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special focus: holemaking

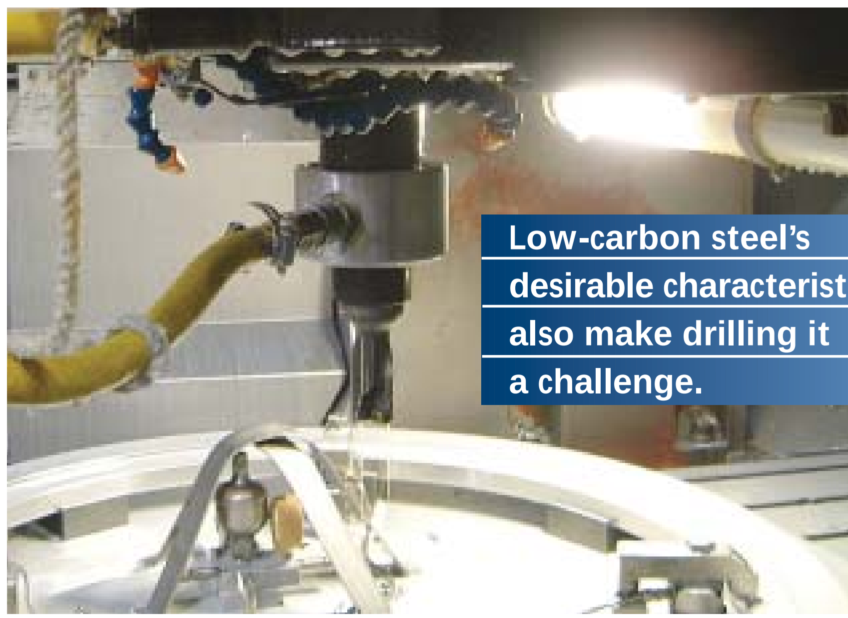
➤BY BRUCE CARTER, SANDVIK COROMANT CO.

Low-Carb DRILLING

The best contract manufacturers learn as much as they can about their operations. By combining knowledge of material properties and the capabilities of their machines and tooling, these shops optimize their processes to increase productivity and minimize waste.

For those serving the automotive industry, this often means knowing how to machine low-carbon steel. Low cost and ease of forming and machining are reasons this material is used to make so many automotive parts, including torque converters and frame and suspension components.

While low-carbon steel is often the material of choice for these parts, it also presents machinists with unique challenges in certain operations. One is drilling with indexable-insert drills.



Low-carbon steel's desirable characteristics also make drilling it a challenge.

All images: Sandvik Coromant

Sticky Situation

A big problem encountered when machining low-carbon steel stems from its ductility. The material typically produces long and stringy chips that are difficult to break. Its gummy nature also results in chips sticking to the cutting tool, and the material's hardness often is inconsistent.

Combined, these characteristics frequently cause chip-control problems. These, in turn, result in unpredictable, difficult-to-control processes.

Chip evacuation is critical when drilling. Poor chip control negatively influences the process a number of ways. Quality suffers in terms of hole diameter, roundness and surface finish. There is also the possibility of the workpiece or tool being damaged or the tool suffering catastrophic failure.

Potential problems are amplified by the manner in which many automotive manufacturers optimize their processes. The large-batch runs common in the industry often necessitate high levels of automation. Long, stringy chips can easily get tangled in fixturing, causing parts to locate inaccurately. At minimum, this increases scrap. Of even greater concern, though, is that an improperly located part could damage or break the drill in an automated process. This could cause damage to tools or parts downstream.

Drilling low-carbon steel with indexable-insert drills demands that more attention be paid to process parameters than when using traditional twist drills. The cutting edges of inserts cannot, by design, be as sharp as the edges of HSS or solid-carbide drills. (Sharp edges are key to the successful drilling of low-carbon steel, as is explained later.) A carbide insert with a perfectly sharp edge would be too brittle to withstand the cutting forces encountered and any tool coating applied would not stick.

Poor chip control leads to additional problems when indexable drills are applied. Chip jamming and hammering can cause insert chipping and catastrophic tool failure.

Despite these challenges, indexable-insert drills are a good choice for low-carbon steel. That's especially true when producing holes 0.750" and larger, an operation that can be cost-prohibitive with solid tooling. It is critical to adequately manage chips, which hinges on selecting the correct tool geometry and cutting parameters.

The Right Tool

Chip-breaking inserts designed for short-chipping materials, such as alloyed or 4140 steel, are ill-suited for drilling low-carbon steel. Typically, the

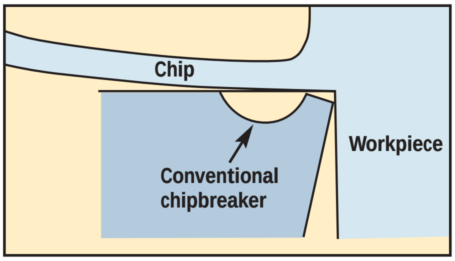


Figure 1: Most chipbreakers are too narrow and shallow to properly curl low-carbon steel chips.

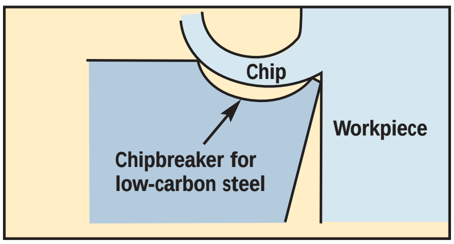


Figure 2: An insert designed for low-carbon steel features a relatively high shear angle and a wide, deep chipbreaker.

cutting edges of these inserts have a large T-land—the flat portion of the cutting edge that protects it when cutting harder materials—and their chipbreakers have shallow, narrow grooves. These features are not conducive to cutting ductile materials.

Chips flow freely from low-carbon steel, and they tend to flow straight out from the cutting edge (Figure 1). While that may sound advantageous, it makes chip control difficult. Chips must be formed into relatively tight curls to be effectively controlled.

Inserts designed for low-carbon steel feature sharper cutting edges than those used for less ductile materials (Figure 2). With a sharper edge, the chip, even though it still flows freely, is cut at a higher shear angle and is directed into the chip channel.

The chipbreaker geometry on such an insert is more exaggerated. It features a wider, deeper chip channel. A low-carbon steel chip simply flows past a conventional chipbreaker, behaving as if there were no geometry present at all.

Occasionally, an insert with the proper geometry is all that is needed to solve chip-control problems encountered when drilling low-carbon steel. But more often than not, consideration also must be given to the drill body.

Straight-flute drills usually are ineffective. The shape, depth and helix angle of the flutes must be designed to efficiently carry chips up and out of the hole. And, flutes should be designed to work in conjunction with the inserts.

For maximum effectiveness, each flute needs to carry the chip formed by a specific chipbreaking insert. This means the flutes of drills for low-carbon steel often have different shapes, as the chips produced by the center and peripheral inserts are formed differently.

The rake angle of the inserts in the drill body also influences chip evacuation. A positive rake is most effective for low-carbon steel because it helps direct chips up the flute (Figure 3). Most indexable drills, however, feature a neutral rake.

Various considerations during the manufacturing of the drill body make a neutral rake easier to produce. Because of this, less-than-optimal chip evacuation historically has been accepted by those who drill low-carbon steel. But that is changing. Today's modern, multi-axis machining centers make it easier to cut drill bodies that have positive rake angles.

The Right Parameters

When machining less ductile materials, such as alloy steel, increasing the feed per revolution often enhances chip control. In low-carbon steel and other more ductile materials, though, the opposite is true. A high feed rate results in a thicker chip, which is difficult to curl into a manageable shape.

To achieve the best chip control in a ductile material, feed per revolution should be somewhat less than that for alloy steel. Depending on an array of factors—the grade and geometry of the carbide, how ductile the material is and how well chips are evacuated—the feed per rev should be about half, or less, than that for alloy steel.

At the same time, the cutting speed should be increased 50 percent or more, depending on the carbide grade. This will raise the temperature in the cutting zone, which, in turn, will soften the chip and make it easier to control.

Coolant pressure and volume also play a role in the drilling process. Many modern machine tools now come equipped with high-pressure coolant systems—80 bar (1,160 psi) or higher. In many cases, high coolant pressures can greatly improve chip evacuation in low-carbon steel.

Given that heat in the cutting zone improves chip control, many might assume increased coolant volume and pressure would counteract the benefits of a higher cutting speed. The reality, though, is that the coolant vaporizes before it reaches the critical area of the cutting zone because of the high temperatures generated there. The high coolant flow entering the work zone is what helps flush chips from the hole.

Case Histories

The experiences of two companies that were having problems drilling low-carbon steel demonstrate the effectiveness of drills designed specifically for the material.

The first company is a large manufacturer of hydraulic cylinders for all types of vehicles. Previously while drilling low-carbon steel, the central insert on the drill used cut a chip that was too long. This led to chipping of the insert. Additionally, chip-control problems resulted in unacceptable tool life.

The first step was to switch to an insert with a geometry designed for soft, ductile materials. Doing so eliminated chipping of the central insert. Tool life for the old insert was approximately 35' of drilled length. Tool life for the center insert is now approximately 65'.

The new insert allowed the cutting speed to be raised from 560 sfm to 760 sfm, which improved chip evacuation. Overall, productivity has increased by 77 percent.

The second company is a subcontractor that produces suspension parts for several truck and heavy-equipment manufacturers. The company was drilling low-carbon steel

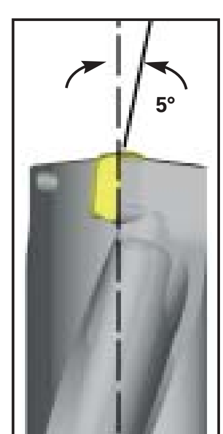


Figure 3: A positive rake angle helps direct chips up the flute, aiding in chip evacuation.

of inconsistent quality. Hardness varied greatly from batch to batch, and sometimes within the same batch. This factor negatively influenced process consistency, both in terms of hole size and the quality of the surface finish.

The holes being drilled have a size tolerance of ±0.004". A pressed insert, with a relatively open tolerance on its inscribed-circle size, was being used. In an effort to consistently meet the accuracy required, the company used shims in the insert pockets. But even this step failed to ensure consistent hole sizes.

The machine used was limited to 3,000 rpm, restricting the options for optimizing the process. The company selected a drill and insert combination with a geometry designed for low-carbon steel. It features a sharper cutting edge, a more positive and smaller cutting land, and a wide, deep chipbreaker designed for ductile materials. The new tooling had the desired effect. The company was able to increase the feed 50 percent. And while the chips are still somewhat open, they are manageable. Chip evacuation is greatly improved. Additionally, the new drill consistently produces holes well within the ±0.004" tolerance without the use of shims.

Manufacturers serving the automotive industry will be using low-carbon steel well into the future. But they don't have to wait to take control of their holemaking operations in the material. These shops can increase their efficiency today by taking a closer look at their processes and applying tooling designed to meet the demands of low-carbon steel. △

About the Author

Bruce Carter is business development specialist for Sandvik Coromant Co., Fair Lawn, N.J. For more information about Sandvik Coromant, visit www.coromant.sandvik.com/us or call (800) SANDVIK .