HOT TOPICS

Issue #1, 2019

The Iron Casting Machining Process

Introduction

Significant previous work has been published on Metallurgical Factors affecting Machinability was previously published in Issue #3, 2000.[1,2,3] Since this publication, additional requests for information have been made. In particular, a better understanding of the cast iron machining process and other metallurgical and non-metallurgical factors affecting iron machinability and a review of any data that may be available.

Machinability is commonly measured by tool wear in many cases, the number of cycles until a tool change is needed for any operation. The criteria for a tool change can be determined by many measurables such as surface finish, appearance, waviness, machining noise or any quality measurable that the machine responsible/OEM deems important.

There are many factors that can influence the tool life. These include general casting design considerations, depth of cut (DOC), location of clamping surfaces/pads, casting design, locations of ingates. Machining setup and process variables will impact the tool change frequency: Clamping force and location, tool and spindle vibration, tool holder design, tool geometry, material selection, machining coolant, surface finish requirements and tolerance stack-up GD & T (Geometric Dimensioning and Tolerancing) are all to be considered. Also, as importantly, there are metallurgical factors that can contribute such as microstructure hardness, microstructure consistency, treatment and inoculation methods and/or materials, metal strain hardening, casting micro inclusions and cast surface cleanliness.

Casting Design and APQP

Tier I responsible suppliers must consider many facets of the casting design and use. The machining process is key and part of the APQP process. It should highlight the design requirements and identify conflicts between machining print, GD&T requirements and the casting print. Once the lowest cost method of machining with sufficiently robust equipment has been determined, the optimal machining operation must be designed. Major datum and locator points, parting line locations, etc. must be built into the casting to allow for proper clamping of the part during the machining operations. A casting DOC increase or decrease of only 0.010" can impact tool life by as much as 50% or more as reported by Penn State.[4]

Machining Setup and Tooling

Over the past 30 years the tooling design and materials have changed tremendously. The Tribology of tool-chip interface and wear mechanisms have been studied extensively. The use of coated Tungsten Carbide and Ceramic cutting tools have replaced high speed steel. The most expensive operation traditionally has been milling, with the use of inserts that are setup in cutters or auto mills. Most inserts can use multiple corners and edges, 6 to 8 is normal but more is possible. Wear of the tool occurs on multiple faces as per Figure 1.

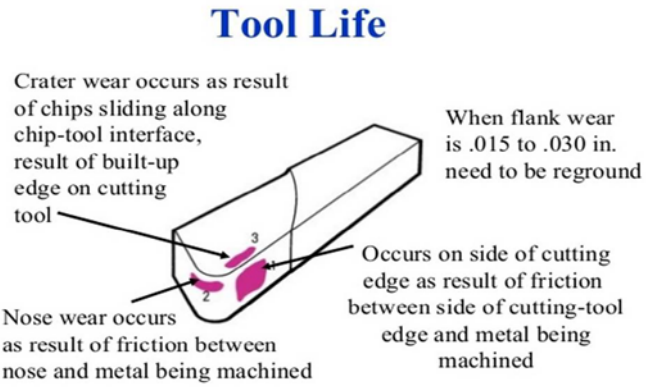

Figure 1. Types of Tool wear. [5]

Cutting fluids are an instrumental part of metal machining due to their improvement of the tool life, reduction of the work piece thermal radiation, flushing away chips from the cutting area, and improving the surface finish. There are four main categories of cutting fluids:

- Straight oils, these oils are non-emulsifiable and very useful in machining operations where they function in undiluted form.
- Synthetic fluids; they are formulated from the alkaline organic and inorganic compounds alongside additives to prevent corrosion.
- Soluble Oils, these usually form an emulsion after mixing them with water. They are the least expensive and are the most widely used fluids in the industry;

- Semi-synthetic fluids, these fluids are basically a combination of the soluble oils and synthetic fluids.

Machining Process and Equipment

Up until the late 1990's, for high volume programs, dedicated equipment and fixturing was custom built for each application. Since then, flexible CNC machining cells are commonplace, sometimes with multiple cells to meet production volumes. CNC machining offers the flexibility to be easily repurposed many times over. A well-designed CNC Tombstone fixtures and casting will securely clamp the part in place to minimize movement and vibration that if inadequate will contribute to tool wear and poor surface finish.

Machining spindles and bearings must be properly specified for each application. Regular scheduled preventative maintenance including vibration analysis will help to identify problems and prevent unnecessary downtime and quality issues.

Metallurgical Aspects

The grade and chemistry of cast iron can influence the tool life. For examples, as is shown in Figure 2, comparing GJS 500-7 to Solid Solution Ferritic Ductile Iron (SSFDI) under 2 different cutting speeds. The single-phase ferritic matrix in SSFDI is a clear advantage for minimizing hardness variation and hence improving machining consistency.[5] In this study the tool life is measured in minutes of operation until a prespecified amount of tool wear is achieved. Metallurgically, the difference between the grades is that the SSFDI has a more consistent microstructure, with minimal pearlite.

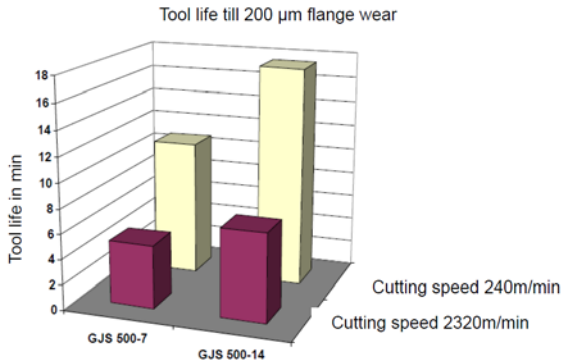

Figure 2. DI Machining Study vs Iron Grade. [6]

Figure 3 shows the relationship between metal removal and inoculation from an industrial study. This was completed on a casting designed for a turning operation.[7] In this study the amount of iron removed until the tool is worn out is the measurement criteria. This study indicates that inoculant selection can influence machinability, as can the type of Mg treatment method used by the foundry.

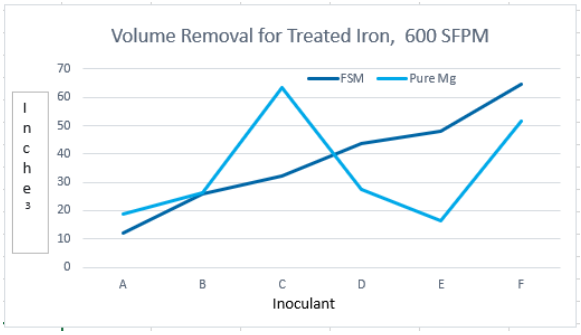

Figure 3. DI Machining Study vs Inoculation. [7]

Figure 4 illustrates the influence of cutting speed and materials on ADI Grade 2, Tool life.

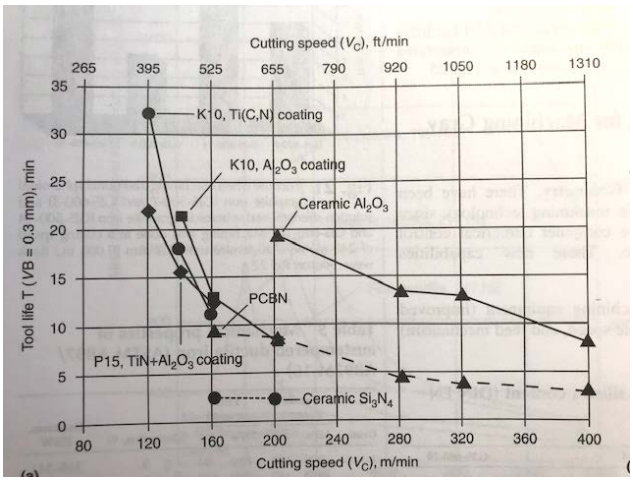

Figure 4. ADI Tool Life vs different cutting tool materials. [8]

As hopefully has been demonstrated, the purpose of this hot topic is to show some revised data, references and that there can be many factors, some metallurgical and some not that can influence the machining of DI.

References and Sources

1) DIS, Hot Topic #3, 2000. Metallurgical Factors Affecting the Machinability of Ductile Iron
2) DIS Project 14, An Investigation of Factors affecting the machinability of Ductile Irons, 1987.
3) DIS Project 20, Machinability of Ductile Iron Castings, 1993.
4) Bob Voigt, Penn State, Machinability of cast irons: from GI to ADI
5) http://www.mech4study.com/2017/03/tool-wear-flank-wear-crater-wear-and-nose-wear-mechanism.html
6) Componenta, 2014, Source IfG Sirion project
7) Elkem Machining of Cast Iron Study, 2003, UA
8) ASM Handbook 1A, page 328, Secondary processing of Cast Iron