Machinability study on GCI brake discs

Effects of material variations and process behavior on tool life

Grey cast iron (GCI) is one of the most used materials in the automotive industry. It has a range of properties that makes it suitable for machining applications. For example, it is fairly inexpensive, has a low melting point, its shrinkage after casting is negligible, and its brittleness makes it less prone to have chip breaking problems. Still, manufacturers experience machinability problems with the material. Automotive Components Floby (ACF), who currently experience machinability issues with brake discs, initiated this study to gain further understanding of tool deterioration in machining of grey cast iron. They provided two brake discs with known relative machinability for the experiments. Machining tests were performed where dynamic cutting forces were recorded, and chip segments were collected. Hardness measurements with nano indentation and SEM microscopy for structure analysis were also performed. The cutting forces and hardness values were analyzed statistically to get representative models for the results.

In turning of GCI, a cutting tool is engaged with a rotating workpiece. Material is removed in the form of chips until a desired geometry is reached. The force generated from the workpiece to the tool can be divided into its three orthogonal components. These components are the axial force F_f, the radial force F_p and the tangential force F_c. A depiction of the forces can be found in ***Figure 1*** below.

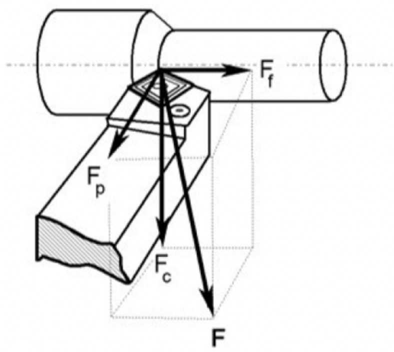

Figure 1*. The cutting force with its three orthogonal components [1].*

During the study, the relation of the axial force and the tangential force showed to be of importance. A low axial force compared to the tangential force reduces the contact surface on the flank face of the insert, which improves machinability.

The segmentation frequency of a turning operation is the frequency at which one chip segment is being produced. The cutting force analyses, where the force signals were transformed to be presented in the frequency domain, showed a lower mean frequency for the material with bad machinability. This shows that a high segmentation frequency is desirable for improved machinability.

The deformed geometry of the collected chip segments showed that the material with bad machinability had to travel longer into the workpiece to produce one segment. This confirms that a high segmentation frequency is desired since the frequency f_s and the segmentation distance e_1 are related to each other according to the equation below. Here, v_c is the relative speed between the workpiece material and the cutting tool.

$$f_s = \frac{v_c}{e_1}$$

When machining GCI, a hard material is generally preferable, as long as the tool is harder than the workpiece. In the case of a harder workpiece, the material will act abrasive on the tool, which reduces its lifespan drastically. If the material is too soft, problems like adhesion of workpiece material on the tool edge can occur. The microstructure of GCI usually consists of ferrite, cementite and pearlite. Ferrite is a soft iron structure and cementite is a very hard iron carbide. Pearlite is a lamellar microstructure, consisting of a mixture of ferrite and cementite. The relatively high hardness of pearlite has proven to be suitable for many machining applications, which is why a high proportion of pearlite is desirable in machining of GCI. The hardness measurements and the statistical analyses of the results confirmed that high hardness in general, and high pearlitic hardness in particular are desirable properties.

When casting iron, chemical compounds can be exposed to the material and inclusions are formed. These can be both wanted and unwanted, depending on how they affect the machinability of the material. Soft inclusions like manganese sulfides can dampen and lubricate the process and are therefore desirable in reasonable amounts. Harder inclusions like carbides and nitrides act abrasive on the tool and are generally avoided. The microstructure analyses gave some unexpected results. It showed that the hardest inclusions were found in the material with good machinability. It also showed that presence of steadite, which is a hard iron phosphide, could facilitate chip breaking, improving machinability. This holds as long as the tool material is harder than the steadite. More expected results were that machinability was improved by a uniform graphite structure and small grain size.

Worn cutting tools were collected from the production line at ACF. These were analyzed under a microscope to clarify the wear problems at hand. The results showed abrasive wear, chemical wear and adhesion of workpiece material to the cutting edge. It was assumed that the wear problems were in part cutting data related, so attempts to suggest development paths for ACF were made. The suggestions were based on a literature survey, and although promising examples of cutting data optimization were found, no real confident proposals could be done. The company's machinability issues are experienced on a batch-to-batch basis, which indicates that each batch needs a unique set of cutting data. That is hard to accomplish, since the company does not have the ability to analyze each batch in house.

References

[1] P. de Vos and J.-E. Ståhl, Metal Cutting - Theories in Practice, Lund-Fagersta: Sweden: Seco Tools AB, 2014.