Effect of Advanced Drilling Processes on Fatigue Life and Surface Quality

S (Chandy) Chandrasekar (IE) and Kevin P Trumble (MSE)

(in collaboration with James Mann (M4 Sciences))

High performance system designs and their discrete components often require manufacture of various hole geometries. These features and their related surfaces are defined by the product form, fit and function requirements which include sliding surfaces, fluid passages, assembly features and even weight optimization. Examples intersect all market sectors – automotive, aerospace, biomedical and electronics. The hole features can range in size from tens of micrometers to tens of millimeters and require diverse hole-making processes such as laser drilling, EDM, mechanical drilling, modulation-assisted machining (MAM), and plunge milling and are often coupled with a diverse range of surface finishing processes. The challenges related to producing the hole and features are even more unique in advanced high-strength alloys like tool steels and nickel-based superalloys with complex heat-treated conditions. The functional characteristics of hole features regarding product performance, life cycle and durability are likely determined by the interactive effects of surface quality attributes (finish, microstructure and residual stress) on fatigue strength. The surface quality attributes, and, by extension, the fatigue strength can therefore vary depending on the specific process used to produce the feature. The project will study the effect of hole-making process type and associated parameters on fatigue life and surface quality.

Samples of drilled holes, with sizes typical of applications such as fuel-injector and turbine engine components, will be prepared in beam/plate specimens suitable for fatigue testing. The surface quality of the holes will be characterized using surface profilometry (topography), optical/SEM metallography (microstructure, defects) and residual stress measurements. Fatigue tests on the samples will be carried out with hole-in-plate configuration specimens following ASTM standards, and the interactive effects of surface quality on fatigue initiation will be documented. Design of Experiments will be used to structure the hole-making and fatigue testing protocols. Based on the results, various analytical models will be used to examine the data and associated validation.

The hole-making processes that we propose to study are hard drilling with polycrystalline diamond (PCD) tools, EDM, laser drilling and MAM. Abrasive flow machining will be used as a means to finish a select set of these holes, as needed, to improve finish and reduce burrs. The alloy systems proposed for study are H13 steel (quenched and tempered) and U720 nickel-based superalloy (heat-treated), encompassing structural applications in diesel fuel systems and aerospace sectors.

Process capability for hard drilling and MAM are available in-house and via an ongoing collaboration with James Mann (M4 Sciences), inventor of MAM technology. A long-standing collaboration with Seco Tools, the world's 4th largest tool manufacturer, should facilitate access to special PCD and diamond-film coated tools. The PIs have extensive prior experience also with EDM hole-drilling via work with Cummins (1989-97, 2 theses, joint patent/machine development), and Sandia (2003-2006, thesis). We anticipate use of industry partner facilities (e.g., Cummins) to access EDM, laser-cutting and abrasive flow machining capabilities.

The deliverables envisaged for this two-year program are optimization of drilling for enhanced fatigue life; and improved understanding of effects of surface quality on hole fatigue resistance.