

Development & Implementation of an Electric Boring Process for the Frame Lug for Main Landing Gear Swing Link on the 777 Airplane

Harinder Oberoi, Paul Gehlsen and Douglas McCoy
Boeing Commercial Airplanes

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ABSTRACT

This paper discusses the process development and implementation of an Electric Boring process for boring the Frame Lug for the Main Landing Gear (MLG) Swing Link bushing on the 777 Airplane. Due to the process reliability issues associated with the equipment traditionally used for this process, primarily air driven right angle motors, a boring process using electric motors was developed and implemented for this application.

The process development focused on equipment selection based on horsepower/torque requirements, laboratory testing for cutting parameters and bore quality generation, equipment reliability testing under operational loads and process efficiency validation. The implementation programme involved the detail design and fabrication of protective enclosure (explosion proof) hardware to prevent the electric motor and its connections from being contaminated by various fluids used in processes in the vicinity of this application. This was mandated per the Fire & Safety regulations of the Boeing Company in its manufacturing operations. Production testing was carried out successfully with finish bore size meeting both the dimensional tolerance as well as the surface finish requirements for this application. An additional honing operation needed with the use of the traditional air driven motor process for meeting the finish size dimensional tolerances was eliminated with the switch to the electric motor boring process. Improved process efficiencies were realized due to the elimination of both the honing operation as well as the high downtime associated with constant breakdown of the air driven motors.

This effort is considered a breakthrough in bringing the electric motor technology to industrial line boring operations where Fire & Safety risks are high but can be

eliminated with the detailed technical development of protective enclosures to prevent contamination of the electrical components and their connections. Additional applications for the use of this process both with the aircraft manufacturing processes as well as within the aircraft fleet support programmes are being targeted for development and implementation of this process.

INTRODUCTION

The main landing gear swing link is part of the mid fuselage section on the 777 airplane. During the integration of this fuselage section from built up skin panel assemblies and other fuselage structure, the two frame lugs, small and large bore, on each side are line bored using fixtures mounted on the Floor Assembly Jig (FAJ). These fixtures ensure accurate positioning of the bore centerline in the airplane co-ordinate system. The large bore diameters range (depending on aircraft minor model on the 777 airplane) from 3.9 inches to 4.175 inches with a dimensional tolerance of + 0.002 inches. The length of the bored hole in the frame lug is 4.0 inches. The starting hole diameters on this large bore in the aluminium forged frame lug (Figure. 1) is around 3.2 inches leaving a final material removal requirement averaging 0.9 inches on the diameter or 0.450 inches radially.

Currently both bores (large & small) are bored using air driven right angle motors. Special boring bars designed by Boeing and fabricated by a supplier are used for these boring operations. The boring cartridges used with these bars use indexable carbide inserts. These motors have been around in Aerospace applications for many years and are primarily designed to drill rather than for boring applications (Figure. 2). These motors are single button start with engaged drill feed mechanism. With heavier cuts and for chip packing conditions an external replaceable shear pin is provided. The main issue with

the current usage of these motors for the boring operations is the high downtime in the process due to constant breakdown of these motors. This results from frequent shearing of the pin due to lack of torque required for rough boring or inconsistencies in torque provided due to variability in air supply. Frequent stoppage and lack of consistency of speed, feed and torque provided has resulted in decrease of process reliability and a degradation of hole quality parameters such as size, surface finish etc. Other air driven motors and spindle technologies were researched as a replacement for these motors but they all suffered to some degree or another from the same issues. With this as a background, a cross-functional team was put together to develop and implement an electric boring process for this application using off the shelf available technology. Extensive research was conducted on electric boring processes in use in applications across many industries both on-site as well as off-site. End users of the electric boring processes were also interviewed for their experiences with this technology.



Figure 1. 777 Section 44, Swing Link Frame Lug



Figure 2. Air Driven Right Angle Boring Motors

ELECTRIC BORING

Electric line boring has been in use across many industries both for on-site as well as off-site applications. In aerospace applications it has seen limited use in on-site applications due to Safety and Fire code

requirements. The Boeing Company Fire Code and Safety regulations mandate strict requirements for any portable machining (boring or other operations) that use electric motors. Prior to the selection of the off the shelf electric motor technology for boring, the team met with the Fire Department and obtained process approval for testing and implementation of this technology. The Fire department's main condition for approval was to have the motors enclosed in a fluid tight casing to prevent liquid contaminants from entering the circuitry and causing an electric spark and fire. The liquid contaminants of primary concern were cutting fluids and other solvents such as MPK (Methyl Propyl Ketone).

After extensive research based on the boring requirements, an off the shelf portable electric boring machine manufactured by York Portable Machine Tools [1] was selected as the equipment of choice for the line boring operations. The equipment selected is shown in Figure 3. This machine uses an electric motor with a 1.2 HP rating providing 35ft/lbs of torque over the 4 fixed speeds (100/150/260/420 RPM). The motor drive is 22 lbs in weight and couples with a feed machine drive which weighs 55 lbs. The overall feed range of the feed drive is 14 inches with feedrate range of 0 to 2.5 inches per minute. The feed torque generated is 200 lbs and the feed mechanism can be manually operated or using the power servo feed. The power servo feed can be controlled with the panel mounted on the feed drive or through a corded remote pendant. All operations of this equipment (power on/off etc) are also controlled by this mounted panel or with the help of the remote pendant. The diameter range of bores that can be machined is from 1.5 inches to 16 inches. The feed drive mechanism rapid traverses at 27 inches per minute and the unit has adjustable limit stops. The lead screw on the feed drive is ACME thread.

Other factors influencing the choice of the Electric Boring Machine [1] included:

- The motor assembly was appropriate for the swing link boring application without major modifications.
- The center line of the swing link bore can be off as far as 0.450 inches. This is an extremely high eccentric load boring pass applying high side loads to the cutting inserts & cartridge, the boring bar and the motor spindle on the first pass.
- The electric motor provides true positive feed with no variation unlike the air driven motor which has feed fluctuations due to air pressure variation and spindle backlash.
- The cost of the electric boring machine [1] is equivalent to the cost of the baseline air driven motors in use.