Drilling and Associated Technologies

‘In all things, success depends upon previous preparation and without such preparation......there is sure to be failure.’

CONFUCIUS

(c550–c487BC)
[Analects]
3.1 Drilling Technology

3.1.1 Introduction to the Twist Drill’s Development

Drilling operations are perhaps the most popular machining process being undertaken today, with their origins being traced back to cutting tool developments in North America in the 19th century. In 1864 toward the latter part of the American Civil War, Steven Morse (i.e. later to design the significant ‘Morse taper’ – for accurate location of the ‘sleeved drills’ into their mating machine tool spindles) founded the Morse Twist Drill and Machine Company in the ‘North’. Morse then proceeded to develop probably the most important cutting tool advance to date, namely, the ubiquitous twist drill. In Fig. 42, several of today’s twist drills are illustrated along with just a small range of ‘solid’ contemporary designs. Morse’s originally-designed twist drill has changed very little over the last 150 years – since its conception. In comparison to the somewhat cruder-designed contemporary drills of that time, Morse stated: ‘The common drill scrapes metal to be drilled, while mine cuts the metal and discharges the chips and borings without clogging’. Morse’s statement was at best, to some extent optimistic, whereas the ‘cold reality’ tells a different story, as a drill’s performance is influenced by a considerable number of factors, most of which are listed in Fig. 43.

3.1.2 Twist Drill Fundamentals

The basic construction of a conventional twist drill is depicted in Fig. 44a. From this illustration two distinct cutting regions can be established: firstly, the main cutting edge, or lips; secondly at the intersection of the clearance and main cutting edge – termed the chisel edge. In fact for a twist drill, the cutting process can be equated to that of a left-hand oblique turning tool, where the rake and clearance face geometries are identical and the correlation between these two machining processes have been validated in the experimental work by Witte in 1982. Both of these regions remove material, with the cutting lips producing efficient material removal, while the chisel edge’s contribution is both inefficient and is mainly responsible for geometric errors in drilling, coupled to high thrust loads.

The main cutting edges are accountable for a relatively conventional chip formation, as shown in the ‘quick-stop’ photomicrograph in Fig. 44b. An oblique cutting action occurs to the direction of motion, being the result of an offset of the lips that are parallel to a radial line – ahead of centre – which is approximately equal to half the drill point’s web thickness and increases toward the centre of the drill. This obliquity is responsible for inducing chip flow in a direction normal to the lips in accordance with Stabler’s Law. The increasing chip flow obliquity can be seen in Fig. 45a, by observing the flow lines emanating from the chip’s interface along the lips and up the flute face. Such an oblique cutting action serves to increase the twist drill’s

1 Stabler’s Law – for oblique cutting, can be formulated, as below:

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\text{Chip flow} \ (\cos \eta) = \cos I \left(\frac{b_c}{b}\right)
\]

Where: \(I\) = inclination of cutting edge, \(b_c\) = chip flow vector, \(b\) = direction of cutting vector.