

Flex Track One Sided One Up Assembly

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ABSTRACT

The Boeing Company is striving to improve quality and reduce defects and injuries through the implementation of lightweight "Right Sized" automated drill and fasten equipment. This has lead to the factory adopting Boeing developed and supplier built flex track drill and countersink machines for drilling fuselage circumferential joints, wing panel to spar and wing splice stringers. The natural evolution of this technology is the addition of fastener installation to enable One Up Assembly. The critical component of One Up Assembly is keeping the joint squeezed tightly together to prevent burrs and debris at the interface. Traditionally this is done by two-sided machines providing concentric clamp up around the hole while it is being drilled. It was proposed that for stiff structure, the joint could be held together by beginning adjacent to a tack fastener, and assemble the joint sequentially using the adjacent hole clamp up from the previous hole to keep the joint clamped up. This process would significantly decrease the costs and complexity that is usually associated with two sided equipment involved in One Up drilling and fastening. This paper will examine the equipment and testing completed to prove out the process of using adjacent hole clamp up to achieve One Up Assembly.

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INTRODUCTION

Boeing is continuously looking to develop and implement automated assembly systems to help meet rate, reduce injuries and improve quality [1]. These automated solutions can generally be split into two categories: Large fixed foundation machines and light weight portable equipment. Both of these categories have pros and cons. Large machine tools have been successfully integrated into aircraft manufacturing for several decades. They typically are very accurate with high quality installations while eliminating most ergonomic issues. They also typically employ One Up Assembly so the parts are all sealed and then drilled and fastened in one pass. This eliminates the laborious steps required to disassemble all of the parts to clean and deburr before sealing, reassembling and fastening. The down side to large machine tools is that they have: high upfront capital costs, long lead times, and due to the fixed foundation they are not flexible in accommodating changing build rates or locations. Portable assembly equipment addresses the major drawbacks of large machine tools but introduces different concerns. Portable drilling equipment such as a track driller is a relatively inexpensive way to address quality and ergonomic issues associated with manually drilling holes. The equipment can be integrated into existing assembly jigs with little or no modification required [1, 3]. The drawback to portable equipment is that it is typically drill only machines. This is due to the difficulty of integrating an inside system with portable equipment to get the necessary clamp up to eliminate burrs and debris at the interface. This still

leaves the requirement to disassemble, clean, de-burr, seal and reassemble the parts which can be avoided if the joint is clamped tight enough to eliminate burrs and debris at the interface.

Boeing Research and Technology procured two different pieces of equipment to develop processes for One Up Assembly with an external track driller and no inside machine. The goal was to use the clamp up from the previously drilled adjacent hole to hold the joint together and eliminate the need for an inside machine. This would require joints that are inherently stiff enough to react the drill thrust and fastener insertion at the adjacent hole in order to maintain a tight join. Keeping the joint clamped together is important for eliminating chips/coolant at the joint interface and minimizing burr growth. We also targeted joints that used interference and transition fit bolt installations. Inside operators or equipment working in series is required for upsetting rivets and clearance installation for bolts. Based on these requirements, and current production needs, we targeted assemblies in wing panel to spar, wing panel splice stringers and fuselage final body join for the 777-200, 777-300 and 777 freighter.

EQUIPMENT

Two different machines were developed to test the parameters needed and determine if the process was feasible. The first piece of equipment shown in Figure 1 was targeted towards wing assembly, specifically looking at the panel splice stringer

assembly and panel to spar assembly. This machine is identical to drill only machines implemented into production that were designed to receive a retrofit to add fastener insertion capability. The drill only machines can drill between the tracks or offset on the outside of the tracks. The machines have an onboard offset camera for synching on datum features of the part. The fastener insertion retro-fit adds the capability to receive fasteners from a fastener feed system, apply sealant to the fastener and insert using a pneumatic insertion module. The fastener insertion module has the ability to detect the proper fastener grip length and determine when the fastener is fully seated to the structure. To eliminate a complicated shuttle design with the drill, camera, and fastener insertion, this machine moves the entire carriage to insert fasteners. This method is only applicable to relatively flat structure because the drill vector and the fastener insertion vector are parallel[2]. On a structure with a lot of contour the fastener insertion vector would not be parallel to the hole vector as the machine carriage would follow the contour of the part, maintaining normality only at the drill spindle.



Figure 1. Electroimpact drill and fasten Flex Track for wing assembly.



Figure 2. Electroimpact drill and fasten Flex Track with Brown aerospace fastener feed system.

The second piece of equipment shown in Figure 2 was targeted towards circumferential joins and specifically looked at the joins completed in final body assembly, joining the forward and aft fuselage sections to the center section. This equipment was very similar to the wing equipment, but employs a shuttle table for the drill spindle, camera and fastener insertion modules to ensure alignment with the tool center point on the curved surface. The machine has active, servo driven, A and B axis to ensure proper normalization in close proximity to skin lap steps, and to help compensate with the increased weight of this machine. All fastener insertion happens with the pressure foot clamped to the part, ensuring proper normalization of the fastener to the hole.

PRODUCTION PART CHARACTERIZATION

The critical aspect of the proposed process is assuring that there is adequate clamp-up from holes using adjacent fasteners. All of the target location cross-sections were analyzed to look at how the drill thrust and fastener insertion would react in the joint. Drawings of the typical cross-section for each location are shown in Figure 3.

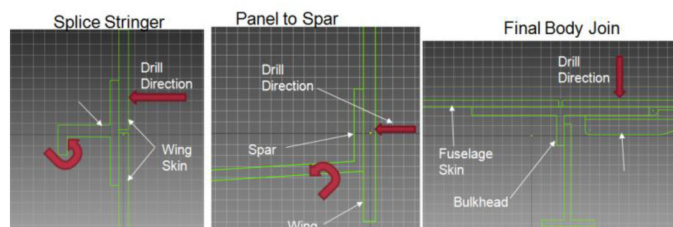


Figure 3. Typical cross-section for each targeted location.

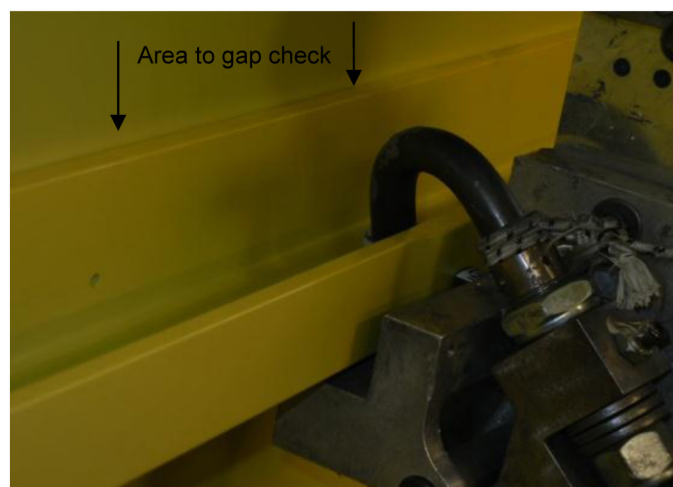


Figure 4. Location between stringer and skin that was analyzed for gaps.

All of the airplane joins were examined across several ship sets with feeler gages to determine what the typical gaps were in the structure as well as what the minimum and maximum gaps are that are seen. These gaps were used to develop tests that would accurately reflect the conditions seen in production. We replicated the known gapping conditions by inserting shims between parts and using scrapped production parts that