Particulate Composites: Engineering, Design, Analysis, Applications

Professor Rand German

office hours – by appointment or just prior or just after class
(FIFO = first in first out)

Justification

Over the past 100 years several significant engineering composites based on particles arose to become multi-billion dollar industries. The applications abound and are found literally everywhere, including automotive tires (carbon-rubber), metal cutting tools (tungsten carbide-cobalt), frangible bullets (copper-tin), paint (titania-acrylic), watch cases (gold-titanium nitride), and dental restorations (glass-ceramic). However, up to now the field has been poorly organized with poor predictive capabilities.

This course details particulate composites, the many variants, and the underlying engineering principles. The intent is to move from the past where "let's see what happens" becomes "let's predict what happens" via models, analysis, and insightful observation. The course mixes engineering, manufacturing, design, analysis, economics, marketing, and application details; termed techno-marketing. This is a new course intended to provide fresh graduates with competitive, leading-edge skills.

Topic Listing By Category

INTRODUCTION
- Background, This Course, Composites, Types of Reinforcements, History, Notations, Novel Properties

DEFINITIONS AND BACKGROUND
- Key Terms, Early Definitions

ANALYSIS TECHNIQUES
- Dimensional, Distributions, Composition, Density, Mechanical, Magnetic, Electrical, Environmental, Wear, Biocompatibility, Standards, Specifications, Accuracy and Precision

PROPERTY MODELS

CONSTITUENTS
- Candidates, Selection Protocol, Definition Documents, Examples, Approach, Porosity Effects, Common Materials, Costs

PARTICLE SELECTION
- General Concerns, Availability, Selection Protocol, Particle Characteristics, Powder Modifications, Powder Fabrication, Mixing, Testing, Discrete Element Simulation

FABRICATION
- Mechanistic Background, Options, Liquid-Solid Approaches, Temperature-Pressure Approaches, Two-Step Approaches, Novel Fabrication, Defects, Process Selection

MICROSTRUCTURE AND INTERFACES
- Microstructure Quantification, Interface Strength, Failures

DESIGN
ME 596, Fall 2015

Concepts, Case Histories, Objective Based Design, Hidden Difficulties, Specifications

OPTIMIZATION
Conceptualization, Protocol, Three Case Studies

APPLICATIONS
Overview, Ten Cases (automotive, dental, friction, electrical, thermal, magnetic…)

PROSPECTS
Growth, Future Focus, Opportunities, Key Points

Grading

Three projects will be assigned during the course. The first will be focused on detailing an application, following along the outline for the course. The second will be a team-based oral report focused on composition-property-fabrication predictions. The third will be associated with proposing a new particulate composite with the associated business case. Each will be presented in class at announced dates, approximately after 4, 8 and, 12 weeks of class. They will be accompanied by submission of PowerPoint presentations and open question and answer periods. The projects will involve the following:
1 – detailed study of an existing application
2 – detailed composition-property analysis
3 – detailed analysis of new particulate composite and business case.

There will be random quizzes given in class. There will be no makeup quizzes.

Grading is based on the following.
25 % quizzes (two low scores not counted)
75 % in class project reports (three at 25% each)

Grade Assignment – 90 to 100% = A; 80 to 89% = B, 70 to 79% = C, 60 to 69% = D, below = F

Book

A PDF of a draft book Particulate Composites: Fundamentals and Applications (Springer, New York, 2016) will be posted for students of the class. This is an unpublished manuscript that is not to be distributed to those outside class to protect my copyright.

Learning Objectives

This course will prepare young engineers with a new perspective to properly position for upcoming engineering design challenges. It provides details on particulate composites, showing applications and growth prospects, while teaching the mathematical and computation tools required to predict properties, solve performance issues, and innovate new solutions to complex design situations over a broad range of applications – from automotive connecting rods to laptop computer heat sinks. The students will become versed in terminology, common systems, and analytical tools to design with these hybrid materials while anticipating common problems.