



## Technical Academy

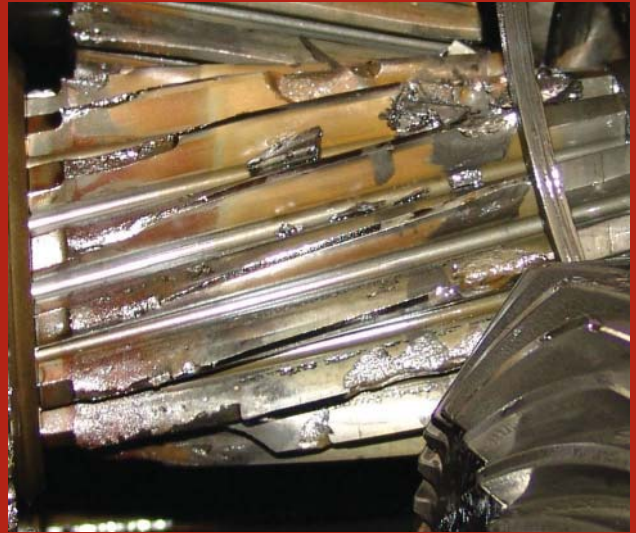
# Gearbox CSI:

## Forensic Analysis of Gear & Bearing Failures — Useful Tools for Optimizing Gearbox Design

Presented by: AGMA & AGMA Foundation

Instructors: Raymond J. Drago, P.E. & Joseph W. Lenski, Jr., Drive Systems Technology, Inc.

December 7-9, 2010  
Sheraton Sand Key Resort  
Clearwater Beach, FL



Why did the gearbox fail? Was it the bearings, the gears, the environmental stresses? This seminar, taught by Raymond Drago, P.E., and Joseph W. Lenski, teaches the forensic analysis of failed gearboxes, including the following topics:

**The role of careful forensic analysis of gearbox failures in future gearbox design**

**Bearings and gear types**

**Limitations of bearings and the gears they support**

**How to optimize bearing and gear combinations**

Gearbox failures are not always related to predicted bearing life and gear service factor calculations. Forensic analyses of gear and bearing failures show that only a few of these failures are the result of true fatigue. Many failures are the result of other contributing factors, often of such magnitude that they overshadow the basic gear and bearing rating

considerations. Therefore, careful evaluation of the forensic analysis is essential during the design process to achieve the best gear and bearing performance.

Furthermore, understanding gearbox bearing failures is critical in eliminating them in future designs. Forensic analysis will determine the root cause and then the designer must determine what has to be done to eliminate this root cause in future designs.

Actual data based upon the presenter's own gear design for the application and rolling element bearing experience will be presented. The presentation is illustrated with numerous photographs and many case study synopses are discussed to provide real world examples of both failures and preventative measures based on an understanding of the failures.

The objective of this seminar is to provide a better understanding of various

types of gears and bearings and educate the designer with the limitations and capabilities of rolling element bearings and the gears that they support, so that the designer can properly apply the best gear - bearing combination to any gearbox, whether simple or complex.

In addition to being colleagues for more than 40 years, the seminar instructors have had the great privilege of working directly together as an integrated "bearing/gear team." Learn from this experience to minimize your problems and maximize your successes in future gearbox bearing designs.

It is our belief that a good gearbox designer is only as good as his or her "bag of tricks!" Join us and fill your personal bag of tricks.

See the seminar outline on the back of this page ...

### Registration Information

**Cost:**

AGMA Members \$1,895

Nonmembers \$2,395

Fees include all education materials, scheduled meal functions, and an opening evening networking reception. A certificate will be awarded upon completion of the seminar.

**To Register:**

Register online at [www.agma.org](http://www.agma.org), or return the registration form to AGMA by fax to 703.684.0242.

**Hotel Information:**

Sheraton Sand Key Resort  
1160 Gulf Blvd.  
Clearwater Beach, FL 33667

**Reservations:**

727-595-1611 (Mention AGMA)

**Room Rate:**

\$125 single/double

## Gearbox: CSI Seminar Outline

### I. Introduction

- Recognize, analyze and correct failures; correlate problems and solutions
- Understand applications; realizing gears, bearings, housing and lubrication interact
- Study failures; “We learn more from failures than successes”
- Diagnosis; recognize the thing that broke may not be thing that caused the failure
- More than one thing can go wrong
- Beware of laboratory analysis

### II. Gear design and failure analysis

- Appropriate application of technology
- Failure types; wear, scoring, interference, surface durability and fracture
- Lubrication failure
- Resonance
- Processes and related damage; handling, marking, electric arc, magnetic particle inspection, etc.
- Compound effects; misalignment with spacing errors, poor lubrication distribution

### III. Material and manufacturing related effects

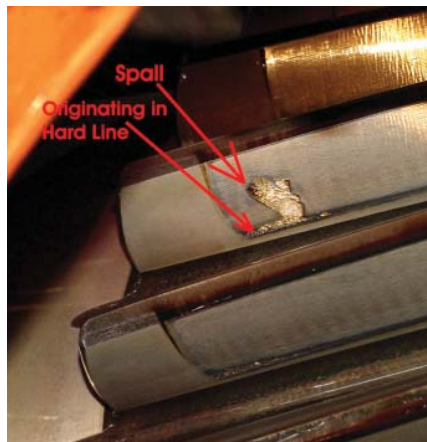
- Inclusions
- Hydrogen embrittlement
- Residual tensile stresses
- Voids and porosity
- Forging problems
- Heat treatment and processing controls
- Grinding burns and cracks

### IV. Preventive measures

- Detailed gear design, manufacture and quality control specifications
- Advanced technology application

### V. Bearing design and failure analysis

- Proper understanding and selection of bearing types and configurations – bearing selection as influenced by gear type and loading
- Design and fabrication controls; how to select a bearing supplier
- Basic bearing B-10 life calculations; standard catalog rating methods and modified load factors
- Methods to reduce manufacturing defects
- Understanding operating conditions as influenced by deflection and load
- Conducting a bearing forensic failure investigation
- Definition of true bearing fatigue failures
- Assembly induced failures
- Operational induced failures; loads, misalignment, lubrication, improper settings and clearance, contamination, dynamics



### Instructors

#### Raymond J. Drago, P.E.

Raymond J. Drago is Chief Engineer of Drive Systems Technology, Inc. (DST), a mechanical power transmission consulting organization that he founded in 1976. Prior to this, Mr. Drago worked for the Boeing Company – Helicopters Division until his retirement after 37 years of service. Currently Mr. Drago is involved in the analysis, design, manufacture, assembly, and testing of many gear systems. In his role with DST, Mr. Drago is active in all areas of mechanical power transmission, including the design and analysis of drive systems in a very diverse field of application from heart pumps to very large mining & mill gears. He has also prepared and delivered more than 150 seminars dealing with various aspects of gear design and analysis.

#### Joseph W. Lenski, Jr.

Joseph W. Lenski, Jr. was a 40 yr. employee of Boeing Company, Rotocraft Division. His field of expertise is that of rolling element-bearing technology with extensive work in drive system design and lubricant development. Since 1973, he has served as chief Bearing Specialist for Drive Systems Technology, Inc. This work has included bearing analysis, selection and life predictions; bearing failure investigations and discussion of various high technology bearing designs and concepts. This work has been done for various steel mill companies, gearbox manufacturers, oil producing facilities and mining companies. He has authored more than 42 technical reports and papers and has prepared a class manual on basic bearing design and bearing failure analysis.