Why Should We Encourage Usage of Interference-Fit Fasteners at Airframe Structural Joints

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It is well established that using interference-fit fasteners will obtain longer fatigue lives to airframe structures, compare to using transition-fit fasteners (or close-tolerance) and certainly clearance-fit. But, common practical manufacturing considerations, drive to less usage of the interference-fit fasteners. This is mainly due to the fact that manufacturing will encounter great deal of difficulties for the interference-fit fasteners installation (corresponding holes alignment, etc.). These difficulties are amplified for principal structural joints containing three member layers, as is for double shear splice joints (attachments of two separate spar sections or double shear skin splices, etc.). This means that were we the most might need interference-fit fasteners, usually we will not use them. For such joints to have interference-fit fasteners, they will be installed using pneumatic steel hammering, in somewhat "aggressive" practical manner. Process Specification (PS) for installation of interference-fit fasteners calls for fastener installation either by tapping the head with a plastic mallet or by driving the pin with a light rivet gun. Concerns were raised that practical "aggressive" installation procedures, might damage the holes such that the fatigue advantage will be insignificant, or even present fatigue disadvantages. There is lack of information for the influence on fatigue lives of the different practical installation methods for these interference-fit fasteners.

Due to this concern, lack of relevant information and manufacturing requirements, there is tendency to design such joints not to use interference-fit fasteners, thus not to benefit of their fatigue advantages.

The present study presents experimental investigation of testing results supported by analyses, for the influence on fatigue life, of the following two parameters:

(1) The fastener-to-hole fit level, per % of diametric interference (positive diametric interference will mean that the fastener diameter is larger than the hole diameter, and the negative diametric interference will mean that the fastener diameter is less than the hole diameter, i.e. clearance).

(2) Two different fastener installation methods. The two fastener installation methods are: hand plastic hammering and pneumatic steel hammering as is practically used at the manufacturing line.

The study presents that the known fatigue advantage of obtaining longer fatigue lives for usage of interference-fit fasteners is being kept by the common manufacturing practice of fastener installation via the pneumatic steel hammering. Significant improvement in the fatigue life is presented for interference-fit fasteners installed via the pneumatic steel hammering compare to transition-fit fasteners installed via plastic hand hammering (and the reference open-hole specimens).

The study suggests positive relation between interference level to fatigue life, i.e., higher interference (per specification) contribute to longer fatigue lives, even for using “aggressive” pneumatic steel hammering.

The very high analytical fatigue life results for interference-fit configuration (relative to open-hole configuration), suggests that any practical installation method (hand plastic or pneumatic steel hammering) is not a factor that is having significant influence on the fatigue life.

The study also suggests that any damage that might be induced to the hole by an "aggressive" installation procedure (as flaws in the hole bore) will have negligible growth (under typical aircraft loading spectra).

The conclusion from that study is that we should encourage usage of interference-fit fasteners, at structural joints, whenever fatigue life improvements are needed.

The test program included specimens representing of typical aircraft structure features and fasteners installation procedures, composed of two layers of AL7050-T7451 0.25" thick plates (each), attached by 4 Titanium Hi-Lok fasteners of 5/16 inch diameter (HLT336AP10-8).

Total of 12 specimens (24 plates) were tested, grouped into four distinct specimen feature type, of: hole-to-fastener interference level & fastener installation method, as follows:

- Group “A” – 4 specimens of "Open-Hole" configuration (as reference), composed of the two 0.25" thick layers, not attached via fasteners, but just aligned, so the 4 holes at each layer will be concentric.
- Group “B” – 3 specimens of which the two layers were attached by fasteners having transition-fit type condition via Hand Plastic Hammering (holes drilled per transition-fit specification).
- Group “C” – 2 specimens of which the two layers were attached by fasteners having interference-fit type condition via Hand Plastic Hammering (holes drilled per interference-fit specification - the more “loose” selected). Note: A third specimen was damaged by the tensile machine.
- Group “D” – 3 specimens of which the two layers were attached by interference-fit type condition via Pneumatic Steel Hammering (holes drilled per interference-fit specification- the less “loose” selected).

The specimens were constant amplitude cyclic loading tested via tensile machine (R=0.05, 16.1 ksi peak stress). In addition, each 500 cycles block, was followed by "simple" set of load markers (5 cycles of 20% higher loading, R=0.05), to enable performance of detailed Fractographic analysis (to cracks growth at holes). The specimens, before tested, had undergo calibration procedure (via strain gages), to ensure no in/out-of-plane bending loading (only tensile), and to acquire data for FEM validations.

All holes (& fasteners) were measured and followed up during testing, to properly evaluate test results.

The specimens were manufactured by IAI Manufacturing Factory & tested at IAI Ground Testing Center.

Figure 1, presents the tests specimen fatigue lives vs. interference data & method of fastener installation.

Test results show that transition-fit specimens (“B”) have quite similar results to “open-hole” specimens.

All the interference-fit specimens (“C” & “D”), having interference level near 1%, did not develop any cracking at any fastener hole. As so, their fatigue lives are significantly higher than the other groups.

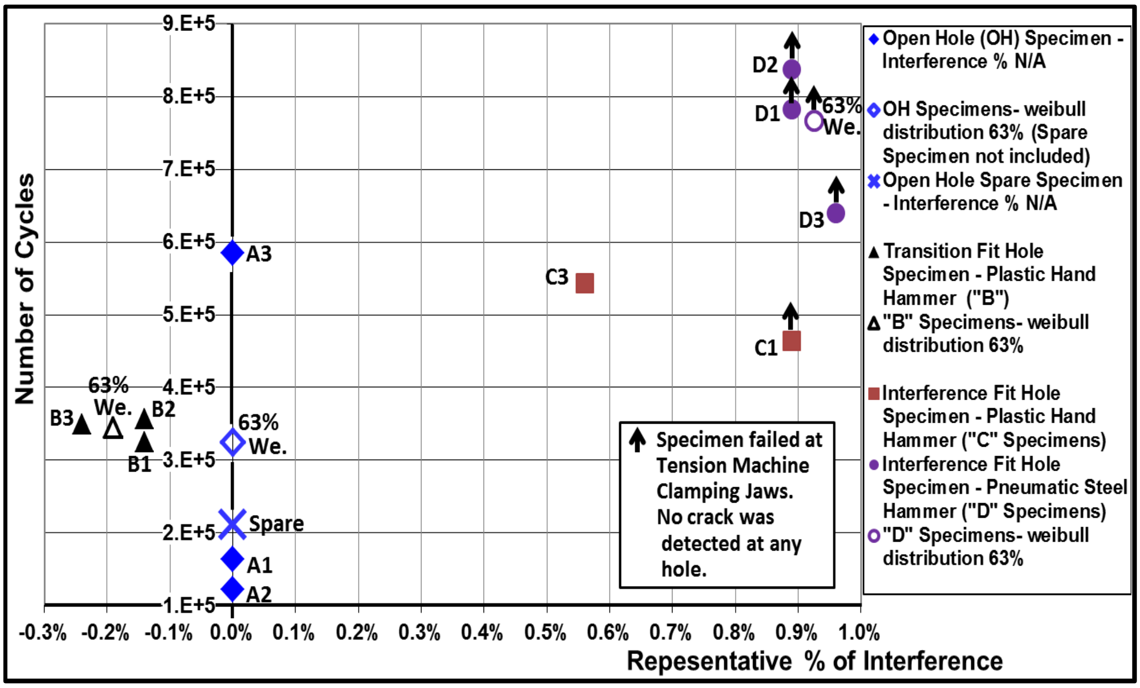

Figure 1. Number of cycles to specimen failure per interference level & fastener installation method

Figure 2, presents, 1% Interference-Fit FEM analyses stress gradient results along line passes through hole center starting at hole edge and ending at specimen canter-line, for: the residual stress due to fastener installation only, Max. & Min. Spectrum, Remote loading applied (16.1 ksi & 0.805 ksi, respectively). Analyses show that stress concentration and local R-ratio, at the interference-fit holes derive significant fatigue life improvement, so, different practical fastener installation methods are not a significant factor.

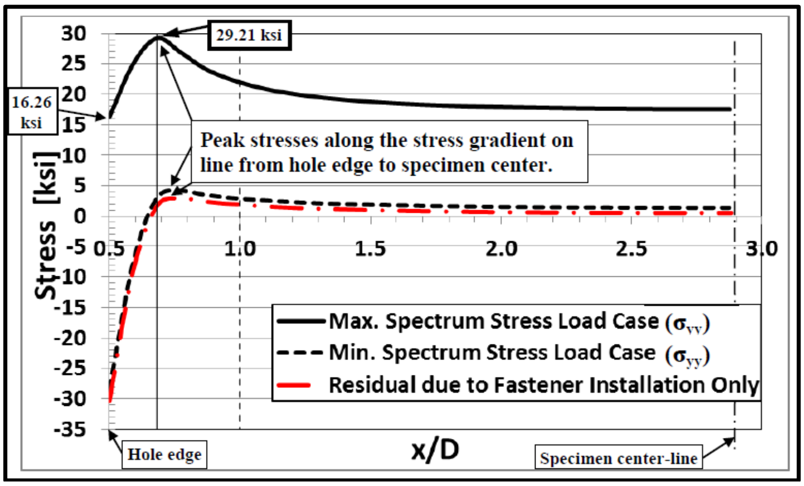

Figure 2. 1% Interference-Fit+Remote Tension Loading, Non-Linear FEM analyses, stress gradients