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Study of the Variability of the Machinability along the Cross Section of Ductile Iron Produced by Continuous Casting

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Abstract

In industry, the increase in the search for new materials is related to the cost and to the strength to weight ratio. In an effort to achieve these requirements new materials with low density and similar strength are employed or the resistance of traditional materials are increased by the addition of alloying elements or heat treatments. The choice usually depends on the mechanical and thermal properties and other aspects, such as manufacturing costs, recyclability, customer acceptance and machinability. Cast irons usually offer good machinability and low production cost, but long bars produced by continuous casting may present variability in their properties, including machinability along their cross sections. This is particularly true in bars with large cross sections. This work evaluates the behavior of the machining torque and surface roughness along the cross section of rectangular bars of nodular cast iron produced by continuous casting in slot-milling operation. It was found that the pearlite microstructure of the matrix and the mechanical strength contributed to the highest machining torque presented by the intermediate and core regions, but they did not affect the surface roughness significantly.

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Keywords: Nodular cast iron; Continuous casting; End milling; Torque; Surface roughness

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1 Introduction

Along with steels, cast irons are the materials most used by the industry and it is used in many sectors, not only because of its inherent characteristics, but also because its immense versatility [1]. In recent years the development of research on the cast irons contributed to this material offering a good competition for steel [2].

The replacement of carbon steel by nodular cast iron bars produced by continuous casting has proved to be an excellent alternative for companies who wish to reduce manufacturing costs, producing more parts per machine hour with less tool costs [3].

The increasing application of ductile iron in the industry gives rise to the need for further improvement in research and innovation, which aims to better understand the performance of these materials under the various types of manufacturing processes. These materials are characterized by good mechanical strength, ductility and higher toughness than grey cast irons, due to the spheroidal form of the graphite, keeping the continuity of the matrix, thus generating less stress concentration [4].

According to Guesser [5], the good machinability of ductile iron is given by the presence of free carbon in graphite form in the matrix, which facilitates to break the chips and act as a lubricant at the chip/tool interface. The presence of graphite is also responsible for lower density (10% less than steel), higher thermal conductivity and higher vibration damping capacity. The ductile iron produced by continuous casting have similar mechanical properties to the steel, with the advantages of being lighter and have better machinability. Figure 1-a illustrates, schematically, the continuous casting process.

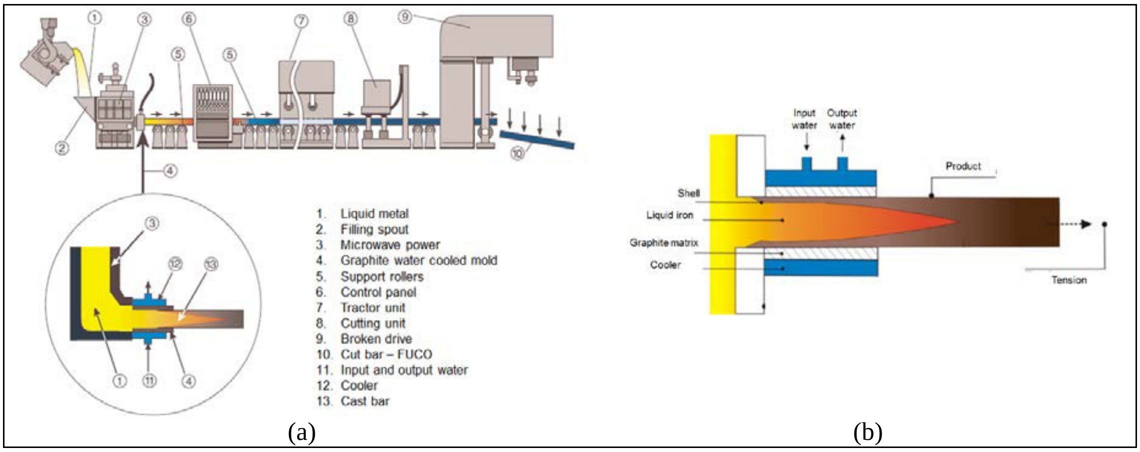

Figure 1: (a) Continuous casting processes of ductile iron (FUCO, 1998); (b) Temperature gradient generated during the casting process of a ductile iron bar (Adapted from [6])

The bar of ductile iron, produced by continuous casting is longer than the mold, thus enabling the production of bars in various geometries. However, the manufacturing process produce heterogeneous properties along the cross section of the manufactured part, because of different cooling rates from the core to the periphery, which may cause different levels of properties and machinability along the material’s cross section (Figure 1-b).

The main variables that determine the microstructure of the ductile iron produced by continuous casting are the cooling rate, the chemical composition and the manufacturing process. The interaction between these variables determines the mechanical characteristics of this material [6]. Usually bars with larger cross sections may show microstructure and properties variations from the core to the periphery, which can affect the functionality of the mechanical component. In particular, for ductile iron bars of the grade 45012, the observations in the machining floor is that there is a difference in machinability between the center and the periphery of the bar.

The aim of this work is to investigate the machinability (milling) of bar of ductile iron, studying the behavior of torque and surface roughness along the cross section of bars produced by continuous casting. The cross section of the bars was divided into three sectors: the periphery, intermediate region and core. It was verified the correlation of the variables that control the machinability (torque and workpiece surface roughness) and the microstructures and mechanical properties of the various sectors.