A Comparative Machinability Study on Three Cast Irons

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Abstract

Compacted graphite iron (CGI) is known to have a poor machinability compared to flaked graphite iron (or gray cast iron) (FGI). The poor machinability of CGI was attributed to the absence of MnS protective layer that only forms at extremely high cutting speeds (above 600m/min) when turning FGI with cubic boron nitride (cBN) tools. This study focuses the machinability study of CGI in the cutting speeds less than 400m/min, the typical cutting speeds of carbide inserts. To delve into the possible difference in the wear mechanisms, the turning experiments were conducted on CGI together with FGI and nodular graphite iron (NGI) with uncoated, single layer and multilayer-coated inserts under dry conditions. In particular, flank wear was measured using Confocal Laser Scanning Microscopy (CLSM) and the wear profiles and flank surface topographies reconstructed from CLSM data for each cast iron are compared. As reported elsewhere, the experimental results indicated that the flank wear of CGI is higher than that of FGI and NGI independent of cutting speed when turning with multilayer-coated inserts. However, with uncoated carbide tools, unexpected adhesion layers covering the entire interfaces on both flank and rake faces were observed when turning CGI and NGI, which reduced their flank and crater wear. By contrast, the flank and crater wear on the multilayer-coated inserts were substantially higher for CGI compared to FGI and NGI without the presence of the adhesion layer. This is not due to the formation of MnS layer when turning FGI as our experiment was conducted at substantially lower cutting speeds where the formation of MnS is not possible. In addition, the adhesion layer was also observed when turning CGI and NGI with single layer TiN, TiAlN and AlTiN coated carbide inserts. The combination of coating material and adhesion layer of CGI and NGI leads to longer tool life compared to turning FGI. To explain the poor machinability of CGI with multilayered inserts, the microstructure of each cast iron was analyzed to determine the content of the main abrasive, cementite, which was found to be similar in all three cast
Therefore, the content of cementite phase alone does not explain the observed difference in flank wear. Finite Element Analysis (FEA) was used to estimate the cutting temperature at the flank and rake surface. The abrasion is the main flank wear mechanism which can be described by the 2-body abrasive wear model as a function of the cutting temperature from FEA. On the other hand, crater wear is generated by a combination of dissolution and the 3-body abrasive wear mechanisms. Based on temperature and pressure profiles from FEA, the predicted crater profiles of multilayer coated carbide inserts are calculated and presented to explain the poor machinability of CGI.

Minimum Quantity Lubrication (MQL) was explored if it will improve the tool life in machining process of CGI. This thesis investigated the turning of CGI at the cutting speed of 250 m/min with uncoated and multilayer coated carbide inserts under dry, MQL and MQL with nano-graphite platelets (M5 grade made by XG Science). The result indicated that the adhesion layer on the cutting edge of uncoated carbide inserts which occurred when turning CGI under dry, MQL and MQL M5 act as a protective layer and reduced the wear. For the multilayer coated carbide inserts, results of turning CGI under those lubrication conditions showed slightly improvement in crater wear without any noticeable difference in flank wear when MQL was applied only on the rake face compared to dry and MQL M5 condition.