MATERION

TECH BRIEF

COMPARISON OF TOUGHMET® 3 AND NICKEL ALUMINUM BRONZES

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 the differences that make ToughMet a superior replacement for the nickel bronze alloy in demanding applications and severe environments.

TOUGHMET 3 ALLOY

Materion's ToughMet 3 is a copper-nickel-tin alloy that is spinodally hardened, giving it a unique combination of mechanical and physical properties. 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 copper-nickel-aluminum alloys that are used for subsea hydraulic 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, non- magnetic copper alloys that are non-galling and resistant to corrosion. Their chemical composition is 14% nickel, 3% aluminum, and 1% iron.

MECHANICAL PROPERTIES

ToughMet 3 provides an advantage over Cu-14Ni-3Al due to its superior strength properties. ToughMet is strengthened by a combination of spinodal decomposition and cold work to produce various strength levels and property ranges. Materion's temper designations are as follows: CX indicates a cast product; AT indicates a hot worked product; and TS indicates a cold worked product. Overall, ToughMet exhibits better strength and hardness than Hiduron 130 and Nibron Special. As shown in Table 1, Cu- 14Ni-3Al's minimum yield strength is 81 ksi. In contrast, all tempers of ToughMet have higher 0.2% offset yield strengths than Cu-14Ni-3Al. Tensile strength and hardness comparisons can be found in Figures 6 and 7 in the Appendix.

Also noteworthy is the fatigue life of these selected alloys. According to the data available, ToughMet exhibits a greater fatigue strength than Hiduron 130 in fully reversed testing (R=-1) at 107 cycles. As shown in Figure 8 in the Appendix, the fatigue strength for Hiduron is 39 ksi while ToughMet tempers exhibit fatigue strengths between 40 and 42 ksi.

TABLE 1. – MINIMUMYIELD STRENGTHS OF CU-14NI-3AL AND T3

Alloy	Minimum 0.2% YS (ksi)
Cu-14Ni-3Al	81+
T3 AT90	90+
T3 CX90	90+
T3 TS95	95+
T3 CX105	105+
T3 TS120U	110+
T3 AT110	110+
T3 TS130	130+
T3 TS160U	150+

GALLING RESISTANCE

Both ToughMet and Cu-14Ni-3Al are considered wear resistant and anti-galling, but ToughMet 3 can provide greater improvements for severe applications. A button-on-block test per ASTM G98 was conducted to determine the comparative galling resistance between ToughMet and Cu-14Ni-3Al. In this method, a load is applied between a button material and block material. Then, the button is rotated to create sliding contact between the metal surfaces. Afterwards, both materials are microscopically inspected for metal transfer, a clear indication of galling. The galling threshold stress is determined as the average between the highest contact pressure at which no galling occurred and the lowest contact pressure at which evidence of galling was found.

For this test, the chosen base materials were ToughMet 3 TS95, ToughMet AT110, and Cu-14Ni-3Al. and the buttons consisted mostly of steels and nickel alloys. Note that the test was run without lubrication at ambient temperature. The galling threshold stress results are displayed in Figure 1. For every button material tested, the galling resistance of T3 TS95 and AT110 far exceeded that of Cu-14Ni-3Al. The maximum equipment load was reached for the ToughMet3 TS95 vs. AT718 test without any evidence of galling. Therefore, the galling threshold stress between these two materials is likely higher than what is reported. Unlike many metals, ToughMet TS95 and AT110 have excellent galling threshold stresses even when self-mated (compare to Nibron vs. Nibron in Figure 1). In fact, self-mated ToughMet still outperformed Nibron's most advantageous pairing of ATI 718.

CRYOGENIC PROPERTIES

Unlike some steels, ToughMet 3 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 published Charpy Impact Toughness data for ToughMet 3 TS95 and Nibron Special at temperatures down to -320 °F.

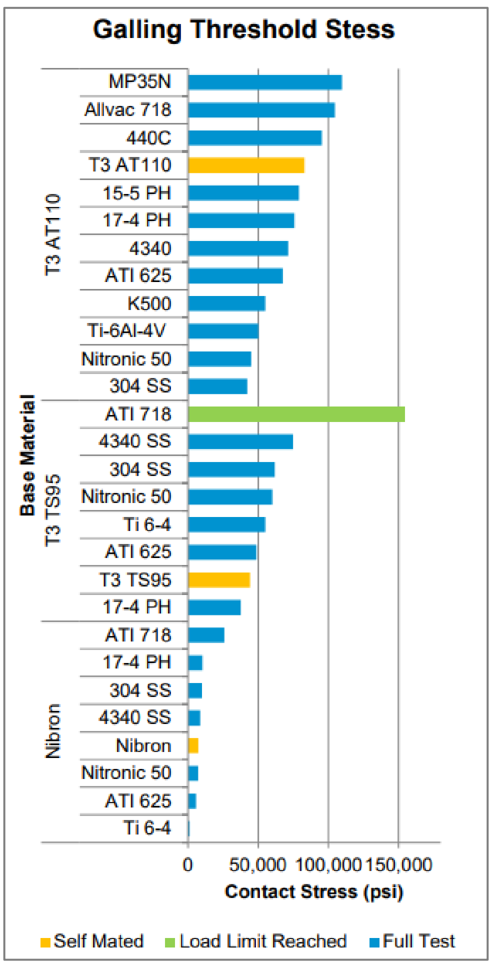

Figure 1. Galling threshold stresses of Cu-14Ni-3Al compared to ToughMet 3 TS95 and AT110 for several material combinations.

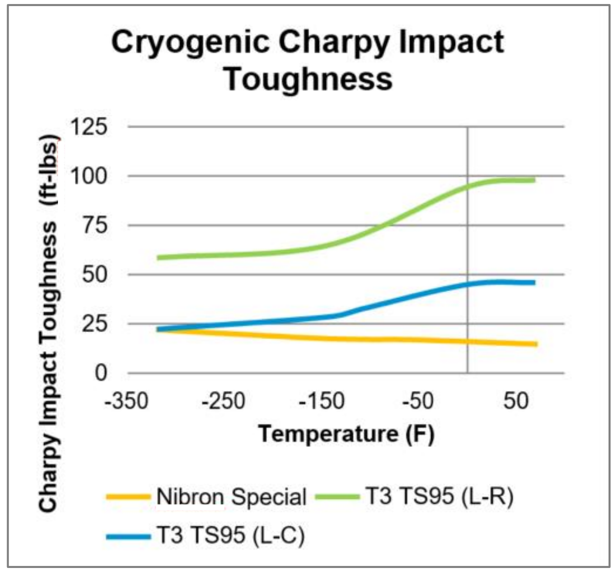

Figure 2. Cryogenic CVN data for ToughMet 3 TS95 and Nibron Special

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 T3 TS95 absorbs a larger amount of energy than Nibron Special and likely demonstrates more ductile fracture behavior despite its higher strength.

SEAWATER CORROSION

Copper–based alloys generally resist biofouling and seawater corrosion but often do not have the strength required for subsea valves, fasteners, and shafts. Unlike most of these copper alloys, ToughMet combines both high strength and corrosion resistance.

To determine ToughMet's general seawater corrosion rate duplicate specimens of T3 AT110 and T3 CX105 were submersed in ASTM D1141 artificial seawater for 91 days. AT110 and CX105 demonstrated 0.46 and 1.00 mpy corrosion rates, respectively (Figure 3). These mass loss results indicate that ToughMet's corrosion resistance is comparable to that of CuNi alloys. When cathodic protection is used in seawater, ToughMet retains its load bearing capability better than cupronickels because it is not susceptible to chloride stress corrosion cracking or hydrogen embrittlement under these conditions. Based on a 30-day immersion test in 3.5% NaCl at 68 degrees Fahrenheit, Nibron Special also exhibits general seawater corrosion rates similar to CuNi alloys. After the 15th day of exposure, Nibron settled at 3.58 mpy and held constant for the remainder of the test duration.

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In order to provide a direct comparison of the corrosion behaviors of ToughMet, and Cu-14Ni-3Al in NaCl environments, Materion conducted a salt fog test in accordance with ASTM B117. The salt solution was 5% NaCl by mass and the salt fog chamber temperature was maintained at 95 degrees Fahrenheit. Each polished sample was oriented 30 degrees relative to the salt spray nozzle and images were taken daily to determine general resistance to corrosion for the two week test. Table 2 displays each sample's surface appearance before and after 336 hours of exposure inside the salt fog chamber. ToughMet AT110 and AT90 demonstrated the least surface degradation.

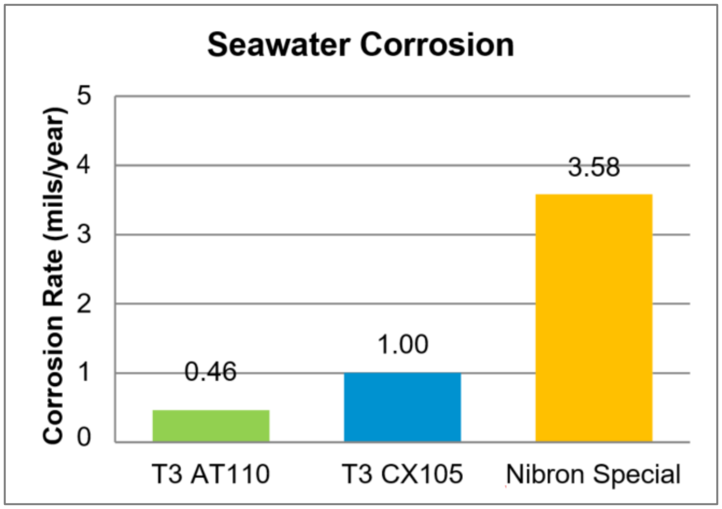


Figure 3. A comparison of general seawater corrosion rates. Nibron Special's corrosion rate is based on a 30-day test, while ToughMet's corrosion rate was obtained from a 91day test.

H_2S 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 the industry standard copper beryllium in H2S environments. 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.

TABLE 2. CU-14NI-3AL ALLOYS VS. TOUGHMET TEMPERS

Before and after 336 hours of exposure in a salt fog chamber

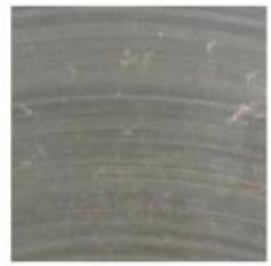
	Before	After 336 hours
Nibron		
Hiduron 130		
AT110		
AT90		
CX105		

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TABLE 3. – NACE MR0175 CORROSION RATES FOR T3 AND ALLOY 25

Alloy	NACE Level	NACE Level V
T3 CX105	0.4 mils/yr.	46.1 mils/yr.
T3 TS95	0.1 mils/yr.	47.7 mils/yr.
T3 AT110	0.3 mils/yr.	51.3 mils/yr.
T3 TS120U	0.2 mils/yr.	55.8 mils/yr.
25 HT (CuBe)	2.0 mils/yr.	266.3 mils/yr.

In accordance with NACE MR0175, the test conditions were 194°F and 0.4 psi partial pressure hydrogen sulfide for Level IV and 302°F and 100 psi partial pressure hydrogen sulfide for Level V. As shown in Table 3, ToughMet 3 exhibited corrosion rates about 80% - 90% lower than copper beryllium in Level IV and V.

COMPATIBILITY WITH OCEANIC FLUIDS

ToughMet 3 provides excellent 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 often 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 75°F and 295°F.

In the test performed with Nibron Special, samples were immersed in Oceanic HW443 at 158oF to accelerate any chemical reactions that would occur. The material loss measured in the test averaged 1.51 mils/year. The analysis states the test conditions were comparable to 4 years at seabed temperature (39°F), indicating an average corrosion rate of 0.38 mils/year. Nibron is considered compatible with Oceanic HW 443, but MacDermid did note that slight pitting occurred on the sample around the fluid-air interface.

In the HW 443 compatibility test performed on ToughMet 3, no pitting occurred. MacDermid concluded that the expected corrosion rate experienced over 100 months at 39oF would average 0.21mils/year. As shown in Figure 4, ToughMet's corrosion rate in HW 443 is significantly less than that experienced by Nibron. Additional tests on ToughMet also

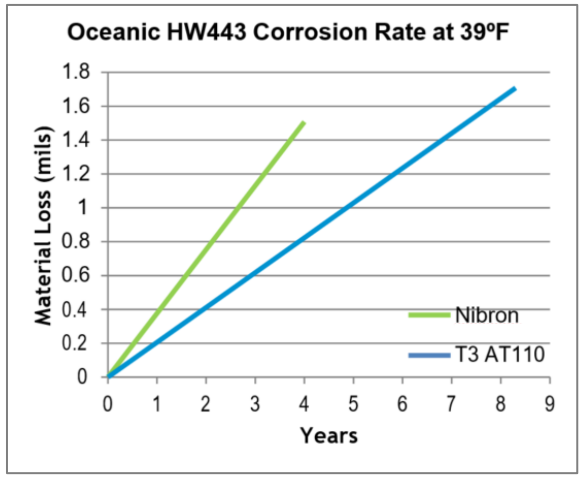

Figure 4. Corrosion of ToughMet 3 and Nibron when immersed in Oceanic HW 443 based on MacDermid Offshore Solutions compatibility tests.

concluded compatibility with Oceanic 540E, 720RC, and 740RC according to ISO 16328-6 methodology requiring that the corrosion rate must be below 0.39 mils/year and that localized corrosion must be less than 0.79 µm in depth.

CONCLUSIONS

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

For more information, visit www.materion.com/PAC.

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APPENDIX

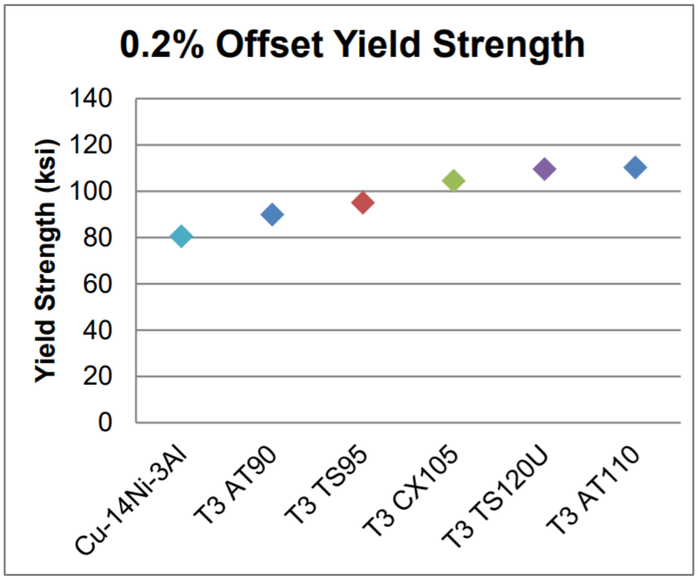

Figure 5. The reported minimum yield strength values for Hiduron 130/Nibron Special compared to the minimum values for various ToughMet tempers.

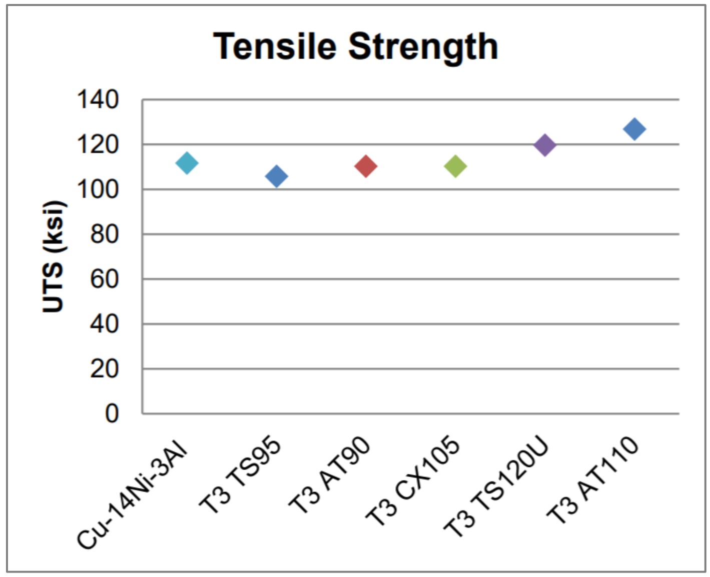

Figure 6. The reported minimum tensile strengths of Hiduron 130 and various tempers of ToughMet 3.

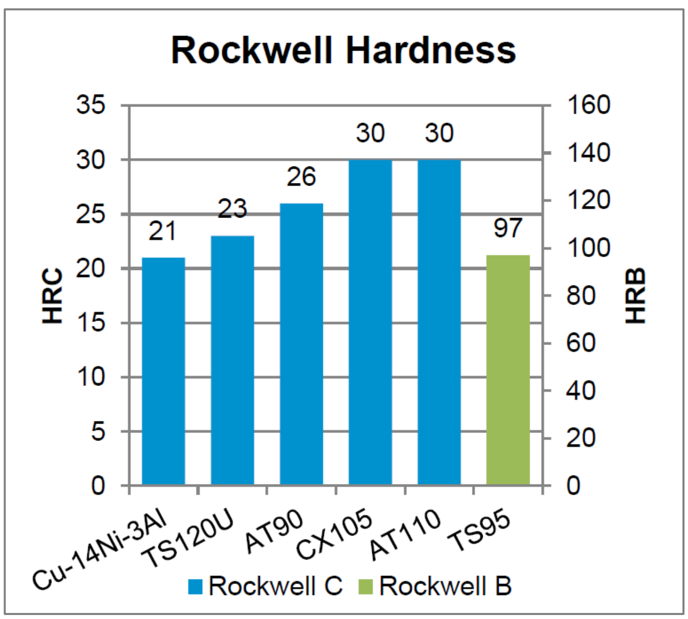

Figure 7. The minimum reported Rockwell C or B Hardness values for Cu-14Ni-3Al and a selection of ToughMet 3 tempers.

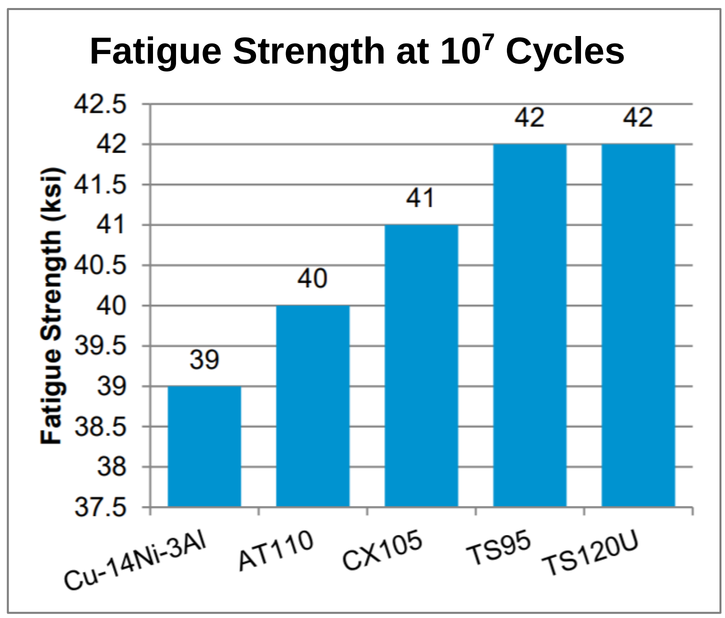

Figure 8. Fatigue strengths documented for ToughMet 3 and Hiduron 130 at 10^7 Cycles, R=-1.

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

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