Tooling up to bend hard

By Tim Heston

May 28, 2009

Different high-tensile-strength metals bend—and spring back—in starkly different ways, so developing a bending strategy takes some serious planning.

At past meetings involving the plate processing department at Peterson Corp., a heavy equipment manufacturer in Eugene, Ore., flange lengths have entered the conversation. So has grain direction of heavy parts coming off the plasma tables, as well as special considerations when bending hole-intensive thick plates.

According to sources, these conversations prove that bending high-tensile-strength material takes more planning than for bending hot- or cold-rolled mild steel, aluminum, or stainless steel (see **Figure 1**).

As David Bishop, business development manager at Wila USA, Hanover, Md., explained, "The term high-strength steel is starting to be applied to a broad range of materials," from Hardox® and Weldox® to armor plate. "And while all those steels offer greater strength characteristics than mild steel, they no longer make up a narrow range of materials."

Specific high-strength materials bend in starkly different ways, which calls for some detailed planning. Tooling, press tonnage, grain direction requirements, and myriad other variables must be put on the table. When dealing with metal that may have a tensile strength higher than 150,000 PSI, a small change in any one variable can significantly affect the resulting bend.

Tooling and Springback

High-tensile-strength materials often require minimum inside radii of several times the material thickness—six times isn't uncommon—just so the metal won't crack. The high-tensile strength by itself causes enough springback on its own, but meeting those large minimum-radius requirements complicates matters even further. Large inside radii require large-nose punches, which deforms more material, which in turn increases springback.

According to Todd Nelson, senior applications engineer at SSAB's Muscatine, Iowa, steel mill, "Springback is related to the amount of material that goes under elastic deformation in your bend, so the greater amount of material that is elastically deformed, the more springback there is."

"You can't look at high-strength steel and think you're going to bend it in the same way that people have been bending cold-rolled steel, hot-rolled steel, and stainless steel," said Bishop. "You've got to allow for the difference in the V opening on the die, grain direction of the material, surface finish on the die and punch tip, springback compensation, and other factors. Some may use an 85-degree die [to attain a 90-degree bend], and they'll quickly find that some materials have more springback than that."

Springback in most high-strength materials requires some hefty overbending, which means the die angle must be more acute. A 60-degree die may be required for a 90-degree bend, and that 60-degree angle requires some serious die height to maintain its structural integrity.

"For several fabricators, I've been talking 20 times the material thickness for the size of the V die," said Steve Whiteley, applications engineer at Wila. "Today we're getting into much, much larger dies."

Some high-tensile material experiences only a few degrees of springback, while others spring back by drastic amounts, up to 35 degrees in some cases. And predicting it can be a tricky affair. According to Bishop, at least one study now in the works is finding that certain high-strength materials spring back much more than others, and the reasons aren't yet completely understood. As industry gains more knowledge, tooling designs—including the common included angles offered—may change.

Tooling manufacturers are developing a healthy database of past jobs using high-strength material, which can help springback prediction, Bishop said. But in ideal circumstances, "the most sure-fire way to get predictable results is to test-bend material before you invest in tooling and especially a new press brake," he said.

"There's information out there, and there is a lot of guidance out there [on springback compensation]," Nelson added. "But it's important to ask under what condition the data was measured, and determine if it's relevant to your application."

Application-specific springback is something Karl Slechta, department lead for the plate processing department at Peterson Corp., knows a little bit about. The company bends thick, high-strength, hole-intensive parts (see **Figure 2**). Chamfering or beveling off the hard heat-affected zones of cut edges is good practice for any high-strength material that will come in contact with brake tooling; hard HAZs left behind from cutting can cause bending problems. And the company bends against the grain, another good practice for high-strength plate.

"Inclusions tend to be elongated in the rolling [grain] direction," explained Nelson. "This mechanical fibering of rolled products leads to different mechanical properties as a function of rolling direction. Typically, ductility and toughness are lower in the transverse direction. Consequently, larger bend radii may be required for bends with the grain to avoid cracking."

But at Peterson, different plate designs change bending characteristics, including springback. "These are plates with a series of holes in them, from round holes to square holes to octagon holes, all of various sizes," Slechta explained. "One plate might have 20 [large] square holes and another plate might have [more than a hundred] 2-in. round holes. A lot more heat is going into the plate with 2-in. round holes than in the plate with large holes." This in turn causes the 2-in. plate to spring back more, and the press brake operation must compensate for this.

Tonnage and Tools

Large radii also complicate matters from a tonnage standpoint, sources said. A large-nosed radius punch shortens the fulcrum, or distance between the tangent point coming off of the descending punch and the lead-in radius of the V die. As the radius increases, that fulcrum length decreases. As the fulcrum length decreases, tonnage requirements go through the roof.

"It's not uncommon for the material being bent to be as hard or harder than the material in a [standard] brake die," said John Wold, president of Addison, Ill.-based Fab Supply Inc. "Standard, nonhardened tools will be destroyed very quickly when you form these very high-strength materials."

"You cannot—cannot—cheat the width of the die opening on this material," Bishop said. "If you do, you're borrowing from Peter to pay Paul. You'll put extreme wear on the tooling, and then accuracy is going to suffer, and you'll expose the operator to a very unsafe environment. Every tool has a tonnage capacity per foot or per meter. It can take only so much."

This material also has a tendency to work-harden during forming. If the metal is formed by a punch with the wrong radius or over an insufficient die opening, problems emerge, "and only sometimes can you tell if the bend is a failure," Wila's Whiteley explained. "Material can work-harden when it's formed, and you may not see it for a while, perhaps a year down the road," depending on the part's use.

High-tensile jobs require extremely hard tool steels that can be 28 to 32 Rockwell in the body, with flame-hardened surfaces up in the 55 to 60 Rockwell range, sources said. Heavy tools can take longer to change out as well, so some shops employ short, modular segments to reduce changeout time, or use adjustable V dies, which use special inserts that can change the die opening, to eliminate changeover altogether (see **Figure 3**).

Material drag over the lead-in radii of the die also is an issue. In some cases the die can be pressed so hard into the metal that, in snowplow fashion, it digs in and pushes material into a kind of "snowbank" at the end of the bend. The result: a very expensive scrapped part.

For this reason, the material itself should be extremely smooth; even residual mill scale can cause problems, sources said. Some tooling options can help matters too. One option is to use hardened inserts such as induction-hardened and chrome-hardened rollers at the lead-in radii of the die shoulders (see Figure 3); these rollers can rotate during the bend to reduce drag as the material is formed. As these wear, they can be swapped out, which is less expensive than replacing an entire die.

The rollers have a greater usable surface area—360 degrees all the way around the bar—which adds to their durability. "It's 18 times more surface area than you'd have from a lead-in standard radius," Wold said, who added that end users have reported a 15- to 25-percent reduction in forming tonnage for certain applications.

As another option, rotational dies eliminate this lead-in radius completely (see **Figure 4**). They entail two rotating elements, one just in front of and another just behind the bend line. Before the punch makes contact, the forming rotors are flat and parallel to the press brake bed, so it literally has no lead-in radii. As the punch exerts downward pressure, each rotating element keeps in constant, static contact with the two legs of the bend. The material, in almost folding-machine fashion, forms up and around the descending punch.

The key phrase here, according to Wold, is static contact. "If your die is sized correctly, all drawing action will be eliminated. If you place your material correctly, you've eliminated any sort of drag or draw over the lead-in radius," because, of course, there is no lead-in radius.

Tonnage and the Brake

It's one thing to destroy tooling; it's quite another to kill a press brake.

According to sources, fabricators should carefully consider tonnage factors before committing to a job. If a company has a 250-ton press brake, some may believe they can bend 5 ft. of 1/2-in. material without any problem.

But that's for mild steel.

"When you're forming high-strength material, tonnage must be carefully considered," Wold said. "It is not uncommon for high-tensile materials to require two to three times the tonnage shown on a standard tonnage chart."

As the tensile strength of the material increases, so does the tonnage required to bend it, Wold explained, adding that concentrated load damage is a serious concern. "Every press brake manufacturer has their own recommendations, but as a general rule, it's not safe to put more than 70 percent of the machine's available tonnage on less than 30 percent of the total length."

This brings the maximum tonnage on that 250-ton brake to 175 tons. So what if a high-strength, 3-ft. part takes 80 tons a foot to bend? That's 240 tons going on 3 ft., enough to cause some serious ram upset and leave an indentation in the brake bed.

Today's brake tonnage offerings, with stiff rams to handle increased pressure, are effectively extending the range of what's considered bendable. "I know one fabricator that has a 2,500-ton machine, and he's bending 1 3/4-inch T1 material," said Gordan Baker, director of product technologies at Pacific Press Technologies, Mount Carmel, Ill. "In fact, we're seeing a lot of machines move into the 1,500-ton range and up to handle this type of material."

Some of this material, obviously, can be quite heavy, so for some applications—particularly those involving all up-bends—certain devices aid material handling, Gordan said. For instance, instead of using a backgauge, some systems use "a hydraulically driven manipulator to move the material to the bend line. And we've developed laser systems so we can see where the bend-line mark is."

Challenging, but Worth It

When fabricators tackle these hard materials, they quickly find that the process requires high tonnage, high-quality tools, and often some major springback compensation—and there aren't many ways to get around these requirements. Avoiding springback with bottoming or coining wouldn't make sense, sources said, because the tonnage requirements would be extreme. A fabricator could anneal prior to bending and reharden after to reduce tonnage requirements, but this would take time and could change the material characteristics, which defeats the purpose of choosing such hard material in the first place.

One the one hand, high-strength material brings with it myriad challenges. But on the other hand, opportunity abounds, even in this economy. "In the last couple of years, with military spending, it's gotten extraordinarily popular," Wold said. "It used to be primarily in the heavy construction industry and mining industry, but now there are so many forming parts for armored vehicles [and similar products], so it's gotten very prevalent. And I would expect [the demand] to continue for a while."