Repair via Isotropic Superfinishing of Aircraft Transmission Gears

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Management Summary

The objective of this paper is to demonstrate that transmission gears of rotary-wing aircraft, which are typically scrapped due to minor foreign object damage (FOD) and grey staining, can be repaired and re-used with significant cost avoidance. The isotropic superfinishing (ISF) process is used to repair the gear by removing surface damage. It has been demonstrated in this project that this surface damage can be removed while maintaining OEM specifications on gear size, geometry and metallurgy. Further, scrap CH-46 mix box spur pinions, repaired by the ISF process, were subjected to gear tooth strength and durability testing, and their performance compared with or exceeded that of new spur pinions procured from an approved Navy vendor. This clearly demonstrates the feasibility of the repair and re-use of precision transmission gears.

Background

The CH-46 Sea Knight aircraft is a medium-lift helicopter in the U.S. Marine Corps. It serves as the "workhorse" of the Corps for troop deployment. From a maintenance perspective, the Navy Depot at Cherry Point (NADEP CP), the Marine Corp's only aircraft depot, scraps many CH-46 transmission gears. Prominent among them is the "mix" gear box collector gear, P/N A02D2066, and its mates, the spur pinion gears, P/N A02D2065, shown in Figure 1. Also frequently scrapped have been the sun gears, P/N 107D2256-7, in the main transmission, and input pinion gears, P/N A02D2059-3, in the "mix" gearbox. Primary reasons for scrapping these gears are minor FOD or contact fatigue damage, usually termed as gray staining (also sometimes referred to as micropitting). The criterion for scrapping the gear is surface damage that snags a sharp scriber when it is traversed over the damage. Annual procurement costs on these four part numbers alone are in the range of several million dollars at Cherry Point. Analysis of the scrap gears indicated a potential greater than 50% for repair and re-use of these gears—with significant cost avoidance.

The primary focus of this effort was to demonstrate that safe re-use of scrap gears that are currently discarded would have significant reduction on sustainment costs. From an operational perspective, several additional issues are also of relevance. They are: the operational lives of gears, vibration levels in the gear mesh pair and the heat losses in gear meshes in a transmission of a helicopter—all of which could benefit from the improved surface finish generated by the superfinishing process. An increase in operational lives and reduction in vibration levels—which would attenuate the occurrence of clutch raceway failure—would directly impact CH-46 sustainment costs. Further, heat losses in gear meshes in a transmission have to be absorbed by additional lubrication oil and onboard lubricant cooling systems. The additional lubricant and the cooling systems required for this purpose add weight to the aircraft and subtract from the payload. Reduction in heat loss in gear meshes would favorably impact aircraft payload.

Technical Approach

As mentioned, the primary causes of a gear being scrapped are FOD (Fig. 2, circled in red) and gray staining (Fig. 3). The effort to demonstrate the feasibility of gear repair was conducted in two major phases. In the first phase, scrap gears from Cherry Point were analyzed for damage, superfinished by the ISF process and then inspected for dimension, geometry and metallurgy. In the second phase, test hardware for traditional gear tooth strength and durability testing was designed and fabricated for the spur pinion (P/N A02D2065). This included a single-tooth fatigue fixture (Fig. 4).

For dynamic tests, the spur pinion and collector gear pair were considered, and a power recirculating test rig was designed and fabricated (Fig. 5). New

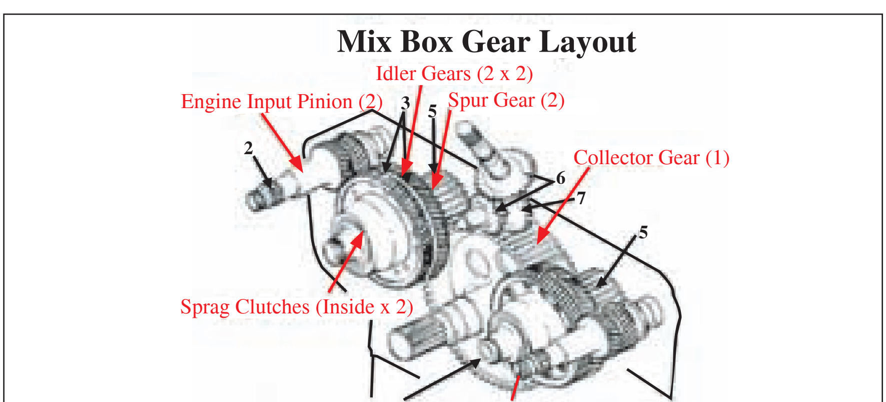

Figure 1—CH-46 mix gearbox.

spur pinions were procured from the approved Navy vendor and sufficient quantities of the scrap spur pinions were repaired by the ISF process. A detailed test plan was defined and presented to the Navy. With test hardware, both the new and repaired pinions were evaluated for single-tooth bending fatigue, contact fatigue and scoring resistance, as per the approved test plan.

Results

The repaired gears (scrap gears that had been superfinished to remove surface damage) were inspected for dimension, geometry and metallurgical integrity. The tooth thickness was smaller than before by the amount of material removed, but still well within the tolerance. The lead, profile and index error were relatively unchanged after superfinishing, and were found to be within OEM specifications. Some of the gears were sectioned, mounted and examined for hardness, hardness profile, retained austenite and residual stress. The repaired gears met all OEM specifications on these parameters. The microstructure of the repaired gears was also examined, and no deleterious impact on the microstructure due to the ISF process was observed. The surface roughness of the repaired gears was generally in the 4–6 µin. R_A, while the ground gears generally had a surface roughness in excess of 16 µin. R_A.

The repaired and new gears were then subjected to bending fatigue, contact fatigue and scoring resistance tests, as per the approved test plan. Standard statistical analysis was also conducted on the collected data to establish the results on a firm basis. In all three tests, the repaired gears met or exceeded the performance of the new gears. Further, the repaired gears—due to their superior surface finish—operated at about 20–30°F cooler than the new gears, as measured by the out-of-mesh oil temperature in the power recirculating test rig.

Conclusion

This project has clearly established that a significant subset of gears that are considered scrap—because of surface damage such as FOD or gray staining—can be repaired and used with significant savings in cost. Consider that the lead times for fabrication of new replacement aircraft gears have, in many instances, extended into the 12–18 months timeframe. Consequently, utilizing scrap gears has the potential of minimizing aircraft downtime and increasing aircraft availability.

While this effort was focused on CH-46 gears, the repair and reuse is applicable to transmission gears of all fixed-wing and rotary-wing aircraft. The implementation of this process will, however, require the approval and acceptance of the aircraft manufacturer. This acceptance and approval is being pursued.

Acknowledgment

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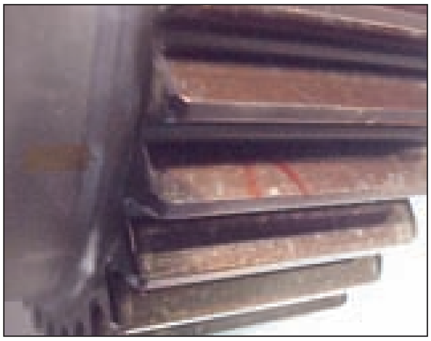
Figure 2—FOD on spur pinion.

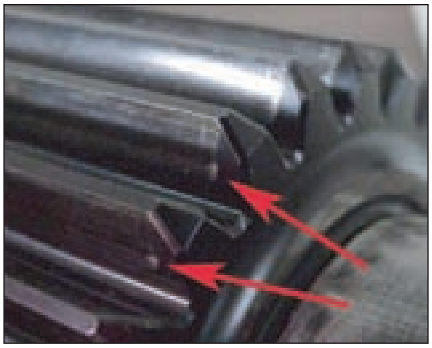
Figure 3—Gray staining on gear teeth.


Figure 4—Single-tooth fatigue fixture.

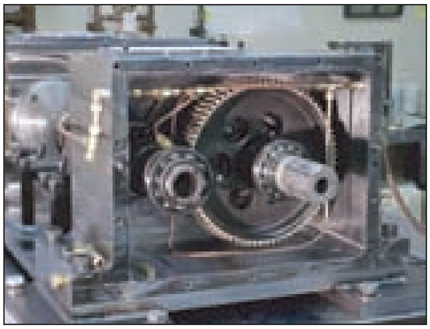
Figure 5—Power recirculating test rig.