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Making headway through the many variables of cast iron machining

Fagersta, March 2013 – Manufacturers face several variables and challenges when determining the right tooling to maintain competitiveness in cast iron machining operations. Not only are there several different types of cast irons, the material itself can vary from one casting to the next. So to choose the appropriate cutting tool insert geometries and grades, manufacturers must understand all the factors involved and take into consideration their entire production chains if they are to successfully achieve the best combination of quality, cost and productivity.

While cast irons are used in a wide variety of industries, the automotive and heavy equipment sectors tend to be the primary end users of the materials, making products such as brake disks in mass quantities and large pumps in short production runs, respectively. These two components also happen to represent two key reasons more manufacturers use cast iron – for very large batch sizes or for part designs that are so complex there are no realistic alternative production methodologies to produce them.

With that said, this article will touch upon machining aspects from the cast iron material perspective, as well as the turning and milling points of view. It should also be noted that there are other aspects to be considered when applying these concepts in the real world production of components such as brake disks or large pumps.

Today’s cast irons are a lot more advanced and better understood than they were 20 years ago. In some cases, this makes them an excellent alternative to steel in a time when there is a constant pressure to lower prices and improve productivity. Generally speaking, cast irons are getting lighter, stronger, more affordable and now have higher wear resistance. These materials also yield free machining, work well in producing complex shapes as well as have high machinability. Keep in mind, however, the level of strength, cost and machinability varies between cast iron types, which include grey, vermicular, silicon alloyed ferritic ductile, nodular ductile and austempered ductile. (See sidebar: A quick look at modern cast irons.) For each type, there are several grades with widely differing mechanical properties. These variations mainly result from the differences in the microstructure of the metal matrix that surrounds the graphite.

In addition to having to choose between the different types of cast irons, manufacturers must also take into consideration that cast iron metallurgy is quite complex. The casting process in its very nature will generate microstructures with properties that vary between a part’s surface and its internal body.
Therefore, one could say that two different microstructures co-exist within the same casting. Also, cast iron quality varies from one foundry to the next, meaning even if the type of cast iron is the “same,” variations in the casting process could generate significant differences, in terms of machinability levels, from one workpiece to the next.

Take grey cast iron for example. Its machinability is affected by variations in the surface and by other near-surface conditions, such as mould residues or free ferrite, the latter which is iron in its purest form, that disturb the manufacturing process in different ways. The former creates harder and randomly located zones, while the latter results in softer areas of the workpiece. These variations cause predictability deviations that influence machinability. Therefore, manufacturers must have carefully planned logistics, from casting to storage to machining, to ensure they have consistent workpiece batches that are large enough for their applications.

It is important to have the properties of the workpiece under the best possible control at any given time. After all, any variations can negatively impact total productivity, either directly or indirectly. When workpiece properties are unclear, manufacturers can look to tooling systems and cutting strategies to make up for any material quality shortfalls. However, the trick is to know what tools and strategies are the right fit for a particular application.

Cutting tool companies are continuously developing new turning and milling products that help overcome the variables and challenges manufacturers face when working with cast iron materials. But this can be a feat in itself because every material, manufacturer and application around the world is unique. A cutting tool company may have product solutions with wide application windows for cast iron, but much depends on individual customer needs and the chosen machining strategy or method. While some manufacturers are willing to spend the money on a wide variety of insert types and grades to optimise every application for maximum productivity, others choose a limited selection of inserts and grades with an “all-around character” to make their processes easier to manage but then experience lower productivity.

Consider grades for turning, which is a high area of focus in this type of machining process. In the past, cutting tool companies would have several insert grades from which to choose. Today, the goal is to reduce the number of grades needed by creating top performance solutions that can still handle a wider range of cast iron materials and specifications, which, in turn, make the selection process easier. Some cutting tool companies are using advanced coating processes to create two- and three-grade strategies for their customers. Seco Tools, for example, has a two-grade turning strategy made possible via its exclusive Duratomic® coating technology grades where aluminum and oxygen are manipulated at the atomic level to create inserts with a combination of exceptional toughness and abrasion resistance for cast irons.

In terms of actual cast iron turning operations, everything is dependent upon a manufacturer’s specific application. Manufacturers must determine the number of operations necessary to accomplish their goals, no more and no less. If the workpiece properties are unknown, a manufacturer may opt to include an extra finishing cut, which impacts product lead times. However, by applying the right tooling for the conditions and requirements of the component, a manufacturer can reduce the number of operations. A more specific turning operation scenario might involve a manufacturer machining components within a just-in-time supply chain as indicated earlier. In such a situation, batches of as-cast workpieces are sometimes out of specification in terms of near-surface conditions, yet must still be machined despite an increased cost per part caused by reduced tool life and productivity. At which point, the manufacturer must carefully decide between different types and grades of inserts, which might include cemented carbide and polycrystalline cubic boron nitride (PCBN) tooling. However, if the foundry supplying the grey cast iron, for example, provides a consistent quality level, manufacturers can reach unbeatable productivity levels using PCBN tooling.

When it comes to milling cast irons, there is a lot more complexity involved as compared with turning the material. While the type of insert grade a manufacturer uses is important, it is even more critical to look at the total cutting solution. A manufacturer must also consider – in addition to insert geometries and grades – cutter body types and the number of cutting edges as related to the component being machined. Doing so plays a key role in achieving a low cost per part.

Today’s cutting tool companies are trying to fulfill customer needs and simplify cast iron machining by providing solutions that are easier to apply and that perform better for as many types of materials and
applications as possible. For example, heat and coolant are not ideal for cast iron machining, especially in milling. Therefore, cutting tool companies are working on top-performing grades for milling in both dry and wet conditions. These companies are also looking to help manufacturers reduce machining times through cutting solutions that can effectively rough and finish in one pass.

In terms of selecting the best type of cutter for cast iron milling, there is no real one-size-fits-all answer. But generally speaking, the type of milling cutter that seems to be making a lot of headway these days would be a negative cutter with inserts that have positive rake angles and in a grade that handles both wet and dry conditions.

By having a positive cutting rake angle in a negative cutter, manufacturers benefit in multiple ways – freer cutting action as well as reduced power consumption and heat generation, all of which leads to longer tool life and an increase in usable cutting edges. For example, consider face milling an engine block where there are a lot of cavities. When the milling cutter machines over each cavity corner, the goal is to avoid chipping those cavity edges. If the manufacturer is using a worn cutter in conjunction with high cutting forces, there is an increased risk of chipping out sections of the workpiece material — a negative cutter with a positive rake angle can help avoid such a scenario.

Keep in mind, however, while one type of cutter may be able to successfully cut all the different types of cast irons, that does not mean it can effectively machine every type of workpiece shape. For that reason, cutting tool companies offer different shapes of cutters, from square shoulder mills to face mills and everything in between. Manufacturers must think about the surface they need to cut, asking themselves: Is it square in form or very long? Are the wall thicknesses thin or thick, weak or stable? And, how secure is workpiece clamping?

Furthermore, manufacturers also need to consider the type of machine tool they are using in their operations. When machining cast iron materials, there is a higher dynamic load, so the machine tool must be highly robust as well as provide high power and high stability. All of which puts strain on the machine. However, in these instances, a negative cutter with the positive rake angle can help lower the power requirements of the machine tool and reduce forces on machine spindles as well.

But in the end, with so many variables to consider, if a manufacturer wants increased productivity and predictability in their cast iron machining efforts, the best action is for them to work closely with their cutting tool supplier.

As a valuable resource, today’s manufacturers must combine their extensive knowledge of their own manufacturing technology with that of a tooling suppliers’ in-depth knowledge of machining. Because of such collaborations, manufacturers keep abreast of the latest advancements in manufacturing, as well as gain an understanding of how machining innovations play into manufacturing process optimisation. The end result is that a shop continues to increase its competitive advantages and differentiate itself as a technology leader in the increasingly challenging global market.

[SIDEBAR]
A quick look at modern cast irons

It wasn’t that long ago when manufacturers viewed cast iron as cheap, brittle and dirty metal. Today, however, through production advancements, cast iron comes in a wide variety of types that are stronger and provide better machinability than ever before. Keep in mind though the level of strength and machinability varies between and within each type.

• Grey cast iron (GJL), among the most common and least expensive of all the types, contains carbides in the form of lamellar graphite particles, which gives it excellent vibration damping properties and makes it ideal choice for engine components. It also has the highest level of machinability when compared to the other types.

• Vermicular graphite cast iron (GJV), also known as compacted graphite iron, gets its name from the worm-like appearance of its graphite particles. It offers greater strength and lower weight when compared to grey cast iron. Because vermicular cast iron is suitable for components subjected to both mechanical and thermal stress, automotive manufacturers are using it for the production of certain components e.g. diesel engine parts.
• Silicon alloyed ferritic ductile cast iron is ideal for the production of wheel hubs and axles. Given its high degree of machinability and excellent mechanical properties, the material is becoming increasingly popular within the automotive industry.

• Nodular ductile cast iron (GJS), which consists of spheroid nodular graphite particles in ferrite and/or pearlite matrix, possesses high ductility, good fatigue strength, superior wear resistance and a high modulus of elasticity, and hence have been the choice of material for transmission housings and wheel suspension parts within the automotive and heavy equipment industry. Besides, special alloys of ductile iron are used in the production of high-temperature components such as exhaust pipes and turbocharger housings.

• Austempered ductile iron, which is manipulated through a sophisticated heat treating process, offers high strength, high fatigue strength, good wear resistance and high values of elongation to fracture, making it a very competitive material in relation to many cast and forged steels. Because of great strength and elastic properties, austempered ductile iron has the lowest level of machinability when compared to the other types of cast iron mentioned here.

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About Seco Tools:
Seco Tools is a leading manufacturer of high performance metal cutting tools. Seco’s product range includes a complete programme of tools and inserts for turning, milling, drilling, reaming and boring as well as complementary tool holding systems. With more than 25,000 standard products, Seco is a complete solutions provider for the metal cutting industry and equips machine tools from the spindle down to the cutting edge.

The company is headquartered in Fagersta, Sweden and represented in more than 50 countries worldwide with 40 subsidiaries, distributors and channel partners.

More information can be found at: www.secotools.com

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