Very Impressive Performance Extreme Removal (VIPER) grinding was first introduced seven years ago as a replacement for creep-feed grinding of nickel-based superalloys. The process helped Rolls-Royce, VIPER’s originator, slash lead-times for compressor blades, turbine blades and engine casings by factors previously unimaginable. Other benefits for the company include reduced thermal damage and consumable costs, as well as improved process consistency. Yet, working with partners such as Makino and Tyrolit, the process has evolved further still.

Today, versatility is almost unlimited, using Makino-NCMT solutions, owing to the ability to mix and match machining processes. While maximum advantage is taken of the VIPER process for roughing and semi-finishing, if finishing is not appropriate, perhaps because a grinding wheel cannot access certain features or a customer does not accept grinding as a final operation, then milling or broaching can complete the machining cycle. Using Makino horizontal machining centres, a milling cutter, drill or other driven or static tool for turning can also be changed during a cycle, allowing second and subsequent machining operations to be carried out in the same set-up.

Although the seminar featured presentations (see box item) from Makino-NCMT, Rolls-Royce, Tyrolit and Teleflex Aerospace, the main attraction was the working demonstrations on five, 7-axis Makino machines housed at NCMT’s Coventry Technical Centre.

The first of two Makino A55-5XR VIPER machining centres performed three separate demonstrations. First, the 5-axis machining of a nickel alloy compressor blade involved grinding a radial dovetail root form followed by a combination of grinding and finish milling of a small-radius scallop, which the grinding wheel was unable to access. The total cycle time was 5.5 minutes. Conventionally, blades are first ground and then set up for a second operation on a machining centre.

The second demonstration involved grinding the fir tree root form for a high pressure turbine blade from solid nickel alloy in a cycle time of 3.5 minutes. The most usual production process for this popular aerospace component is in a ‘Nagare’ cell formation comprising, say,
GRINDING

Fir tree root form grinding for a high-pressure turbine blade from solid nickel alloy in a cycle time of 3.5 minutes. Normally, such components are ground from a closer-by-forming on a dedicated grinder. The most usual production process is in a Nagare cell comprising, say, 10 separate machines tended by five operators to clamp every part once on each machine.

10 separate machines tended by five operators to clamp every part once on each machine – however, using a Makino VIPER machining centre, parts generally come off complete in two operations.

Grinding of a radial seal slot, 2.6 mm wide by 7.3 mm deep over a 200 mm length, formed the third demonstration. Two small, aluminium oxide wheels were used, one for the outside radius and another for the inside radius to achieve perpendicular groove sides. Two-axis control of the grinding wheel plus b-axis positioning of the component achieved the required contouring of the slot.

A second Makino A55-5XR was shown cycling through the process for grinding the teeth and face register of a gear for a racing car transmission. NC contour dressing with a diamond disc created an involute form on the grinding wheel so that barrelling on the teeth could be produced by interpolating just two CNC axes on the machine. After hobbing and hardening, the gear first had its register ground on the Makino, followed by finish grinding of each of the 45 teeth in one pass in six minutes.

The first of two Makino A99e-5XR-CD VIPER machining centres demonstrated the complete grinding of root slots on a turbine disc – thought to be a world first. To simulate this, an Inconel billet was inserted into a cast iron fixture. Using continuous dressing (CD), roughing was achieved in two passes using a 300 mm diameter by 25 mm wide Tyrolit wheel. One half of the dresser gave the square form to the first wheel for roughing, the other half was used to dress the second wheel, which finished the profile of the slot floor, using ‘dab’ rather than CD.

A third wheel was automatically exchanged into the machining area – the operation also required automatic programmable coolant nozzle change. A CD cut was again employed to semi-finish grind the fir tree root form, first on one side and, following 180° rotation, on the second. A fourth and final grinding wheel used the same dresser in dab mode to finish grind the root form in two passes to an accuracy of 0.01 mm.

Various other machining operations were demonstrated on this machine, including drilling and spiral milling of air cooling holes in the root slot, precision OD grinding of a bearing journal, grinding of a high-precision curved-tooth coupling, and turning of a hook groove using a static tool in the spindle.

CD, high-speed machining of a 700 mm long, industrial turbine blade made from Inconel 718 was simulated on the other Makino A99e-5XR-CD: an air-cut cycle showing the strategy for roughing, semi-finishing and finish-grinding the root block using three separate wheels. A single dresser was used continuously to maintain the profiles on all three wheels, quadrupling stock removal rate to 200 cc/min compared with non-CD VIPER grinding.

The largest machine, a Makino A100e-5XR-CD with 1,700 by 1,350 by 1,400 mm travels, was set up to demonstrate how the benefits of VIPER grinding are transferable to large nickel alloy components like a 1,100 mm diameter jet engine casing.

The machining sequence started by showing how 2D contouring with a flat, 50 mm wide wheel and roll dresser can perform much of the grinding required on such a part, including coning of an entry angle. Automatic exchange to load the second, 30 mm wide wheel and a V-form dresser was followed by machining of a diameter. The third operation was milling the profile around the bosses on the periphery of the casing, while operation four involved drilling holes through an internal flange.

Make money – break the rules

Peter Hill, engineering fellow – manufacturing technology at Rolls-Royce, provided delegates with a presentation entitled ‘Make money – break the rules’. This is reference to 10 years ago, when the company first decided that its existing processes were not suitable in the face of increasing competition.

“We wanted to machine turbine blades, discs, nozzle guide vanes, segments and combustion casings quicker, for better profit,” he states simply. Incredibly, after just three days of trials, the principles of VIPER were born. Today the Derby facility of Rolls-Royce houses seven, 5-axis Makino A55 machines (six with robots). The technology has reduced seven operations on a curved root form, to one, and reduced a 15 minute machining cycle to less than five. Some half-million turbine blades down the line, by achieving a standard deviation of less than 0.004 mm, scrap is virtually zero.

Now, using the latest generation Makino-NCMT VIPER machines, Rolls-Royce is looking for a ‘roll-up’ of operations such as milling, grinding and deburring. With batch-of-one and zero-set as targets, the company is driving towards even greater reductions in machining time, lead-time and costs.