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Application of ICME to Optimize Metallurgy and Improve Performance of Carburizable Steels

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[The statements and opinions contained herein are those of the author and should not be construed as an official action or opinion of the American Gear Manufacturers Association.]

Abstract

QuesTek Innovations LLC has applied its *Materials by Design*® computational design technology and its Integrated Computational Materials Engineering (ICME)-based methods to successfully design, develop and implement two new high-performance gear steels (*Ferrium*® C61™ and *Ferrium* C64® steels) that are being used in demanding gear and bearing applications in ground and aerospace military, commercial aerospace, high-performance racing, oil and gas and other industries. Additionally, QuesTek has successfully designed and developed two new high-performance steels (*Ferrium* S53® and *Ferrium* M54® steels that can be used in gearing applications). All four *Ferrium* alloys are commercially available from Carpenter Technology and have been awarded SAE AMS numbers for procurement. QuesTek has also designed several other high performance alloys using ICME technologies, including a stainless nitridable bearing and gear steel and alloys for additive manufacturing applications.

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Introduction

QuesTek Innovations LLC ("QuesTek") of Evanston, IL uses its proprietary *Materials by Design*® expertise and technology in conjunction with its ICME-based methodologies to rapidly design, develop and qualify advanced alloys into demanding applications. Accelerating the historically slow and expensive materials design and development process, QuesTek's approach integrates extensive thermodynamic and kinetic databases with advanced computational modeling tools to develop and optimize precise chemical compositions and processing parameters ensure specified property targets and meet desired performance goals. Optimization of design demands consideration of tradeoff in materials properties, necessitated by competing requirements.

QuesTek has computationally designed and developed many new ultra high performance alloys, coatings, and materials including iron-, copper-, aluminum-, nickel-, molybdenum-, and titanium-based materials and numerous others. As a global leader in the field of ICME, QuesTek has proven that these materials can be developed much faster and at lower cost, while also providing unique, optimized properties that directly meet user-defined material performance goals for demanding applications in aerospace, oil and gas, high performance racing and other industries.

Ferrium C61 and Ferrium C64

Background

Ferrium® C61™ (AMS 6517) and C64® (AMS 6509) steels are commercially available secondary-hardening gear steels that provide significantly improved tensile strength, case hardness, fracture toughness, fatigue strength, corrosion resistance, and temperature resistance, resulting in performance benefits over conventional gear steels such as AISI 9310 or Pyrowear® Alloy 53. Table 1 provides a comparison of typical alloy properties.

Ferrium C61 and C64 carburizable gear steels have been approved for use in a variety of demanding applications in next generation helicopters as upgrades from incumbent aerospace gearing and shaft steels that have been used for decades, being applied to demanding flight critical applications including transmission gear boxes and rotor shafts. Further, these steels are being applied to gearing components in high-performance racing, wind energy and oil and gas sectors.

Both C61 and C64 steels utilize an efficient nanoscale M₂C carbide strengthening dispersion within a nickel-cobalt lath martensitic matrix. These *Ferrium* steels were designed considering the complex interplay of critical design factors including: martensitic matrix stability (M_s temperature); M₂C carbide thermodynamic stability and formation kinetics; matrix cleavage resistance; and embrittling phase thermodynamic stability.

Table 1. Tabular comparison of gear steel properties (typical)

Typical alloy properties	YS, ksi	UTS, ksi	Core hardness, HRC	EI, %	RA, %	Fracture toughness, ksi√in	Achievable surface hardness, HRC	Tempering temperature, °F
AISI 9310	155	175	34-42	16	53	85	58-62	300
Pyrowear® Alloy 53	140	170	36-44	16	67	115	59-63	400
<i>Ferrium</i> ® C61 (AMS 6517)	225	240	48-50	16	70	130	60-62	900
<i>Ferrium</i> ® C64 (AMS 6509)	199	229	48-50	18	75	85	62-64	925