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The influence of sulfur on the machinability of gray cast iron FC25

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Abstract

The present research deals with the influence of sulfur on gray cast iron machinability. Tupy Fundições produced the workpiece materials in usual commercial manufacturing conditions with sulfur levels raging from 0.065 to 0.18%. The influence of different of sulfur contents on gray cast iron machinability was studied for turning operation at 100, 150 and 200 m/min cutting speeds. Uncoated cemented carbide tools were used, and ‘flank wear’ assessment criterion was applied. The sulfur increase from 0.065 to 0.18% did not produce significant alteration on mechanical properties nor on material microstructures. It was verified that for an effective reduction of the adhesive wear during the machining the smallest area occupied by the manganese sulfide must be $(18 \pm 6) \times 10^{-3}$%. The machinability of gray cast iron FC25 with 0.12, 0.15 and 0.18% of sulfur does not differ significantly when machined at 150 and 200 m/min. In relation to gray cast iron FC25 with 0.12% of sulfur, the material with 0.065% S presented a tool life reduction of 24, 32 and 38%, for the speeds 100, 150 and 200 m/min, respectively. From this research, important results were obtained, becoming viable the use of a higher sulfur percentage on gray cast iron FC25 production, without the detriment of mechanical properties, microstructure and machinability.

Keywords: Gray cast iron; Machinability; Sulfur; Manganese sulfide

1. Introduction

The expenses for removing material from a workpiece, during manufacture, reach more than US$ 100 billions, yearly at USA [1,2]. Only four machining processes are responsible for 75% of this value. They are: turning, drilling, milling and grinding. The machinability is then an important issue when economic aspects are to be optimized.

Machinability may improve with the proper choice of machining parameters (depth of cut, feed, cutting speed, cutting fluid, tool insert geometry and tool material) or through workpiece material adjustments. Manufacture improvements involve two aspects: technical and economic. Among technical aspects are: the possibility of producing a part according to restrictive specifications, the easiness of chip removing and the better performance of chip formation mechanism, etc. The economic improvements can be associated to: low wear for the tool, small cutting forces and low energy consumption, which combined can lead to shorter machining times and lower cost per part.

An extensively used method to improve machinability, without changing materials mechanical properties and microstructure, is the addition of certain inclusions. Such inclusions, named engineering inclusions, make possible the reduction of cutting forces and tool wear.

Opitz [3] described the first known reference concerning the beneficial effects of engineering inclusions on machinability. He identified the growth of a built-up layer on the surface of a carbide tool during the machining of calcium-deoxidized steel. Ever since, the uses of theses inclusions have been widely studied.

Manganese sulfide is among the machining favorable inclusions. Depending on adequate conditions, the inclusions build a protective layer on the tool surface, named built-up layer (BUL), which promotes wear reduction of the tool and diminishes the cutting force [4–7].

Differently from steels, where manganese sulfide inclusions are intentionally obtained to improve machinability, gray cast iron presents these inclusions as a natural result of the foundry process in cupola furnaces. To avoid the combination of sulfur (embedded in coke and scrap steel) with iron, which results in iron sulfide with low melting point, manganese is added

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to promote the development of more stable manganese sulfide inclusions.

The manganese sulfide inclusions generate good results with respect to costs and productivity, motivating constant studies aiming to machinability improvements. The presence of manganese sulfide inclusion in gray cast iron is able to reduce the coefficient of friction up to five times at the chip–tool interface, thus increasing tool life [8].

Therefore, the goal of this work is to analyze the machinability of gray cast iron FC25 for a large range of sulfur contents. The effects on properties are to be inspected, specially the influence of manganese sulfide on machinability.

2. Theory review

The sulfur influence and the role of manganese sulfide inclusions on gray cast iron machining are shown in the flowchart of Fig. 1. Special highlight is given to the influence of sulfide manganese inclusions on the machinability of gray cast iron, because its economic benefits.

2.1. Morphology and distribution of manganese sulfide inclusions

Increasing sulfur contents in gray cast iron alters the morphology of manganese sulfide inclusions and increases inclusions size. This explains the better results obtained by Erickson and Hardy [9] in turning tests with manganese sulfide inclusions of type III (0.12% S) than with manganese sulfide inclusions of type I (0.02% S). However, for steel the best results are obtained when type I inclusions are present in the material [10–16]. According to Ramalingam et al. [13] these results can be explained because inclusions of type III come together with abrasive inclusions.

2.2. Volume of manganese sulfide inclusions

The manganese sulfide inclusions are more ductile than the matrix. Thus, the MnS inclusions are intensely deformed in primary and secondary shear zone, generating micro-cracks which promote chip breaking ([5]; 1993 apud [7]). Therefore, as the

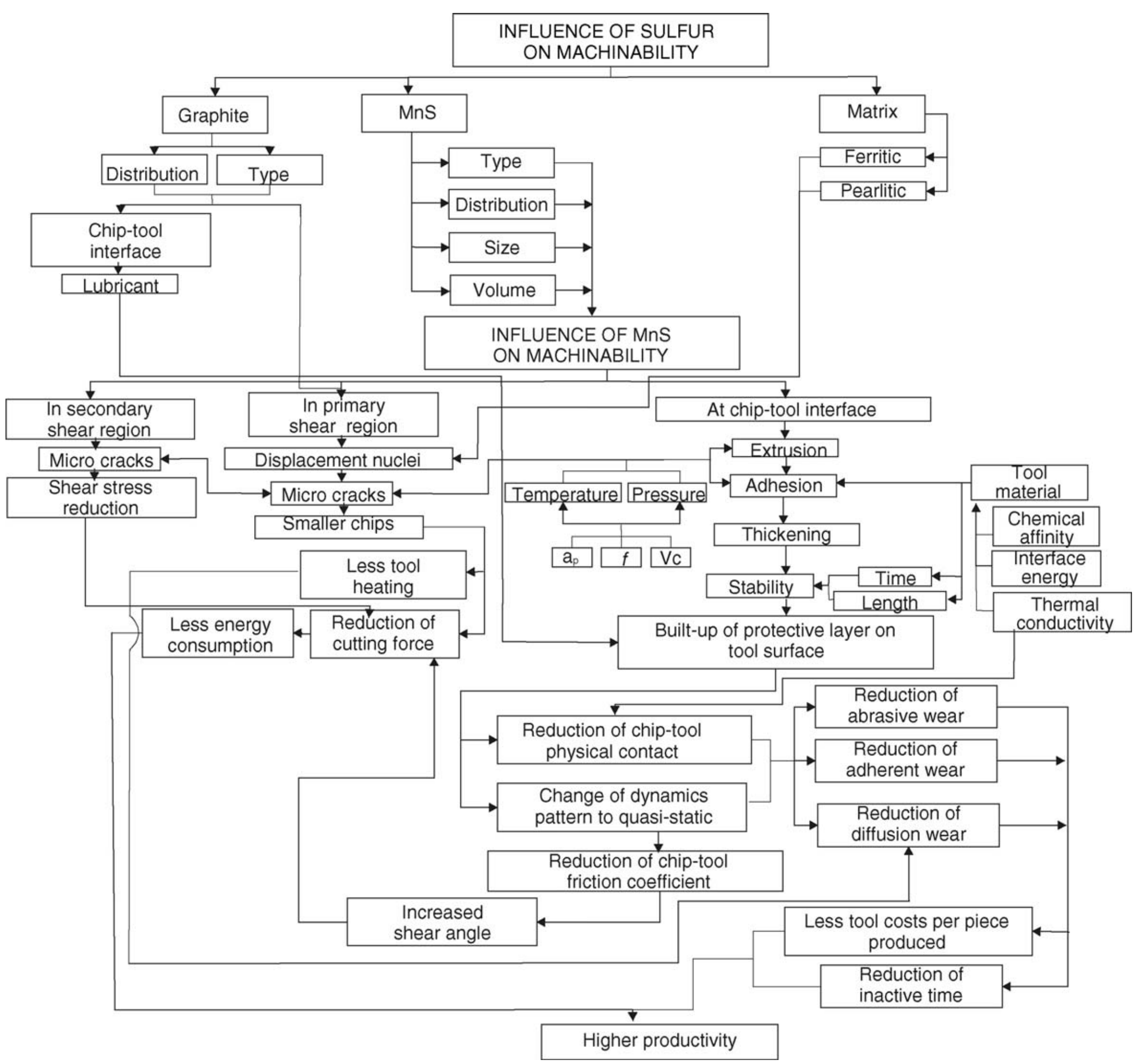

Fig. 1. Flowchart showing the sulfur influence on gray cast iron machinability [20].