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By Bill Kennedy,
Contributing Editor

Chopper Shop

A small, Philadelphia-area shop is using a 55,000-psi, 2,000-mph abrasive waterjet to help grow its primary business: making parts for Boeing aircraft.

B. Kennedy and Boeing (bottom)

At Davidson Fabricating, an abrasive waterjet cuts 18"x15" plates from 0.050"-thick 7075 aluminum and pierces 27 0.098"-dia. holes. Davidson Fabricating uses AWJ technology to cut aluminum parts for the Chinook helicopter, Boeing's longest-running aircraft production program.

Small companies are still an engine of growth for the U.S. economy, and one of the ways they can grow is by employing innovative ideas and new technologies. A good example of this process is Davidson Fabricating Inc., a family-run sheet metal shop. It has grown from 12 to 30 employees over the last 6 years, in part by installing an abrasive waterjet machine. Also, the shop is adding another AWJ machine to help it handle growing demand.

James Davidson Sr. founded Davidson Fabricating in Broomall, Pa., in 1963. His son, Jim, is now owner and president of the company. Jim oversees all operations, while General Manager Colleen Hurst and Shop Foreman Jamie Davidson, Jim's son, handle day-to-day activities.

Davidson Fabricating serves a variety of customers, but most of its work involves cutting parts and fabricating assemblies for aircraft maker Boeing Co. Most are aluminum components for the venerable Chinook helicopter, Boeing's longest-running aircraft production program, and the new V-22

Learn more about waterjet cutting

Read more commentary on waterjet cutting by visiting Bill Kennedy's blog in the CTE Community section online at www.ctemag.com.

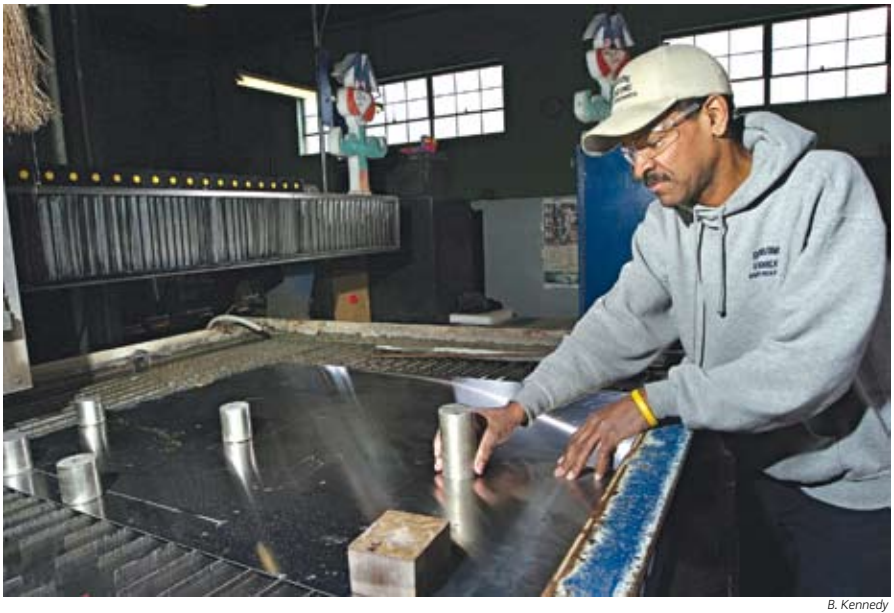
Osprey twin-rotor aircraft. The Osprey's first combat-zone deployment was in Iraq in October 2007.

Most of Davidson's parts range in size from inches to feet. Assemblies are generally 1' or 2' square. Production volumes range from single-digit to hundreds, "depending on how many aircraft they are building," said Jamie Davidson. Chinook orders include replacement parts and parts for new models. New part orders for the Osprey are rising as production ramps up.

Boeing has grown in significance as a Davidson customer since the mid-1990s. At that time, Davidson cut aluminum sheet with bandsaws or shears and blanked holes with a Weidemann CNC turret punch press. To meet increased demand, Davidson sought alternative ways to cut sheet metal in 2000. Customer requirements immediately ruled out laser and plasma cutters because both create a heat-affected zone at the site of the cut and the high temperatures generated can alter the metal temper condition.

Davidson Fabricating has grown from 12 to 30 employees over the last 6 years, in part by installing an abrasive waterjet machine. Also, the shop is adding another AWJ machine to help it handle growing demand.

AWJ technology provided the solution. In 2003, Davidson consulted with Romeo Engineering Inc., Fort Worth, Texas, a manufacturer of waterjet cutting systems, composite-fabricating machines and automation systems, and bought a Romeo Silver unit consisting of a 6'×12' table and a PC-based CNC. The machine features a high-pressure system from KMT Waterjet Systems (then Ingersoll-Rand Waterjet), Baxter Springs, Kan. The system has a 30-hp motor driving a hydraulic pump that,



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Operator Malcolm Robinson positions weights on a sheet of 0.050"-thick 7075 aluminum to assure it doesn't move while being cut with an AWJ.

through an intensifier, produces 55,000 psi of water pressure.

Jamie Davidson estimated that 90 percent of the shop's work is processed in the AWJ at some point in production, including 500 different part numbers for the V-22 and 600 part numbers for the Chinook helicopter.

A Part's Progress

Robert Lee, offload coordinator/programmer for Davidson, outlined the steps in producing parts on the AWJ. If a customer's part drawing includes a large number of features, such as holes and complex edge geometry, Lee redraws it in Pro/Engineer CAD drafting software before loading it into the fabrication CAM software from Shop Data Systems. "If it's a pretty simple part, I'll just enter the data [directly into the CAM software] from scratch," said Lee, "because sheet metal cutting involves just X and Y dimensions."

Next, from a menu of material types and thicknesses, Lee selects the workpiece material for the part and the software sets the initial cutting speed. He noted that although cutting parameters will vary significantly from one material to another, such as aluminum to steel, differences within one material group generally are small. In aluminum, for example, the different hardnesses between a T-6 temper condition and a "0" (annealed alloy) "might affect cutting speeds only a little bit," he said.

Davidson has found that the most effective way of transferring the CAM program from Lee's office to the AWJ machine is manually carrying a floppy disk. Wireless intranet data transfer was attempted, but welding near the AWJ interfered with the wireless signal.

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Davidson Fabricating employs an abrasive waterjet to cut these 3½"x1"x0.100"-thick 7075-T73 aluminum components and pierce their four 0.098"-dia. holes for the V-22 Osprey twin rotor aircraft.

At the machine, operator Malcolm Robinson loads the floppy disk and starts the operation. On a new job, the standard procedure is to cut one piece and then send it to inspection to confirm its accuracy. "If Malcolm sends a part to inspection and a hole is not as circular as it should be, then you know you need to change something," Lee said.

Working with the thin sheet metal used in the parts Davidson manufactures means "You can't just turn the

machine on and walk away," said Robinson. "The material may pop up; you have to keep an eye on it." He often uses short steel cylinders as weights and moves them around during the cutting operation to maximize the aluminum sheet's stability and flatness. One reason to minimize workpiece warping, Robinson said, is that the distance between the cutting tip and the work determines the size of the cut or hole and needs to be maintained at about ⅛".

Jamie Davidson described another way to stabilize thin workpieces. "If it's real thin material—0.012" or 0.015" thick—you can stack a couple sheets of the material together, then put a masonite board on top and bottom so you are actually cutting through the masonite and through the sheets at the same time." The method also provides more parts per operation.

Although the CAM software sets the operation's basic cutting speed, the Romeo machine features a hand-held pendant control that enables the operator to vary the cutting speed for special conditions, such as slowing the rate for tight part geometries. The rate of abrasive flow is variable as well. Both speed and abrasive flow rate may need to be adjusted in thicker materials to avoid a tapered cut—where the kerf is larger at the top than at the bottom of the part.

Lee said Davidson's production schedule is customer-driven; at regular intervals he reviews the pending jobs and rearranges their order to reflect demand. As this article was being written, Davidson was taking delivery of a new 5'×10' Romeo table, equipped with a KMT Streamline SL-V 30 pump system. Jamie Davidson said in addition to adding cutting capacity, the smaller unit will speed the processing of smaller parts because the operator can handle smaller sheets of aluminum more efficiently.

AWJ Basics

Waterjet cutting technology was introduced in the early 1970s, when high-pressure (50,000 psi), 0.005"-dia. streams of water were first employed to cut soft materials, such as cardboard and food products. In the early 1980s, a stream of abrasive grains was added to the high-pressure jets, making them capable of cutting hard materials, such as Inconel and ceramics, as well as work-

The economics of abrasive waterjet cutting

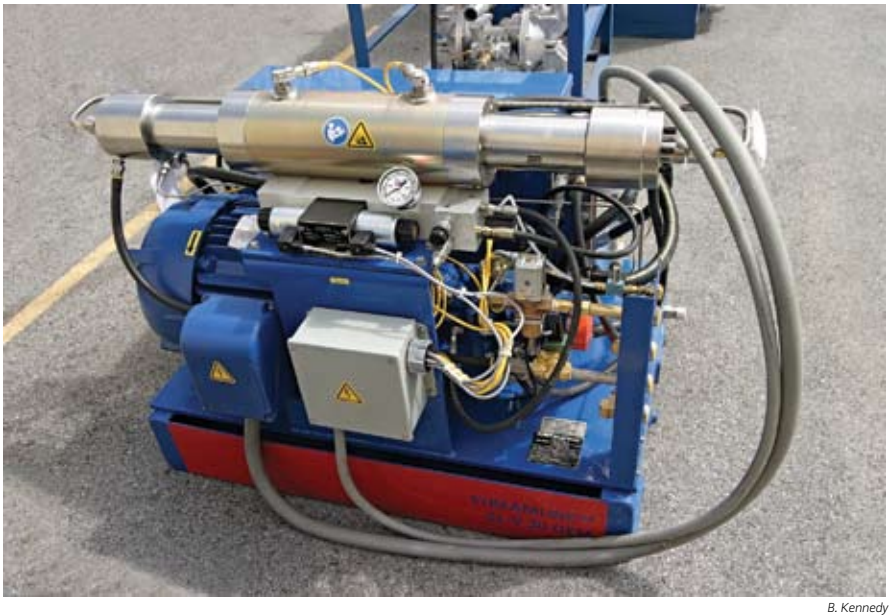
PAUL OEHLER, VICE PRESIDENT for CNC systems, Romeo Engineering, outlined the economic considerations of a shop like Davidson Fabricating that uses an X-Y table to cut flat parts. He presented general assumptions that waterjets in that class typically cost $23 to $25 per hour to operate, and added to that $10 an hour for an operator to load and unload parts. "You don't want somebody programming at the machine," he said. "The machine makes money when it's making noise. Throughput is really important."

"If a shop charges $135 per hour for waterjet services and their direct cost is $35 per hour for the operator, maintenance, electricity and consumables, the AWJ will produce a return of $100 per hour," Oehler said. Considering a typical finance payment on the machine of $2,500 per month, "as long as they can run the machine for 25 hours a month, it's paying for itself in a week's worth of run time. So the other three weeks of the month, as long as they hustle up and keep the machine making noise, can be very profitable," he said.

For a job shop processing a variety of parts, scheduling is the way to gain maximum return on investment. "You want to have the operator loading and unloading metal, plastics, stone, anything that is going to cut very quickly in the mornings and the afternoons," Oehler said. Heavy materials such as 2"-, 4"- and 6"-thick plate should run unattended at night.

No operator is needed during the long cutting cycles, and machine monitoring systems assure that operations will halt if a problem occurs. Use of long-lived AWJ components, such as diamond orifices, also contribute to reliability. "When you come in the next morning, there is a tank full of parts," Oehler said.

—B. Kennedy



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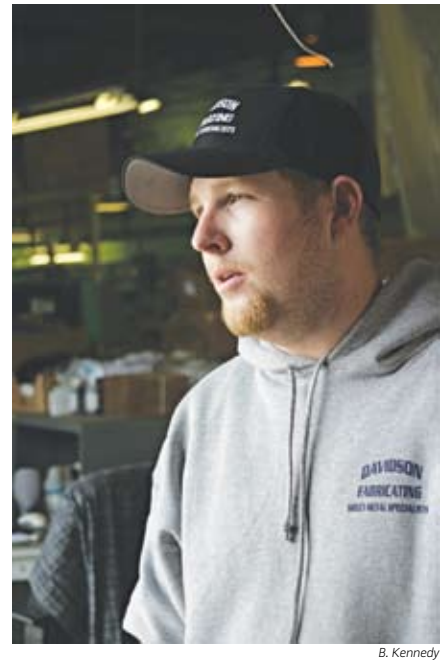
This two-stage intensifier Streamline SLV 30 pump from KMT Waterjet Systems produces 55,000 psi of cutting pressure via two pumping steps: a motor-driven pump generates an alternating flow of hydraulic fluid to the intensifier (the silver cylinder) in which a single-piston reciprocating plunger maintains the high pressure.

pieces up to 10" thick.

Development of worktables and CNCs that permitted accurate workpiece fixturing and precise cutting head motion created a practical tool with many applications. Today, AWJs cut materials ranging from wood, marble and stone to titanium and leather. Three-, 4- and 5-axis systems use CNC technology to cut complex part contours and 3-D shapes. Machines with multiple cutting heads boost throughput.

Single-stage direct-drive pumps or two-stage intensifier setups generate the high-pressure waterjet. Single-stage or piston pumps are configured like auto engines, with multiple pistons connected to a crankshaft. While they are energy efficient, pump pressure is directly dependent on water flow, which limits the use of multiple cutting heads. Two-stage intensifier systems involve two pumping steps; a motor-driven pump generates an alternating flow of hydraulic fluid to an intensifier with a single-piston, reciprocating plunger that maintains the desired pressure. Because an intensifier produces a constant level of pressure independent of flow volume, it can service multiple cutting heads.

The high-pressure water travels into a cutting head, into a plug called a jewel, made from ruby, sapphire or diamond, and through the jewel's 0.005"-to 0.030"-dia. orifice. The tiny opening produces jet speeds as high as 2,000 mph. The most common orifice material is sapphire; jewels cost $15 to $30 each and provide 50 to 100 hours of cutting life. Diamond orifices last 15 to 20 times longer than sapphire jewels, but cost 10 to 20 times more.



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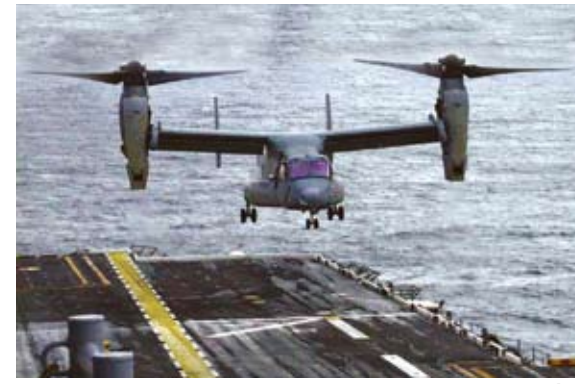
Jamie Davidson, Davidson Fabricating shop foreman.

Abrasive grit, usually garnet, is pulled into the jet just below the jewel. The grit is produced in different sizes; finer

grits produce smoother surfaces, while coarse grits cut faster. Davidson uses a medium-size 80-grit garnet abrasive.

The abrasive is drawn into the high-velocity jet in a mixing, or focusing, tube at 0.5 to 2 lbs./min. Most mixing tubes are made from tungsten-carbide composite materials that last 100 to 150 hours. Mixing tube nozzle orifices that focus the jet as it leaves the cutting head range in diameter from 0.015" to 0.060". Cut kerf size produced by the jet is about 10 percent larger than the nozzle's diameter.



Boeing

Davidson Fabricating uses AWJ technology to cut aluminum parts for the new V-22 Osprey twin-rotor aircraft, which was first deployed in combat in October 2007 in Iraq.

In general, the thickness and hardness of the material being cut determine the cutting speed of an AWJ. According to KMT Waterjet Systems, an AWJ operating at 60,000 psi, employing a 0.010"-dia. orifice and applying an abrasive flow of 0.7 to 1.0 lbs./min. of medium-fine grit will cut 0.25"-thick aluminum at about 23 to 34 ipm. For a 0.50"-thick workpiece, however, cutting speeds will be from 11 to 15 ipm, and in 0.75"-thick aluminum, the speed will drop to 5 to 7 ipm. Cutting speeds for 0.75"-thick stainless steel or titanium will be from 2 to 3 ipm.

The high-pressure fluids used in an AWJ create maintenance concerns much different than other machine tools. The key to generating and maintaining high pressures is a series of seals, which wear as the pistons, plungers and high-pressure fluids pass through them. Seals in the intensifier and cutting head require regular replacement. Average intensifier seal life is about 500 to 600 hours, although Davidson reported life of more than 900 hours with a new seal

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In 2003, Davidson consulted with Romeo Engineering Inc., Fort Worth, Texas, a manufacturer of waterjet cutting systems, composite-fabricating machines and automation systems, and bought a Romeo Silver unit.

design from KMT Waterjet. According to KMT, the seals conform to the shape of the cylinder and thereby provide a better seal. Seal life is determined by more than simply time; water quality is also a main factor. Chuck Schmidt, Northeast area manager for KMT Waterjet, said hard water negatively affects seal life. The solution can be as simple as having the shop water tested and installing a water softener.

Where water flows at extremely high speed, as in the orifice and the focusing tube, abrasive wear dictates regular replacement. Davidson said his shop's jewel/focusing tube arrangement is called a 10-30 setup for its 0.010" jewel and 0.030" mixing tube nozzle. He reported that the shop's 0.010"-dia. sapphire jewels last 60 to 80 hours. Nozzles are replaced when holes and cut kerfs become irregular. However, Davidson doesn't throw away the used nozzles. "We save them for a couple jobs where we know we can get away with having bigger holes, because they are going to get opened further on assembly." CTE

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