

Minimization of In-Process Corrosion of Aerospace Gears

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American Gear Manufacturers Association



TECHNICAL PAPER

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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

Corrosion of gears during the manufacturing process costs the aerospace industry millions of dollars every year. The goals of the project discussed herein were to identify the root causes of in-process corrosion of gears and develop preventative practices. A series of advanced manufacturing tools including statistically designed experiments (DOE), process flow charts, and failure modes and effect analysis (FMEA) were utilized in a systematic study of the potential causes. Test specimens included two different types of carbon steel alloys that are common base materials used to manufacture precision gears. The specimens are subjected to various process conditions that were identified as key process inputs that could be contributing to corrosion initiation. Some of the examined and tested factors were: coolant types, coolant concentrations, base material heat treat condition, base material magnetism, specimen surface finish, preservative oil application, and iron particle content in the coolant. Samples were tested in a humidity chamber to determine the candidates that were most likely to cause the onset of corrosion. Results of the DOE were examined for main and interaction effects. Potential solutions were identified and implemented that minimize the corrosion of gears during the manufacturing process.

This paper discusses problems associated with the corrosion of aerospace gears during the manufacturing process. The DOE, FMEA, test specimen preparation processes, and other initial steps used to conduct the experiment are presented. The test results are tabulated and graphs are generated to develop clear pictures for the identification of potential solutions. Additionally, a section is included to discuss the impact of chemical attack and residual coolant on corrosion. The results of an investigation of the use of an adapted on-line Digi-Galv (PCI-Win) probe to provide quick indications of a coolant's corrosion-inhibiting capabilities also are presented.

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Introduction:

Carbon steels have primarily been used to manufacture aerospace gears due to their mechanical characteristics. An alloyed low carbon steel is easily case hardened to obtain a hard wear surface while maintaining the ductile core characteristics. The microstructure achieved will accept the heavy loading, shocks, and elevated temperatures that gears typically experience in applications. The carbon steel machinability allows for general machining practices to be employed when producing aerospace gears versus the more advanced metal removal processes required by stainless and nickel base alloys.

As a consequence of using non-stainless steel for gears, in-process corrosion (rust and chemical attack) of gears is possible during the manufacturing process. Surface corrosion of carbon steel gears and shafts can lead to unacceptable stress risers in the material if action is not taken to remove the surface pitting and neutralize the cause. Once the corrosion effect begins, it will continue to attack the grain boundaries of the material. The result is reduced mechanical properties of the alloy that can lead to component failure at performance levels well below typical operating conditions.

Prior to this project, the corrosion problem was minimized by the use of oil-based preservatives and rust-inhibiting machining coolants. However, as the negative affect on exposed production workers and the environment was better understood, and with disposal costs escalating, the gear manufacturing industry changed to water-based coolants and degreasing agents. This shift was immediately followed by an increase in rust. The result was more costly gears from increased rework, scrapped gears, increased preventative activities and manufacturing flow inefficiencies due to out of sequence processing. The replacement of corroded gears created additional delays. Corrosion of gears in the manufacturing environment continued to plague the entire gear industry, therefore an investigation to minimize the corrosive effect was warranted.

Objectives:

The objectives of this study were to identify the root causes of the observed in-process corrosion of gears and to develop preventative practices to mitigate its occurrence during the manufacturing of gears. Specifically, the objectives were:

- Utilize advanced manufacturing tools such as statistically designed experiments (DOE), process flow charts, and failure modes and effect analysis (FMEA) to systematically study the potential causes of the in-process corrosion.
- Evaluate the impacts of chemical attack and residual coolant on corrosion; including the investigation of an adapted on-line Digi-Galv probe as a predictive tool.
- Identify and implement preventive practices to reduce in-process corrosion.

Approach, Scope, and Methodology:

This study was conducted in two phases: Phase I was to identify root causes of in-process corrosion by conducting a comprehensive study, using manufacturing process bench marking, at two gear production facilities. The Phase I study was augmented by controlled laboratory experiments. The desired end product of Phase I was to understand the sources of corrosion on gears during the manufacturing process and to identify solutions to minimize the corrosion problem. Phase II was to implement the identified solutions to a restricted area of the manufacturing floor to test them in a production environment.

Phase I involved defining the boundaries of the gear making process, developing detailed process maps that describe all of the steps required to produce the gears, verifying the actual inputs at each process step, and performing the Failure Mode and Effects Analysis (FMEA) to assess priority of the process parameters. After the process conditions that could potentially be contributing to corrosion initiation were identified and prioritized, the design of experiments (DOE) were planned and performed.