14Ni-3Al alloys that are used for subsea hydraulic and electrical connectors, marine fasteners, and sea water valves. These alloys can also be found in airframe components or in high performance internal combustion engines. Like ToughMet, they are promoted as high strength copper alloys that are non-galling, resistant to corrosion, and have low magnetic permeability.

MECHANICAL PROPERTIES

ToughMet 3 provides an advantage over Cu-14Ni-3Al due to enhanced strength properties. ToughMet is strengthened by acombination of spinodal decomposition and cold work to produce various strength levels. Overall, ToughMet 3 exhibits better strength than Hiduron 130 and Nibron Special. As shown in Table 1, the yield strength of Cu 14Ni 3Al is reported to be a minimum of 555 MPa with a minimum tensile strength of 770 MPa. In comparison, all tempers of ToughMet have a higher 0.2% offset yield strengths than Cu 14Ni-3Al. Strength comparisons can also be found in Figures 6 and 7 in the Appendix.

Table 1.—Minimum Yield Strengths of CuNi4Al3 and T3

Alloy	0.2% YS (MPa)
Cu-14Ni-3Al	**555+**
T3 AT90	620+
T3 TS95	655+
T3 CX105	720+
T3 TS120U	755+
T3 AT110	760+

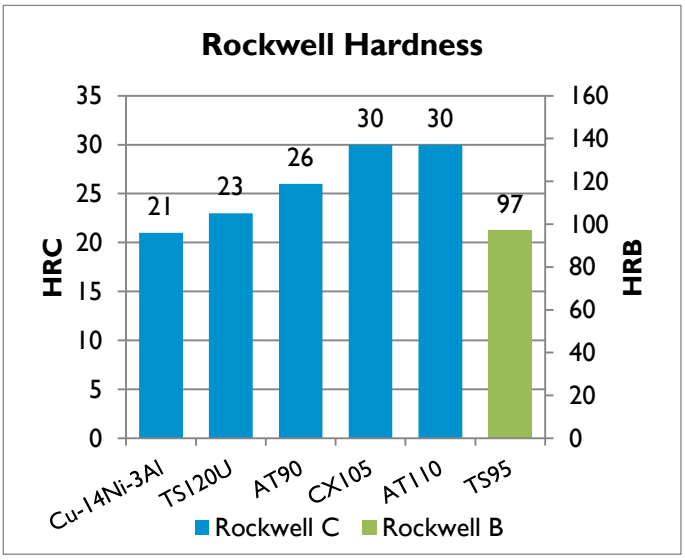

Figure 1. The minimum reported Rockwell C or B Hardness values for Cu-14Ni-3Al and a selection of ToughMet 3 tempers.

Also noteworthy is the fatigue life of these selected alloys. According to the data available, ToughMet exhibits a greater fatigue life than Hiduron 130 at 107 cycles. As shown in Figure 9 in the Appendix, the fatigue strength for Hiduron is 270 MPa, while T3 AT110's fatigue strength is 345 MPa.

Lastly, both ToughMet and Cu-14Ni-3Al are considered wear resistant materials, but ToughMet 3 can provide greater improvements for severe applications. Figure 1 shows a comparison of the hardness data reported for these alloys which is often the most significant indicator of wear behavior. The hardness of CX105 and AT110 is 30 HRC minimum whereas the hardness of Hiduron 130 is 21 HRC [2].

[1] ToughMet® is a registered trademark of Materion Brush Inc. HIDURON® is a registered Trade Mark of Langley Alloys Ltd NIBRON SPECIAL® is a Registered Trade Mark of Columbia Metals Ltd.

[2] Rockwell Hardness for Cu-14Ni-Al has been converted from Brinell hardness (HB 229).

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CRYOGENIC PROPERTIES

Unlike some steels, both ToughMet3 and Cu-14Ni-3Al do not have ductile-to-brittle transitions at cryogenic temperatures largely due to their face center cubic crystal structures. Figure 2 shows Charpy Impact Toughness data for ToughMet 3 TS95 and Nibron Special at temperatures down to -196oC. Materion tested the CVN impact strength of TS95 in accordance with ASTM E-23. The samples were taken longitudinally from mid-radius with notches cut in both the longitudinal circumferential (L-C) and longitudinal radial (L-R) orientations. The Nibron CVN data was obtained from 1.0" diameter rod with longitudinal samples taken from the 1/4T position. The results show that regardless of notch orientation, T3 TS95 absorbs a larger amount of energy than Nibron Special and likely demonstrates more ductile fracture behavior.

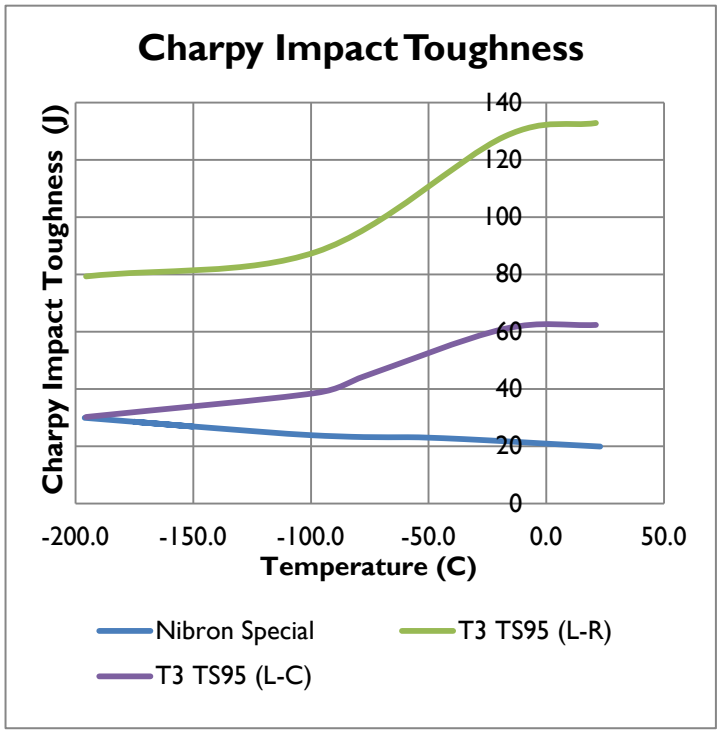

Figure 2. Cryogenic CVN data for ToughMet 3 TS95 and Nibron Special

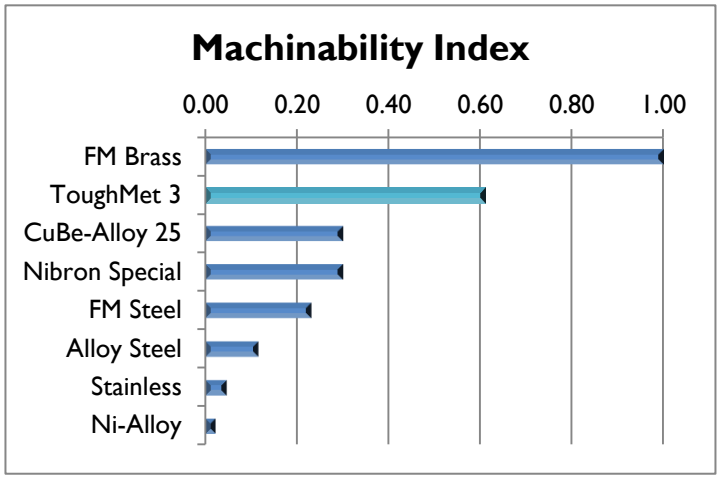

Figure 3. A comparison of relative machinability ratings compared to free machining brass (CZ121).

MACHINABILITY

Machinability is an important factor to consider when designing a product since quality and cost are affected by how easily a metal can be drilled, turned, etc. Although difficult to quantify, the machinability of alloys can be compared relative to free machining brass (Cu-36Zn-3Pb). Given a 100% machinability rating for free machining brass, ToughMet's machinability index is 61% as shown in Figure 3. This far exceeds that of other high strength alloys like Nibron Special which has a machinability rating of 30%.

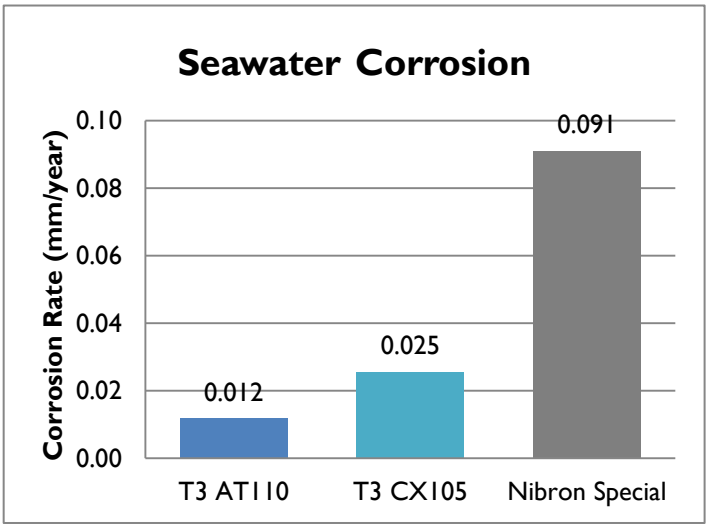

Figure 4. A comparison of general seawater corrosion rates for Nibron Special and ToughMet 3 after immersion in artificial seawater.

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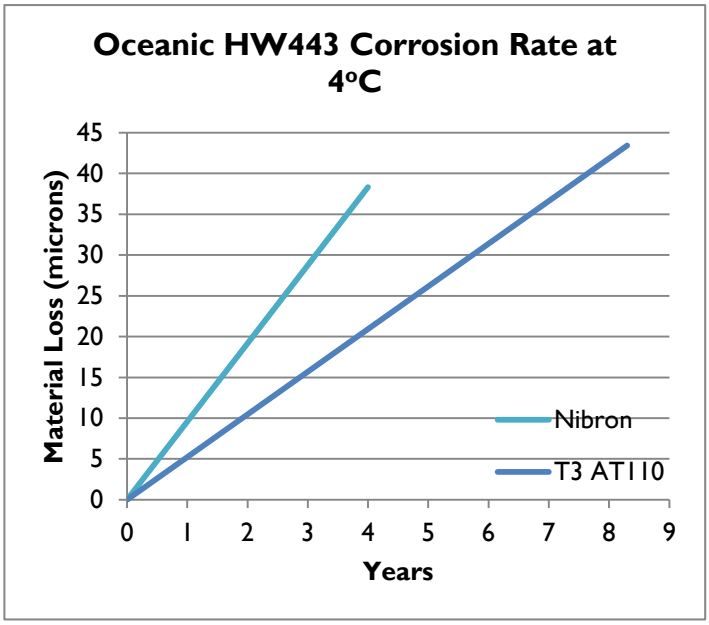

Figure 5. Corrosion of ToughMet 3 and Nibron when immersed in Oceanic HW 443 based on compatibility tests conducted by MacDermid Offshore Solutions.

COMPATIBILITY WITH OCEANIC FLUIDS

ToughMet 3 provides even greater compatibility with MacDermid Offshore Solutions' control fluids. These water based hydraulic media are used for their low viscosity in subsea production and control systems to protect against wear, corrosion, and microbiological degradation. Because ToughMet 3 and Cu-14Ni-3Al come into contact with Oceanic® subsea production control fluids in marine applications, compatibility is important to consider. Both materials have been assessed in similar immersion tests using MacDermid's Oceanic HW 443 fluid commonly used for open and closed loop Subsea Production control systems operating between 25°C and 145°C. In the test performed on Nibron Special, samples were immersed in Oceanic HW443 at 70oC to accelerate any chemical reactions that would occur. The material loss measured in the test averaged a 38.3 µm/year. The analysis states the test conditions were comparable to 4 years at seabed temperature (4oC), indicating an average corrosion rate of 9.575µm/year. Nibron is considered compatible with Oceanic HW 443, but MacDermid noted that slight pitting that occurred on the sample around the fluid-air interface.

In the HW 443 compatibility test performed on ToughMet 3, no pitting occurred. In this case, MacDermid concluded that expected corrosion rate experienced over 100 months at 4oC would average 5.21µm/year. As shown in Figure 5, ToughMet's corrosion rate in HW 443 is 46% less than that experienced by Nibron. Additional tests on ToughMet also concluded compatibility with Oceanic 540E, 720RC, and 740RC according to ISO 16328-6 methodology requiring the corrosion rate must be below 10 µm/year and that localized corrosion must be less than 20 µm in depth.

H2S CORROSION

Although ToughMet has not been directly tested against Cu-14Ni-3Al in a hydrogen sulfide corrosion test, both are promoted as alloys that outperform industry standard copper beryllium in H2S environments due to enhanced corrosion resistance. In one experiment, the corrosion rates were measured for various ToughMet 3 tempers and Alloy 25 (C17200) to determine NACE Level IV and V corrosion rates. According to MR0175, the NACE test conditions were 194oF and 0.4 psi partial pressure hydrogen sulfide for Level IV and 302oF and 100 psi partial pressure hydrogen sulfide for Level V. As shown in Table 2, ToughMet 3 exhibited corrosion rates about 10 to 20% that of copper beryllium in Level IV and V.

Table 2.—NACE MR0175 corrosion rates for T3 and Alloy 25

Alloy	NACE Level IV	NACE Level V
T3 CX105	10.0 µm/yr	1.17 mm/yr
T3 TS95	2.5 µm/yr	1.21 mm/yr
T3 AT110	7.6 µm/yr	1.30 mm/yr
T3 TS120U	5.1 µm/yr	1.42 mm/yr
25 HT (BeCu)	50.8 µm/yr	6.76 mm/yr

CONCLUSIONS

Both ToughMet 3 and Cu-14Ni-3Al alloys are promoted as high strength copper alloys with resistance to wear, galling, and corrosion. However, in a direct comparison, ToughMet provides clear mechanical property advantages such as increased strength, better fatigue life, and greater hardness for wear resistance. Even further, ToughMet's mechanical properties are well retained at cryogenic temperatures. ToughMet can provide added benefits over nickel bronze if machinability, seawater corrosion, compatibility with subsea control fluids, or performance in hydrogen sulfide environments is a concern.

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APPENDIX

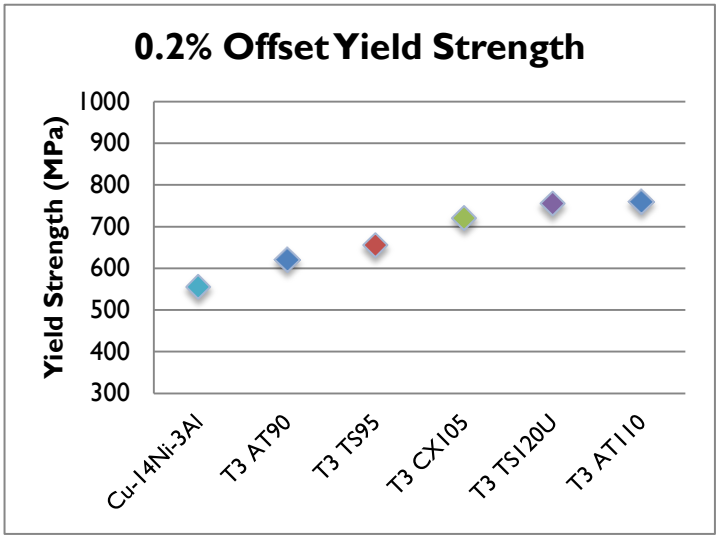

Figure 6. The reported minimum yield strength values for Hiduron 130/Nibron Special compared to the minimum values for various ToughMet tempers.

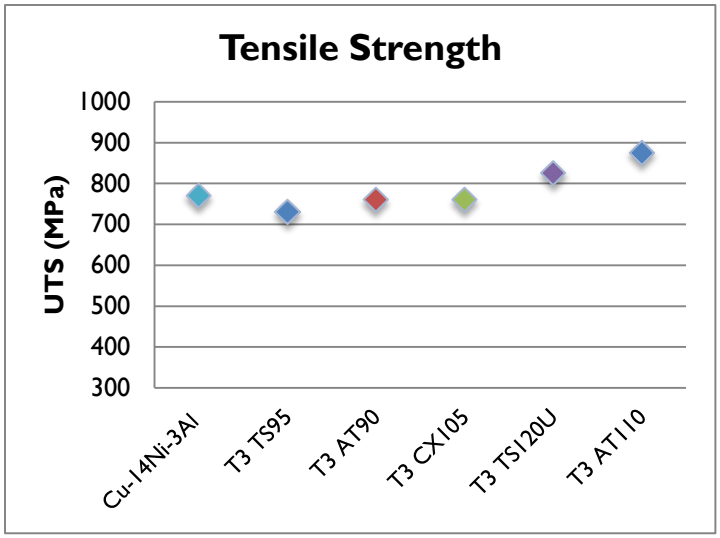

Figure 7. The reported minimum tensile strengths of Hiduron 130 and various tempers of ToughMet 3.

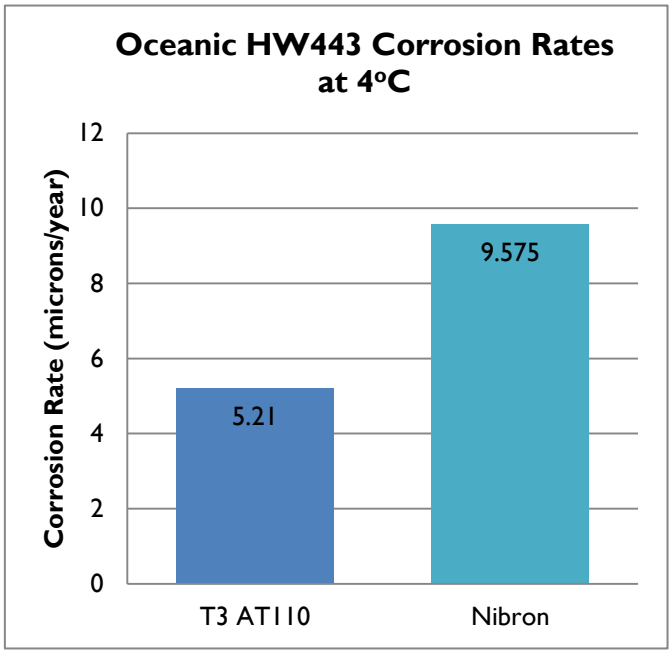

Figure 8. Corrosion rates determined by MacDermid Offshore Solutions for ToughMet 3 and Nibron in contact with Oceanic HW 443 at seabed temperature.

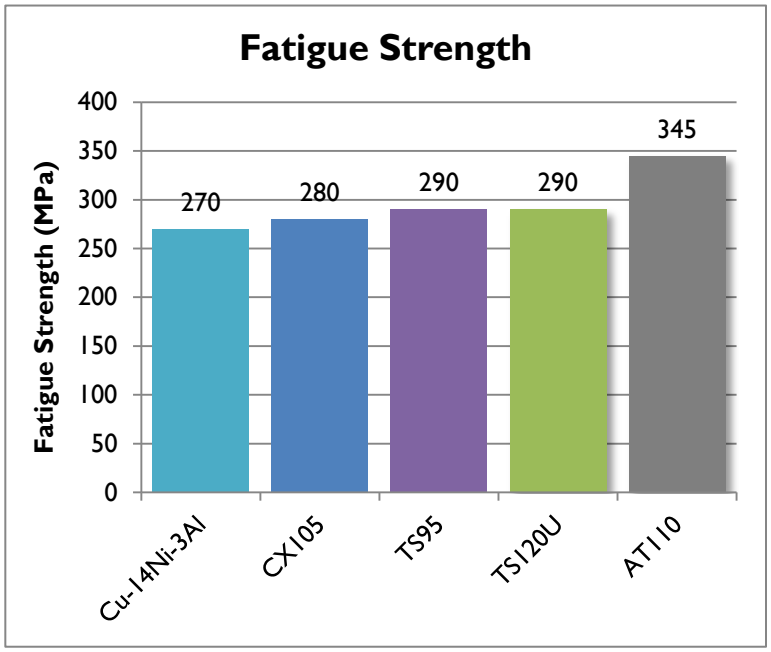

Figure 9. Fatigue strengths documented for ToughMet 3 and Hiduron 130 at 10^7 Cycles, R=-1.

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