An Experimental Investigation of the Influence of Cutting-Edge Geometry on the Machinability of Compacted Graphite Iron

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ABSTRACT

Compacted graphite iron (CGI) is considered as the potential replacement of flake graphite iron (FGI) for the manufacturing of new generation high power diesel engines. Use of CGI, that have higher strength and stiffness as compared to FGI, allows engine to perform at higher peak pressure with higher fuel efficiency and lower emission rate. However, not only for its potential, CGI is of an area of interest in metal cutting research because of its poor machinability as compared to that of FGI. The higher strength of CGI causes a faster tool wear rate in continuous machining operation even in low cutting speed as compared to that for FGI. This study investigated the influence of cutting edge geometry at different cutting parameters on the machinability of CGI in terms of tool life, cutting force and surface roughness and integrity in internal turning operation under wet condition. It has been seen that the cutting edge radius has significant effect on tool life and cutting forces. The results can be used to select optimum cutting tool geometry for continuous machining of CGI.

Keywords: Coated Carbide, Compacted Graphite Iron (CGI), Cutting Edge Radius, Cutting Force, Edge Geometry, Flake Graphite Iron (FGI), Machinability, Sub Surface Machined Hardness, Surface Roughness

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INTRODUCTION

Background

The increasing environmental demands to reduce emissions and fuel consumption are placing continuous pressure on the automotive industry to search for a new material for engine block and other structural parts in place of Flake Graphite Iron (FGI), which is also known as Lamellar Graphite Iron (LGI) or Gray Cast Iron (GCI). An economic way to reduce the fuel consumption and hence emission is to increase the peak pressure by using a stronger material, like CGI, in the manufacturing of engine, which can withstand the higher pressure and has all other satisfactory material properties for engine applications. This can even decrease the weight of the engine and hence the material used because of its higher strength. Mohrdieck, (2003) mentioned that in case of heavy duty truck diesel engine the peak pressure can reach up to 200 bar for maintaining an efficient combustion with lower emission. This high pressure will surely increase the forces on all components in the engine. Thus, the engine material must have higher strength to withstand the increased forces in addition to all the other engineering and environmental requirements. Compacted graphite iron (CGI) has around 75 percent higher tensile strength, 45 percent higher stiffness than FGI, mentioned by Dawson, S. (2008). The wear resistance of CGI is approximately double of that of FGI. Although, the thermal conductivity and damping capacity of the CGI are comparatively less than that of the FGI, these properties are still good enough to use the material in engine components (Dawson et al., 1998). Nayyar et al. (2009) have showed that the mechanical properties of CGI material can be controlled by appropriate choice of chemical composition and cooling rate. Later, Nayyar et al., (2012) have seen almost 8 times difference of tool life between pearlitic CGI and ferritic CGI, at a cutting speed of 300 m/min with coated carbides. CGI was first commercially used to manufacture the disk brakes of high speed rail trains in 1999 (Buchholz, 2003). Today automobile companies are investigating the possibilities of using CGI to manufacture future truck engines. But these companies are facing a true problem in using CGI because of the potentially high cost involvement in the machining. Tool life is considerably lower for machining CGI as compared to FGI. It was seen by Nayyar et al. (2009) that the tool life, when machining pearlitic CGI, could decrease by 15 times than when machining pearlitic FGI in continuous operation at a cutting speed of 300 m/min with coated carbides tools.

Graphitic Cast Iron Grades

The CGI is a grade of graphitic cast iron different from other grades such as FGI and Spheroidal graphite Iron (SGI) with respect to graphite shape. Physical and mechanical properties of cast irons are largely determined by the size, shape and orientation of graphite particles in their microstructure. In FGI, graphite particles appear as flakes and are randomly oriented in iron matrix. In SGI or ductile cast iron, graphite particles appear as individual spherical nodules. In CGI, the graphite particles are found as randomly oriented worm-shaped compacted features. These worms are shorter and thicker as compared to the flakes in FGI and have rounded edges (Dawson, 2008). The optical micrographs of polished cross-section samples in Figure 1 show the shape of graphite present in FGI, CGI and SGI. Figure 2 shows the scanning electron micrographs of deep-etched samples of FGI, CGI and SGI. It can be seen that the graphite worms in CGI are connected to their neighbor in a complex coral morphology. A strong adhesion exists between the graphite particles and the iron matrix in CGI because of such shape and orientation of graphite particle. This is the major cause of the improved mechanical and physical properties of the CGI (Dawson, 2008). Contrary to this, the graphite present in FGI is thin and interconnected. This can easily leads a crack to propagate through the material. The graphite present in SGI is spherical in shape, which makes the material even stronger than CGI as the crack has to pass through the stronger
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