

Automated Floor Drilling Equipment for the 767

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ABSTRACT

A new portable floor drilling machine, the 767AFDE, has been designed with a focus on increased reach and speed, ease-of-use, and minimal weight. A 13-foot wide drilling span allows consolidation of 767 section 45 floor drilling into a single swath. A custom CNC interface simplifies machine operations and troubleshooting. Four servo-driven, air-cooled spindles allow high rate drilling through titanium and aluminum. An aluminum space frame optimized for high stiffness/weight ratio allows high speed operation while minimizing aircraft floor deflection. Bridge track tooling interfaces between the machine and the aircraft grid. A vacuum system, offline calibration plate, and transportation dolly complete the cell.

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INTRODUCTION

Boeing Everett required improved automation capabilities to replace aging, unreliable equipment and eliminate hand drilling operations. Lexan templates and machined aluminum drill jigs have been required to drill both the low accuracy floor panel fastener holes and high accuracy galley and lavatory mounting "hardpoint locator" holes in the fuselage floor grid of the 767 aircraft family (767 passenger, 767 freighter and the KC-46A Pegasus tanker shown in [Figure 1](#)).

To fill this need, Electroimpact developed the 767 Automated Floor Drilling Equipment (AFDE) model E3600 ([Figure 2](#)). This is the latest in Electroimpact's line of AFDE machines.

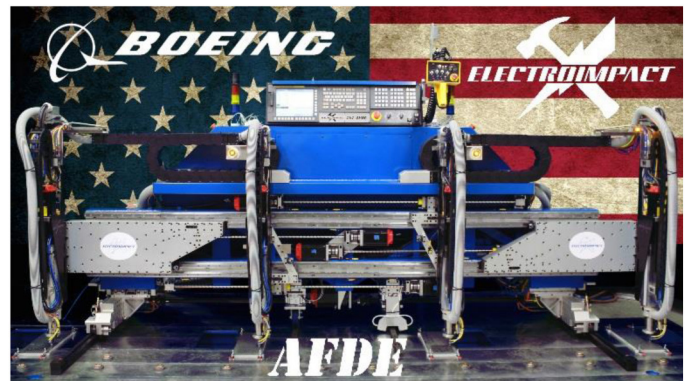


Figure 2. Electroimpact 767AFDE model E3600.

The reintroduction of an automated floor drilling system offers improved process cycle times, more accurate and repeatable hole placement capabilities, and a custom user interface that is safer and more ergonomic compared to hand drilling. The machine's custom user interface was designed using Fanuc Picture and a C-language executable to simplify machine operation and troubleshooting.

The new AFDE has a list of potential process cost savings.



Figure 1. Boeing KC-46A Pegasus tanker, one of the aircraft variants to be drilled by the Electroimpact E3600. Image by Boeing.

MACHINE FRAME STIFFNESS AND DIMENSIONAL STABILITY

The E3600 was designed to drill the entire width of the 767 floor grid in a single swath, thus cutting in half the operator intervention required compared to traditional two-swath processes used on other widebody AFDEs. This necessitated a machine with a 13 foot transverse drilling span (22% greater than Electroimpact's previous AFDE) that was still light enough to ride on the floor grid without excessive deflections. Electroimpact utilized valuable experience gained from its previous AFDEs including those that drill the 737 aircraft [1, 2]. Additional Finite Element Analysis (FEA) was done to optimize the new machine frame for high stiffness/weight ratio.

Frame FEA

The AFDE main space frame is supported at each end by a machine base, which in turn clamps down to tooling tracks to prevent liftoff of the light machine due to drill thrust force. The limiting load case is where the machine's four drill spindles are clustered near the aircraft centerline and drilling simultaneously. Each spindle is capable of 404 lb max thrust to allow for the customer requirement of aggressive drilling in titanium. This set the limiting load case for FEA, in which 1616 lb of thrust needed to be reacted by a machine which itself has total weight less than 1600 lb due to the need to ride on the aircraft floor grid. The machine's frame weight could only be a fraction of this and was thus monitored closely during FEA iterations.

Acceptable deflection of the new frame was defined based on a successful previous AFDE frame design Electroimpact had in production. Comparison FEA models of expected deflection caused by worst case drilling thrusts were made to ensure the new frame was at least as stiff as the one in production. The final design of the new frame ended up 15% stiffer than this baseline.

As a result of the worst case drill thrust load, the new space frame acts as a torque tube, and the main challenge was limiting the twist it exhibited. Twist on an early frame model is shown in [Figure 3](#). To reduce this twist, covering the outside frame faces entirely with a "skin" of aluminum was considered but this limited maintenance access to the frame interior where various utilities are run. Frame thickness in X contributed to stiffness but was limited by the proximity of floor grid holes the machine needed to drill relative to the edge of the floor grid ([Figure 4](#)).

In the end, a mixture of vertical braces on two faces combined with an aluminum-skinned rear face ([Figure 5](#)) resulted in minimal frame deflection, acceptable weight, and maintenance

access. The final frame design weighs 287 lb, less than 18% of the drill thrust load it needs to react.

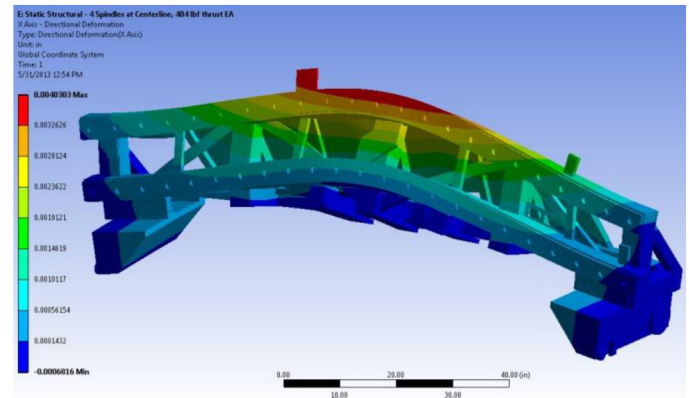


Figure 3. Frame twist on an early frame FEA model.

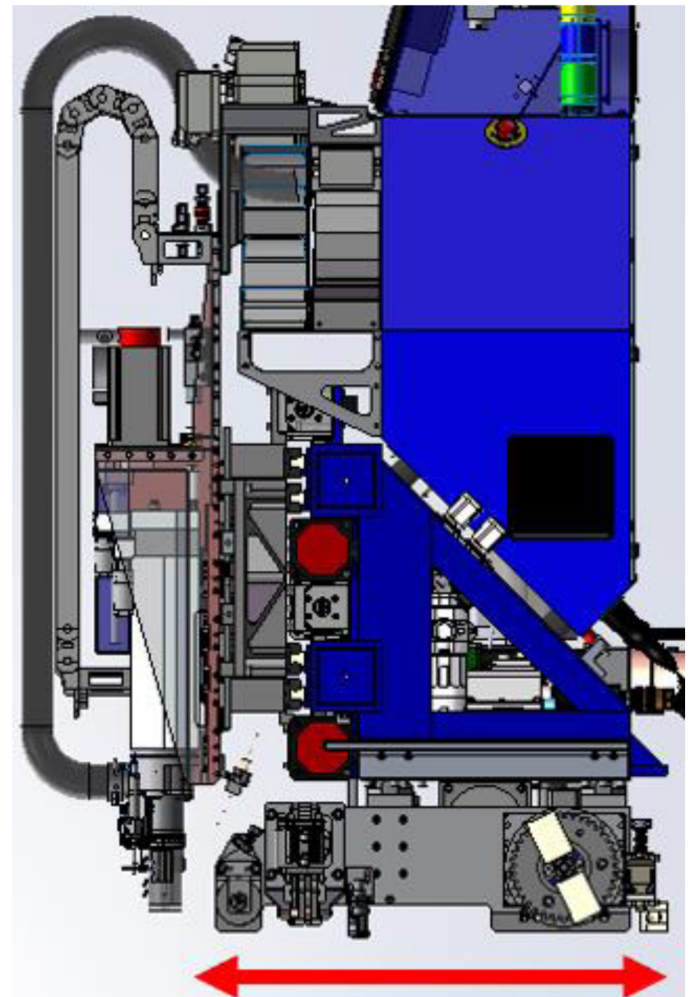


Figure 4. Frame width in X was limited due to proximity of floor grid holes relative to edge of grid.



Figure 5. Machine frame rear face with aluminum "skin" prior to major machine assembly.

Frame Fabrication

Electroimpact had previously acted on lessons learned about long-term dimensional stability from its (now 20-year old) 777AFDEs. This resulted in changes to how the main machine frame was designed and fabricated for its 737AFDEs including the use of multiple stress relieve steps [1]. Since the multiple stress reliefs reduce yield strength of the frame aluminum, the maximum Von Mises stress in the frame was checked and confirmed to be well under (2400 psi) minimum yield strength.

Since the new 767AFDE frame had increased frame length over previous models (to support 156" vs. 128" of transverse spindle travel), extra attention was given to minimizing frame distortion during fabrication including keeping it flat during stress relieve with a jig (Figure 6).

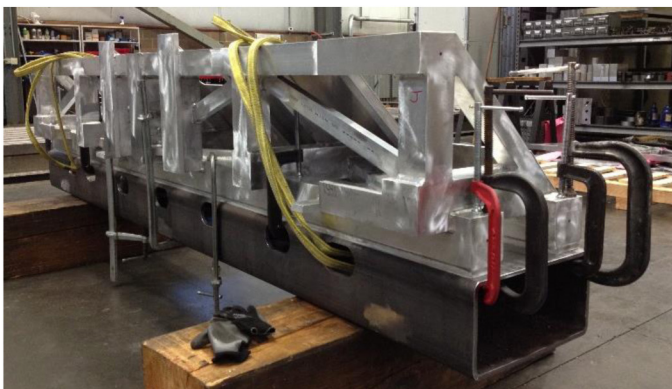


Figure 6. Main machine frame prior to first stress relieve operation.

As a result of the frame stiffness FEA optimization and care taken during fabrication, all four drills can move within a 0.002" (+/-0.001") wide line in X while they travel over 156" in the Y direction.

THE X DRIVE SYSTEM

Bridge Track Tooling

Since the machine operates on the 767 floor grid, its X axis accuracy is heavily dependent on the design and quality of the bridge track tooling (the interface between machine and aircraft

which is installed on the floor grid prior to drilling). On previous AFDE jobs, Boeing Tooling had handled fabrication of the bridge track, but for the 767AFDE Electroimpact received both the equipment and tooling contracts. This sourcing allowed Electroimpact to ensure seamless integration of the machine and tooling while utilizing a high quality rack and pinion drive system.

The 767AFDE travels on an AGMA 11 quality gear rack mounted to a supporting base extrusion which tools directly to the airplane floor grid. Beside the rack sits a rail which is ground to match the pitch line height of the rack (Figure 7). These bridge tracks are mounted on the floor grid prior to drilling.

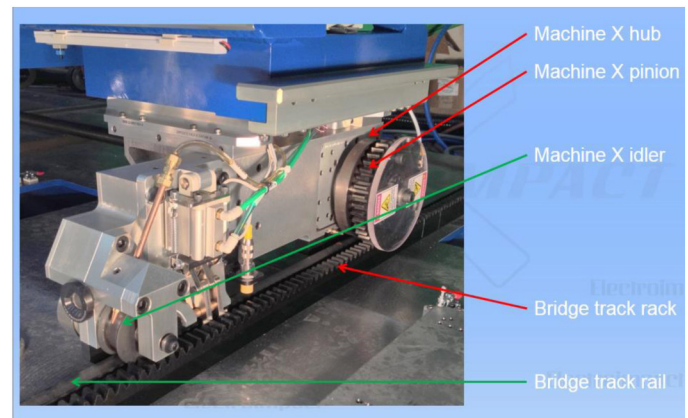


Figure 7. 767AFDE X axis drive system.

Each machine X drive consists of a belt-driven high speed shaft connected to an ultra-low backlash multi-stage planetary gearbox. The output of the gearbox connects directly to an AGMA 14 quality pinion gear and a ground hub at the pitch diameter. The hub rides on the bridge track rail to set correct engagement of the gear into the rack.

Waterline Deviation Compensation

The bridge tracks mounted to the airplane floor act as the machine bed for the AFDE. However, due to airplane build tolerances Boeing could not guarantee the flatness in Z ("waterline deviation") of the floor to better than 0.100".

To compensate for X axis inaccuracies caused by this waterline deviation, Electroimpact employed a mechanism originally designed into its 737AFDEs [1]. (Figure 8). This mechanism, located on each base of the machine, employs a die spring (located at red arrow) to force the X hub down to the bridge track rail (orange arrow), which in turn ensures the X pinion gear remains fully engaged in the bridge track rack (blue arrow). On level tracks, the die springs are compressed to a stop. On out-of-level tracks, both front X idlers (Figure 7) remain down and one of the X pinion gears is pushed down to meet the rack while the other pinion gear remains on its stop.