

Development of Orbital Drilling for the Boeing 787

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ABSTRACT

The new materials and material combinations such as composites and titanium combinations used on today's new airplanes are proving to be very challenging when drilling holes during manufacturing and assembly operations. Orbital hole drilling technology has shown a great deal of promise for generating burr free, high quality holes in hard metals and in composite materials. This paper will show some of the orbital drilling development work Boeing is doing with Novator to overcome the obstacles of drilling holes in a combination of both hard metals and composites. The paper will include a new portable orbital drilling system designed for these challenging applications as well as some test results achieved with this system.

INTRODUCTION

Orbital drilling is a technique that offers a number of advantages over conventional drilling in the assembly of aircraft structures. With the new materials that are being used in today's aircraft these advantages become even more beneficial. Boeing has been working with Novator to develop a motor that can be used in a production environment to realize these benefits.

MAIN SECTION

ORBITAL DRILLING GENERAL BENEFITS - Orbital drilling (Fig.1) is based on machining the material both axially and radially by rotating the cutting tool about its own axis as well as eccentrically about a principal axis while feeding the tool through the material.

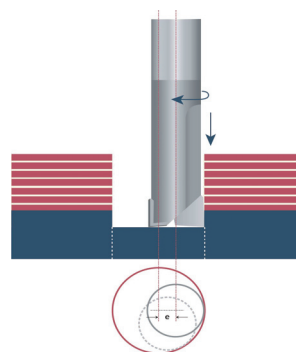


Fig 1 The Principle of Orbital Drilling

Orbital drilling is characterized by a tool diameter that is less than the diameter of the hole; a tool cutting edge that is intermittently in contact with the hole edge; small chip formation; and a low thrust force.

These characteristics offer certain benefits. For example small chips in combination with a tool diameter less than the hole diameter allows for efficient chip removal using vacuum, see Fig. 2). Efficient chip removal, in turn, prevents heat build up and eliminates the risk for matrix melting in composite materials and heat affected zones in metals. In addition, it eliminates the risk for chip induced damage and makes cleaning of structures obsolete.

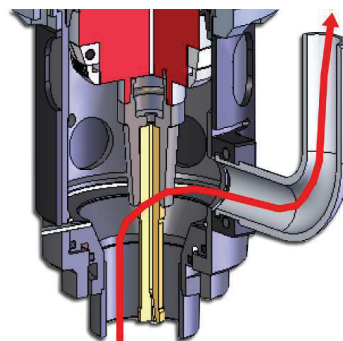


Fig 2 Efficient Chip Evacuation

An intermittent cutting edge contact with the part, allows for efficient cooling and makes dry drilling possible. It increases the tool life in dry drilling. Dry drilling is highly desirable as it reduces cost and improves the environment. In some applications, minimal quantity lubrication (MQL) is required to reduce friction.

A low thrust force allows for burr-less drilling in metals; delamination-free drilling in laminated composite material. It minimizes the risk for part deflection when drilling in thin structures, and it facilitates automation using light equipment such as industrial robots, which are force-sensitive.

The eccentricity, e , or off-set, is an adjustable parameter. By adjusting the off-set, a tool of one diameter can be used to drill several holes of different diameters.

MAJOR FUNCTIONAL REQUIREMENTS - The overall objective of our developing an orbital drilling system is to exploit the benefits of the orbital technology in Boeing assembly applications. The Boeing 787 offers many challenging applications and the first target is applications related to the final assembly of the aircraft. For this application, the following major requirements were outlined.

Portability - The unit is intended to be used in areas of limited accessibility. It is therefore important that the unit is portable and that the outer dimensions of the unit are within geometrical constraints to avoid collision with surrounding structure.

Variable manual offset adjustment - Principally, there are three possibilities to control the off-set: fixed, manual, and programmable. To efficiently deal with the tight dimensional requirements a fixed off-set was excluded. In order to comply with the portability requirement, a manual off-set was selected as a programmable off-set would result in a larger and heavier unit.

Programmable feed rate and orbital speed - The motor's intended use is in advanced material stacks containing CFRP, Titanium and Stainless steel in various combinations and thicknesses. To reach the required hole tolerances through such stacks and at the same time avoiding composite delamination and burr formation in the metal. It is important to optimise (program) the feed rate and orbital feed continuously throughout the forward and return stroke of the drilling cycle to enable shorter cycle time and improved cutter life.

Automatic hole identification and loading of programs - It was required that the unit from an operator's perspective would principally work the same way as any other conventional semi-automatic power tool used in production today. Therefore, in order to comply with this requirement, and at the same time taking full advantage of the programmable capability, it was necessary to incorporate a hole identification system such that when the machine is docked in a certain position in the drill jig, the machine is able to identify the hole to be drilled and

assign a pre-optimised drill program to control the drilling cycle.

Efficient chip and carbon fiber dust evacuation - It is highly desirable for the drilling process to be as clean as possible in order to minimize health related issues and cleaning of structures after drilling. Therefore, the drill unit should include an efficient chip- and carbon fiber dust evacuation capability.

Minimal Quantity Lubrication (MQL) and pressurized air through the spindle - Minimal quantity lubrication dispensed through the cutting tool is important both for ensuring the required hole quality and for maximum tool life when drilling in hard materials such as Titanium and Stainless steel. For this purpose, the machine was designed with the capability to feed MQL- and pressurized air to the tip of the cutting tool. It was also required to be able to shut off the MQL with a short time delay such as to engage it in metallic members and disengage it composite members.

Pressurized air through the cutting tool is also necessary in order to create the necessary air flow for chip and dust evacuation.

Operational requirements - A major challenge was to design the system with a weight below 10 kg as the unit was handled manually, sometimes in very confined access areas. In addition, a number of dimensional requirements were specified for accessibility purposes. A number of obvious requirements related to health and safety and operation were specified.

BRIEF DESCRIPTION OF THE SYSTEM - The PM-40 system includes the following main components:

- Orbital drilling unit
- Nosepiece attachment
- Supply unit
- Orbital drilling manager (HMI)
- Embedded motion controller
- Hole identification system using RFID

Orbital drilling unit - The orbital drilling unit includes a spindle axis driven by a pneumatic spindle motor that rotates the cutting tool about its own axis; a radial offset mechanism; and eccentric rotation mechanism; and an axial feed mechanism.

The radial offset mechanism basically comprises of an inner eccentric cylindrical body having an eccentric hole; and an outer cylindrical body having an eccentric hole. The inner cylinder is radially supported in the eccentric hole of the outer cylinder and is rotatable therein so as to allow for a manual adjustment of the offset and a mechanical lock is released.