Effect of Process Parameters on Hole Diameter Accuracy in High Pressure Through Coolant Peck Drilling Using Taguchi Technique

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ABSTRACT
Machining with pressurized coolant is nowadays widely accepted technique in the manufacturing industry, especially in high performance machining conditions. The data on the effects of variation of high coolant pressure in drilling operation is limited. This paper presents the effect of high coolant pressures along with spindle speed, feed rate and peck depth on hole diameter accuracy. Experiments were performed on EN9 steel with TiAIN coated through coolant drill on CNC vertical machining center. Taguchi technique was employed for design of experiments and analysis of results. Results showed that the higher values of optimal coolant pressure and spindle speed were demanded for drilling at bottom of hole as compared to that for drilling at top of hole. The optimal values of feed rate and peck depth were same for both the cases of drilling at top and bottom of hole. Use of high coolant pressure in drilling permits higher peck depth for better hole diameter control which results in reduced cycle time and hence production cost.

KEYWORDS
Drilling, High Pressure Coolant (HPC), Hole Diameter Error, Main Effects Plot, Peck Depth, Signal to Noise Ratio, Taguchi Method, Through Coolant Drill

INTRODUCTION
Machining efficiency and hence productivity depend on proper selection of the machine, cutting tool, machining parameters and coolant. Not only the selection of coolant, but its parameters play a vital role in machining efficiency. In the direction of improving coolant performance, high pressure cooling, cryogenic cooling, atomized coolant spray are the demanding trends in the industry and research field (Blau et al., 2015). Cryogenic cooling (Govindraju et al., 2014; Jerold & Kumar, 2005) and atomized coolant spray method (Nath et al., 2014; Lopez et al., 2006) are still in research stage and are costly techniques. Conventional cooling methods supply coolant with maximum coolant pressure up to 6 bar (Palaniswamy et al., 2009). Hence machining process in which coolant is supplied at a pressure greater than six bar is known as high pressure coolant machining.

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Following are the major difficulties existing in drilling operation.

First difficulty is in effective cooling and lubrication of cutting zone. In drilling, coolant supplied by conventional method can’t reach the cutting zone at sufficient flow rate and pressure, resulting poor cooling and lubrication action at cutting zone (Sanchez et al., 2012). Cooling and lubrication action become less effective as drilling depth increases, resulting thermal distortion of hole.

Second difficulty is in evacuation of chips (Dhar et al., 2006). In drilling chips are formed at the bottom of hole and accumulate there. The conventional coolant flushing system is incapable to evacuate these chips at faster rate, due to insufficient coolant volume flow rate and pressure. This results in clogging of chips in drill flutes and hole surface (Melling et al., 2002) and chips weld to the drill flutes, causing rise of tool temperature as well as work piece temperature. These will result in distortion of workpiece and poor dimensional accuracy of hole.

Third difficulty is in chip breakability. Coolant supplied by conventional method can’t penetrate deeply in to the tool-work piece interface as well as tool-chip interface and hence has poor chip breakability. This result in higher coefficient of friction, larger tool-chip contact length (Palaniswamy et al., 2009), higher thrust forces and hence poor dimensional control of hole.

Hence there is need to study the effect of high pressure coolant supplied directly at cutting zone in drilling using through coolant drill. High pressure coolant approach in drilling can supply coolant at high pressure and flow rate at cutting zone. The performance of machining in high pressure coolant environment was studied by various investigators.

Dhar et al. (2006) studied influence of HPC in drilling operation on chip shape, hole roundness error and tool wear. Study was carried out at fixed cutting speed, feed rate and cutting depth at 40 bar pressure of straight run coolant. The length to diameter ratio of four was maintained. The investigation concluded that better chip formations, less roundness deviation at top and bottom of holes were obtained with high pressure coolant drilling. Lopez de Localle et al. (2000) investigated role of pressurized coolant in drilling and turning operations on Inconel 718 and Ti6Al4V using through coolant drill. The study was carried at 110 bar coolant pressure and at different cutting speeds. The results concluded that high pressure drilling with internal coolant results improved tool life, even at higher cutting speed compared to conventional external coolant drilling.

Denkena et al. (2014) investigated influence of optimized coolant flow rates on tool wear for turning, grooving, side milling and drilling. The study was carried on duplex steel, with Sandvik Coro drill inserts of diameter 8 mm with 5.8% emulsion coolant at 40.2 bar pressure. In milling and drilling operations, higher feed rate demands higher flow rate and higher cutting speed demand lower flow rate. They also concluded that reducing flow rate naturally reduces pressure, which further reduces pump power to considerable level. Jung and Ni (2003) studied the variability of pressure and flow rate of cutting fluid in gun drilling operation of SAE 1045 steel and SAE 319. The experiments were conducted using SAE 30 oil at 75 bar pressure for different gun drilling geometry and cross sections of coolant channel. It was concluded that high pressure coolant and optimized gun drill coolant channel geometry will result efficient chip evacuation in gun drilling process.

Zabel and Heilmann (2012) conducted different experiment on AISI 316L stainless steel with internal coolant facility small drills and oil as coolant. They concluded that chamfer in the tool tip results improved productivity compared to twist drills. Woon et al. (2014) studied deep hole gun drilling of Inconel 718 with emulsion fluids of 10% and 15% neat oil with EP additives at 50 bar and 70 bar of pressure. Results concluded that as tool edge radius increases, axial force of tool increases, resulting buckling and deflection of tool, which further results in hole misalignment towards thin wall. Bermingham et al. (2014) used uncoated WC-Co solid drill for drilling operation of Ti-6Al-4V components. HPC at 70 bar pressure was used for through spindle coolant drilling tools. Drilling trials were carried at different speed, table feed and peck depth. Productivity and tool life was considerably improved in drilling with HPC, as cycle time was reduced by 17% to 43%. This was due to reduced tool changes and increased material removal rate with HPC machining. The economic analysis showed that use of HPC can decrease the production cost by 15% to 64%.