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Waterjet—An innovative tool for manufacturing

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ABSTRACT

The use of multi-axis waterjet machines as a manufacturing tool is rapidly increasing. A wide range of materials can be machined ranging from carbon fibre composites on the latest aircraft fuselages to difficult to machine exotic alloys and state of the art metal matrix composite materials. This work presents an overview of the range of materials and gives examples of geometries that can now be formed using this technique. The surface finish and processing interaction during machining is also outlined. Cutting, drilling and to a limited extent, milling will be considered.

1. Introduction

Waterjet technology is one of the fastest growing machining processes. It is environmentally friendly, can machine almost any material (Summers, 1995; Momber and Kovacevic, 1998) and can cut metal to depths of over 100 mm (Etchells, 1997; Wang, 2003). It is used in a wide range of industries from automotive and aerospace to medical and the food industries (Etchells, 1997; Summers, 1995). Current applications include stripping and cutting of fish (Etchells, 1997; Floyd et al., 1991), cutting of car carpets (Assarsson, 1994), removal of coatings from engine components (Blades and Sohr, 1993; Scrivani et al., 2000; Engine Year Book, 2002a,b) to cutting of composite fuselages for aircraft construction (Hashish, 2008). The impact of the water alone is enough to machine a material, however, with the addition of abrasive, the material removal rate in the process is several orders of magnitude higher (Wang, 2003).

2. The technology

The technology and applications behind waterjet machining has been investigated since the early 1960s. There are established reference sources such as Summers (1995), Momber and Kovacevic (1998) and Wang (2003) which are essential reading and give a deep insight into this technology. There are also recognised authorities in various aspects of waterjet technology, for instance, Hashish (1988, 1991, 1993), for machining, materials behaviour during machining, characteristics and quality of surface after waterjet treatment (Kovacevic et al., 1997), Professor H. Louis for cleaning, machining, precise cutting, abrasives, surface quality, medical applications (Momber, 2003) and Dr A. Momber for wear of materials treated by waterjets, erosion of ductile materials (Momber and Kovacevic, 1998, 1999; Momber, 2003). Their work in this field is still being cited and used today along with the work of many other eminent publications, authorities and institutions. The scope of this current paper is to give an overview of the range of materials and applications the technology has moved into in the past few years rather than present a critical review of the current state of the art of all these applications to date.

Recent developments have seen the components of the waterjet system become more reliable and robust. Pump technology is such that pressures of over 4.14×10^8 Pa (4140 bar or 60,000 psi) are commonly used and pumps producing 6×10^8 Pa (6000 bar or 87,000 psi) have just recently been introduced to the market (Flow, 2008a,b,c; KMT, 2008a,b; World Pumps, 2009). Such pressures are capable of reliably machining a whole range of materials. These high pressures also allow the use of multi-heads which can enhance the process viability due to the increased throughput (Manufacturing Talk, 2005; Chalmers, 2006).

Head and nozzle design has led to excellent systems being available with minimal maintenance and accurate performance. Fig. 1 shows the detail of a typical waterjet head in this case used for cutting. The water is accelerated through an orifice. This can be ruby, sapphire (usually for water only applications) or diamond with a hole that is, for abrasive water jet machining typically between 0.2 mm and 0.4 mm in diameter. The water then passes into a chamber where the abrasive (if it is being used) is introduced. Finally, the water then passes into a nozzle which is made of hard tungsten carbide or boron carbide material and usually has a diameter of between 0.5 mm and 2 mm. For water only applications the chamber and the nozzle need not necessarily be used. The nozzle life is dependent on its design and the material it is made from. A normal nozzle (equivalent to a Roctec 100 from Boride Products) generally needs changing after around 100 h of processing time when used in typical applications, such as cutting with 80 mesh (150–300 μm)

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Fig. 1. Close up of a typical abrasive waterjet head.

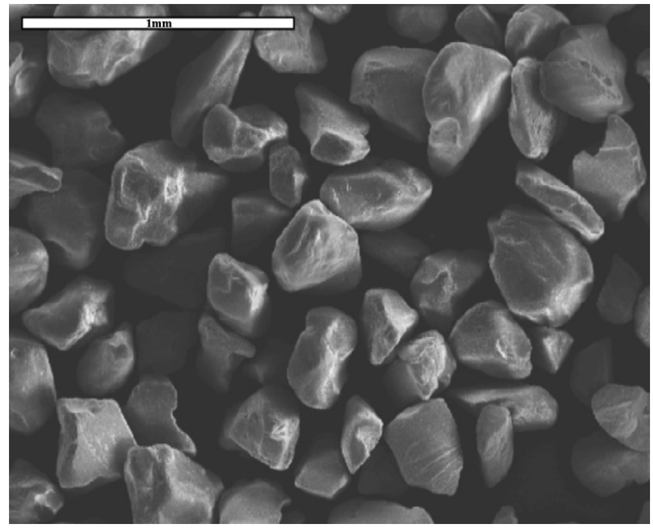

Fig. 2. SEM image of GMA 80.

garnet (GMA, 2007). A ruby orifice is commonly used in abrasive waterjet machining and tends to last longer than the nozzle. Diamond orifices have the longest life time (3 times longer) but are significantly more expensive (5–10 times). More recently, for ease of use, the waterjet manufacturers have introduced an integral diamond orifice and mixing chamber unit (KMT, 2008a,b). This is more expensive but saves issues with alignment and is suitable for applications where repetitive work is being undertaken.

2.1. Abrasive types

The most common abrasive used in waterjet cutting is garnet. It is supplied from various sources and the work horse in the United Kingdom is GMA 80 which is 80 (150–300 μm) mesh (garnet from a source in Australia – Garnet Mines Australia, GMA, 2007). A scanning electron microscope (SEM) image of this abrasive is shown in Fig. 2. GMA 80 cuts most materials with a good surface finish and processing time. Other mesh sizes and suppliers can be used. A finer mesh size such as 120 mesh (100–200 μm) produces a smoother cut surface (Momber and Kovacevic, 1998; Agnew, 2001; Wang, 2003) but the cutting time is increased than if a coarser grade is used (Summers, 1995; Agnew, 2001). If a coarser grade such as 60 mesh (200–400 μm) is used a rougher cut surface finish is achieved but the cutting speed is increased, decreasing the cutting time (Agnew, 2001; Wang, 2003; Chalmers, 2006). Also, thicker materials can be cut. The choice of mesh size is also dependant on the orifice and nozzle used. The abrasive flow rate is dependent on how the abrasive mixes with the water and how the abrasive is drawn into the mixing chamber. Nozzle blockages can result if the abrasive flow rate is too high, the particle size too large or large particles in the distribution or in some cases if the abrasive is too fine and it does not flow properly (Summers, 1995; Chalmers, 2006; Wang, 2003). Vacuum assist can be added to help the abrasive flow too (Flow, 2008a,b,c). Also, it does not necessarily follow that the higher the flow rate the better the cut. For each setting there is an optimum abrasive flow rate above which increasing or decreasing the abrasive flow only serves to roughen the cut rather than enhance it (Wang, 2003;

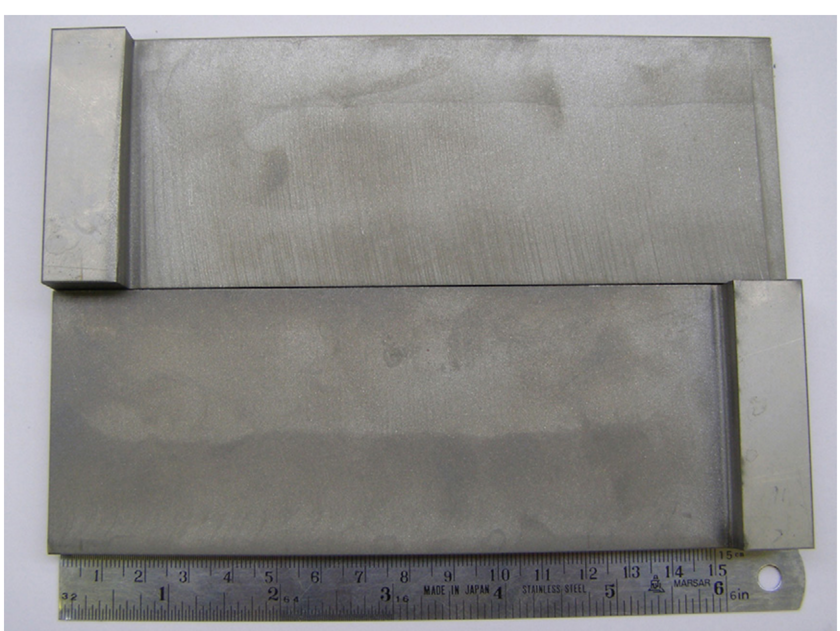

Fig. 3. Material cut at two different cutting speeds.