Continued Improvements in Alloy Conductors

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Abstract

Percon® 28 is the latest conductor alloy developed by Fisk Alloy. Percon 28 is designed to exceed the requirements of ASTM B624 and the related specifications MIL-DTL-29606 and NEMA WC 67. Whereas ASTM B624 specifies a minimum of 60 ksi (414 MPa) tensile strength and 85% IACS electrical conductivity, Percon 28 offers 80 ksi (550 MPa) minimum tensile strength and 85% IACS electrical conductivity. Hence, there is no sacrifice in electrical conductivity while minimum strength is increased by 33% from 60 ksi to 80 ksi. Percon 28 has high resistance to thermal softening enabling the conductor to be insulated with high temperature insulation such as fluorocarbon polymers and withstand high operating temperatures when in use. This alloy is manufactured utilizing casting and processing techniques not requiring costly or unconventional methods. Percon 28 is an environmentally “green” alloy and does not contain any hazardous elements such as cadmium or beryllium.

Through its increased strength Percon 28 provides substantially greater flex life than current alloys meeting the requirements of ASTM B624. Similarly, savings in conductor weight and size can be achieved by reducing the gauge size of conductors made from Percon 28 so as to have the same break load strength of larger conductors that are made from lower strength alloys. Percon 28 is suitable for aerospace, medical, electronic, automotive and other applications requiring high strength, exceptional flex life and looking for weight savings.

Introduction

Copper alloys are utilized in applications where mechanical properties of copper are insufficient for the application. The addition of other elements to copper to make an alloy for increased strength will reduce the electrical conductivity relative to pure copper. Cadmium-copper C16200 (C162), a binary solid solution alloy, was one of the original copper alloys used for high strength applications. Cadmium is an effective element for improving the properties of copper. The addition of 1% cadmium to copper, as in cadmium copper alloy C162, reduces the electrical conductivity less than 10% while greatly increasing the strength of the alloy.

The addition of (non-hexavalent) chromium to copper results in a precipitation hardenable alloy which depending on the chromium content can attain an electrical conductivity of greater than 80% to 90% IACS when thermally treated. Copper-chromium alloys have a soft temper break strength of hard copper but unlike hard copper have stable properties at elevated temperatures. Copper-chromium systems provide the basis for high performance conductor alloys combining properties of strength, conductivity and elongation as proscribed by ASTM B624. For example Alloy C18135 (a.k.a. PD135) is a copper-chromium-cadmium alloy. Percon 24 is a copper-chromium-zirconium alloy. Both alloys are engineered to meet the requirements of ASTM B624. Alloy C17510, a substantially more expensive beryllium containing alloy, recognized in the industry as CS95 or HS95, has been used where even higher levels of strength than ASTM B624 are needed. Whereas ASTM B624 requires an electrical conductivity of 85% IACS and 60 ksi strength, alloy C17510, an ultra-high strength alloy, attains a 95 ksi (655 MPa) strength at a sacrificed electrical conductivity of only 63% IACS.

Environmental and health concerns resulting in the introduction of RoHS regulations created a flurry of activity to introduce products which did not contain hazardous metals such as cadmium. Percon 17, Percon 19 and Percon 24 are green conductor alloys introduced by Fisk Alloy over a decade ago to address the issue of hazardous metals in conductors. Percon 17 and 19 are alloys designed to replace soft and hard cadmium copper C162 respectfully. Percon 24 was designed to meet the requirements of ASTM B624 and in so doing provide a replacement for the copper-chromium-cadmium alloy C18135.

Over the intervening years Fisk Alloy continued the work on alloy development to improve alloy conductor properties significantly beyond what has been available. This work has culminated in the introduction of Percon 28, a new high performance copper-chromium alloy which is also environmentally green.

Existing Alloys

The challenge of improving the properties of a metal by alloying is typically faced with a compromise; increasing one characteristic results in decreasing the other. As stated, for copper alloys increasing the strength causes a reduction in electrical conductivity. Soft copper has 100% electrical conductivity and 35 ksi tensile strength. Specifications for soft C162 vary but they are typically

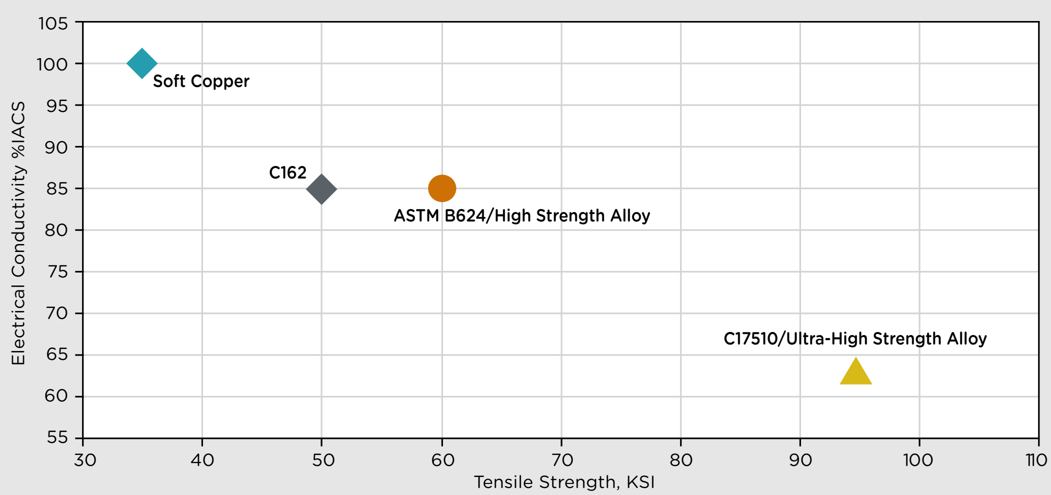

FIGURE 1 : ELECTRICAL CONDUCTIVITY VS TENSILE STRENGTH OF STANDARD ALLOYS

85% IACS and 50 ksi (350 MPa) tensile strength. As previously stated, ASTM B624 requires an electrical conductivity of 85% IACS and 60 ksi tensile strength while C17510 or the ultra high strength alloy has an electrical conductivity of 63% IACS and 95 ksi tensile strength. These combinations of properties are illustrated in Figure 1.

Development of Percon 28

An ideal high strength alloy would provide increased tensile strength without any reduction in conductivity. Hence, the aim for Percon 28 was to develop an alloy which maintains the required minimum 85% IACS electrical conductivity but raises the tensile strength as far as possible. A further goal was for the alloy to be cast and processed via standard technology to assure an economical product and that this alloy would also be environmentally friendly. The combination of properties for the resulting alloy, Percon 28, is illustrated in Figure 2.

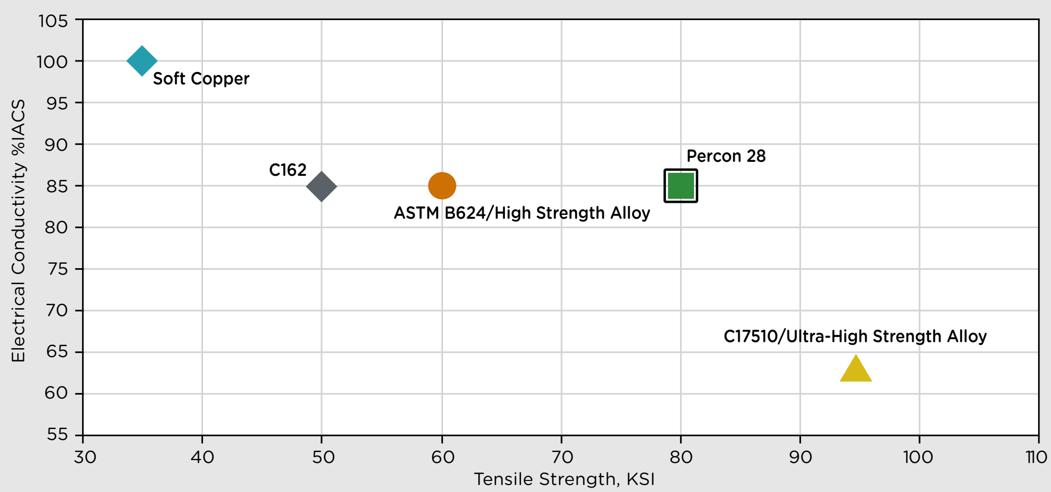

FIGURE 2 : PERCON 28 COMPARED TO THE EXISTING ALLOYS

Percon 28 is also based on the copper-chromium system. As such, it is also a precipitation hardenable alloy. The alloy chemistry has been engineered to provide the optimum combination of tensile strength and electrical conductivity while providing high softening resistance.

Performance

Flex Life : Flex life of a 26 AWG 19/38 unilay construction Percon 28 conductor was compared with those of other copper alloy 26 AWG 19/38 unilay conductors. The test was conducted according to ASTM B470 and the results are shown in Figure 3. The specified test parameters for the test are: mandrel diameter 0.0625 inches; mandrel spacing 0.026 inches; weight 149 grams; 30 cycles per minute over a ±60° arc. The results are an average of many tests conducted on each alloy. The figure compares Percon 28 to copper as well as other alloys. Percon 24 and C18135 are alloys meeting requirements of ASTM B624 (high strength alloy) and HS-95 is the ultra-high strength alloy. The flex of copper is set at a unit of one and the relative flex life of other alloys are

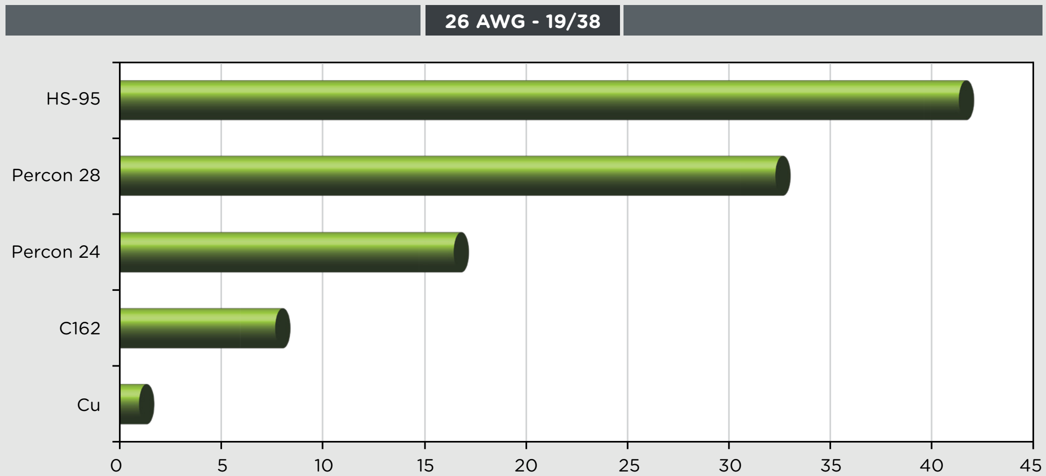

FIGURE 3 : ASTM B470 FLEX LIFE OF COPPER ALLOYS RELATIVE TO COPPER

compared as multiples thereof. As expected, the ultra-high strength alloy provides the highest flex life. Percon 28, however, shows twice the flex-life of the existing ASTM B624 alloys and achieves nearly 80% of the ultra-high strength alloy flex life and does so with 35% higher conductivity.

Softening Resistance : Softening resistance is an important consideration for conductors. Softening resistance of Percon 28 was determined at 350°C and 400°C for times up to 1 hour. The results are shown in Figure 4 where it is

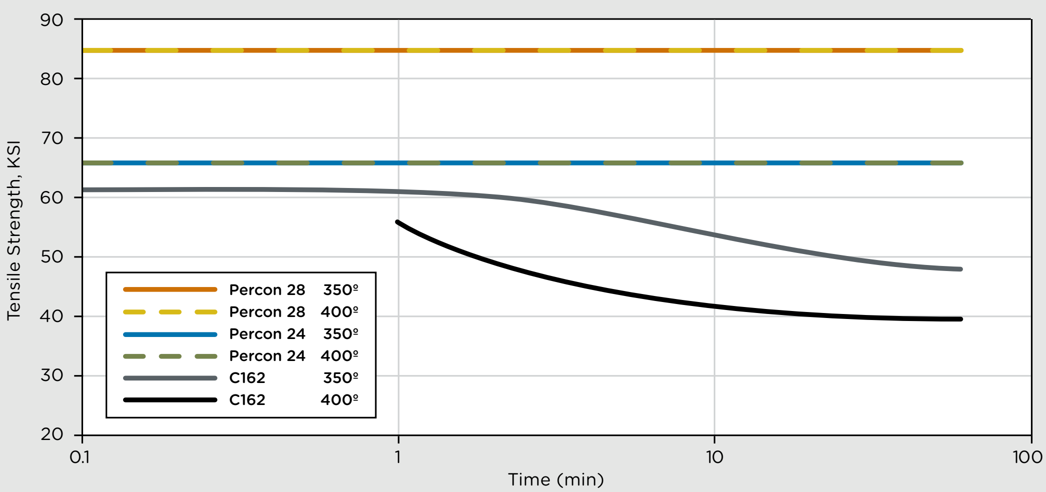

FIGURE 4: SOFTENING RESISTANCE OF CD-CU, PERCON 24 AND PERCON 28

compared to Cd-Cu alloy C162, Percon 24. Softening behavior of alloy C18135 is similar to Percon 24 and is not included to simplify the chart. All three alloys, Percon 28, Percon 24 and C18135 as copper-chromium based systems are quite stable up to 1 hour at these temperatures and do not soften to any measureable extent. Cd-Cu C162, on the other hand, shows drastic softening at these temperatures.

Applications: Opportunities for Weight and Size Reduction

Percon 28 is suitable for applications in aerospace, automotive, medical, electronics, etc. where high electrical conductivity, high strength and flex life are key attributes. The high strength and high flex life of the alloy may be used to either improve performance where the existing alloys are found wanting or save weight by reducing the conductor gauge size while maintaining a high breaking load.

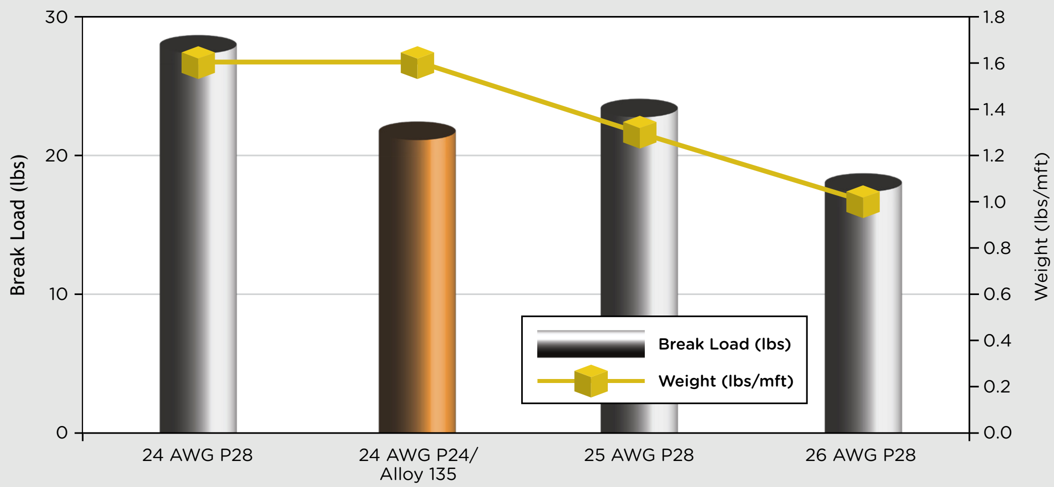

FIGURE 5 : BREAK LOAD & WEIGHT OF PERCON 28 COMPARED WITH ASTM B624 ALLOYS

In an aerospace application requiring an ASTM B624 conductor the weight saving achieved by using Percon 28 to reduce the gauge size was analyzed. The application utilized a 24 AWG 19/36 unilay construction. The analysis is illustrated in Figure 5 where the weight and break load for the 24 AWG conductor made from alloy C18135 and Percon 24 is compared with Percon 28 in three different gauge sizes, 24 AWG, 25 AWG and 26 AWG.

Since the density of C18135 and Percon 24 are nearly identical both alloys will have the same conductor weight at 24 AWG. They also have the same minimum break load. At 24 AWG and in comparison, Percon 28 provides a 28% higher minimum break load. Using Percon 28 and reducing the gauge size to 25 AWG reduces the conductor weight by about 18% yet still provides 5% greater break load strength. Using Percon 28 and reducing the gauge size to 26 AWG will reduce the weight by 35% but the break load only reduces by 19%.

Conclusion

Engineered specifically for applications in high performance conductors Percon 28 offers:

- Savings by reducing the overall conductor gauge size without sacrificing break load strength 33% higher minimum break strength providing greater performance than typical ASTM B624 alloys.
- Twice the flex life of typical ASTM B624 alloys.
- Excellent softening resistance at elevated temperatures.
- Full compliance with RoHS and other environmental standards.
- Provides opportunities for weight savings.