AN INVESTIGATION OF SOME GEOMETRICAL AND PERFORMANCE ASPECTS OF TWIST DRILLS

by

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SUMMARY

A brief review of some major thin shear zone cutting analyses and experimental trends for orthogonal and oblique cutting with single edge tools has been carried out. The Merchant type cutting model was found to be very adequate for force prediction purposes. This type of analysis has been developed and successfully used for predicting the forces in peripheral milling and turning operations. The few analytical temperature models for orthogonal cutting have also been reviewed and their uses discussed. The Boothroyd type model was found to be a promising analysis to develop for drilling operations.

From a survey of drilling it has been found that despite the international agreement in the general geometry of conventional twist drills ambiguities in the drill specification and geometry exist. This became apparent from the few reported analyses of the drill point grinding methods and the variety of different drill sharpening methods shown to be used in practice. The studies of performance parameters in drilling have mostly adopted the empirical approach. The effects of many drill geometrical features, work materials and cutting conditions on the forces and drill life have been tested so that a number of important qualitative trends have been established. A few empirical force equations have also been reported but difficulties in finding similar equations for drill life have been experienced. The published empirical equations accounted for only a few cutting variables which limited their use in practice. Analyses of the forces in drilling based on the thin shear zone cutting model have been attempted by some workers in recent years. These have been partially successful but the various difficulties encountered suggested that further investigations using this approach were necessary. Some analytical studies of the temperatures and life in drilling have been found but these have not been developed to the same extent as the force analyses.

A method for predicting torque and thrust in drilling has been developed in this thesis. The method is based on a thin shear zone cutting analysis for the twist drill and fundamental cutting parameters such as the shear stress and friction angle found from conventional single edge orthogonal cutting test data. In order to account for the variation in cutting geometry along the drill lips and the chisel edge, the cutting edges were divided into a number of single straight edge elements. An oblique cutting analysis was developed for the elements on the lips with the orthogonal cutting analysis applying to the chisel edge elements. The edge forces and their variations were also allowed for each element. Provision was also made to predict the chisel edge forces empirically when the continuous chip formation model failed to apply in this region. The total torque and thrust were found from the summation of the elemental torques and thrusts respectively. Due to the complexity of the analytical expressions a computer program was devised to evaluate the forces in drilling. A series of single edge orthogonal cutting tests were run and processed to obtain the basic cutting data required for the force prediction method proposed.

The force prediction method was assessed by running drilling tests for a wide range of drills and cutting conditions for two work materials. Drilling tests with and without pre-drilled pilot holes were run so that a comparison between predicted and measured thrusts and torques for the lips and the whole drill could be made. In all cases good agreement between predicted and measured values was found. The grand average percentage errors for the torque and thrust were less than 5% and less than 10% respectively for the lips and the drill as a whole. The proposed method was therefore considered to be very satisfactory.

Further applications of the force prediction method were also considered. The effects of the specified drill point geometrical features, feed and speed on the torque and thrust were studied numerically using the force prediction computer program. Agreement with previously published trends was generally found. Using data generated from the proposed method it was possible to establish the mathematically simpler torque and thrust equations usually found by the empirical approach. The empirical type equations developed in this thesis, however, included the relevant drill point geometrical features not included in the equations reported in the literature. The use of these equations for selecting the drill geometry for minimum torque and thrust in drilling was illustrated.

The forces predicted from the proposed method have also been used for drill temperature studies. A temperature analysis for the drill lips based on Boothroyd type model was developed. The effects of drill point geometry and cutting conditions on tool-chip interface temperature were numerically tested and empirical type temperature equations were obtained. The influence of the geometrical and other cutting variables on temperature and drill life were considered from a qualitative point of view although quantitative predictions were not attempted.

The analytical approach adopted in this thesis provided a very satisfactory alternative to the popular empirical methods used in the study of forces in drilling. However further investigations are needed to assess the suitability of this approach for other performance parameters such as drill life.