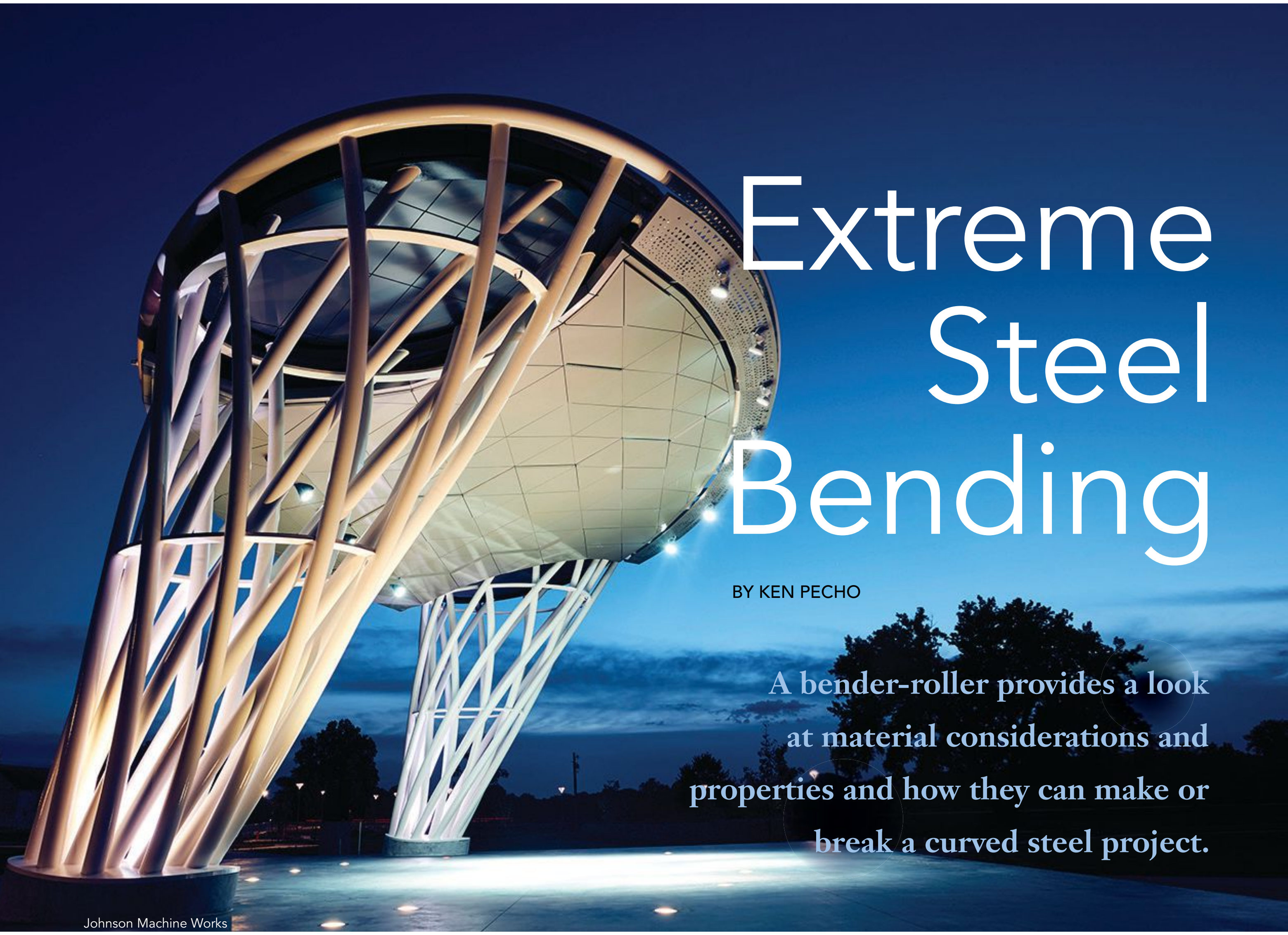
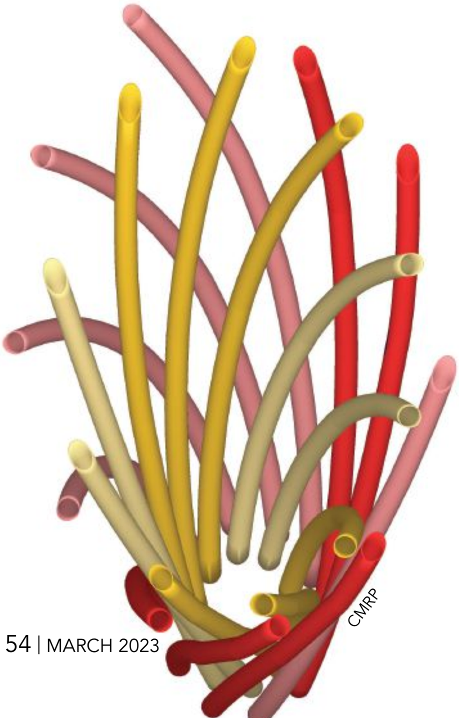


Johnson Machine Works

Extreme Steel Bending

BY KEN PECHO

A bender-roller provides a look at material considerations and properties and how they can make or break a curved steel project.



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WHEN I WAS FIRST APPROACHED with the topic of "extreme bending" for an NASCC: The Steel Conference presentation, my mind immediately envisioned jumbo rectangular tubes and heavy beams (like HSS20×12 rectangular tubes and W40×211 beams) being pulled through massive bending dies on the largest of our three roll section benders, all being curved into some insanely challenging geometry like a helix or a parabolic conic section.

I would talk about how our extreme rolling machines twist and bend massive structural steel members with the grace of a fine sculptor!

But as I continued to ponder the idea, it became apparent to me that the sheer size and geometry of a curved member alone don't define extreme bending. Rather, it is defined as the scientific approach to considering and analyzing—to what some might consider an extreme level of detail—a specified curved structural steel member. This approach focuses on material types and their mechanical properties, the condition the material is in during the bending process, the geometry of the bend and how severe the bend radius is, and whether the bend can be achieved through current bending technologies.

Here, we'll provide a quick look into the most important factors bender-rollers must consider when reviewing a project request. When it comes to structural projects, the most typical materials are mild carbon steel, stainless steel, and aluminum.

Once a material is chosen, the bender-roller must determine the viability of the curve and the likelihood of its success based on the material's characteristics. Bender-rollers understand that when performing a curve, we are slightly altering the material's mechanical properties, inducing stresses, straining its inelastic fibers, and ultimately increasing hardness and strength while reducing ductility and formability. It is our intent to only work the material as much as is needed to achieve the desired bend geometry. Severely overworking a member due to insufficient machine strength or the inability to hit a specific geometry through applied machine forces can have negative effects on its ductility—and in some cases, may cause the member to fracture or rupture.

In the Range

Structural steels are primarily mild carbon steels. This steel type is extremely strong yet ductile enough to be easily curved into a specified shape. It all starts with the elastic range. In a material's elastic range, forces can be applied to the member, but when removed from this range, any deformation regresses and the member's original shape is restored. Beyond a material's elastic range is the plastic range, and this is where the curving process takes place. As bender-rollers induce a radius into a member, we intentionally set a permanent plastic deformation into the material. Two important material properties to consider when curving a member in the plastic range are yield strength, the point where permanent plastic deformation starts, and tensile strength, the point at which a material's failure starts to occur. A lot can be ascertained from looking at the relationship between the two.

By analyzing the yield and tensile points along the curve (and following the curve from point to point), the shape and slope of the curve, and the difference between yield and tensile points, you can get a better understanding of how the material reacts to bending forces and how it behaves during the bending cycle. Many bender-rollers will get calls from engineers asking what the minimum achievable bend radius is for a specific member size and shape. While a minimum bend radius is typically tied to a bender-roller's equipment and individual capabilities, the strain ratio of a member can be used to predict the approximate limits of the bending radius.

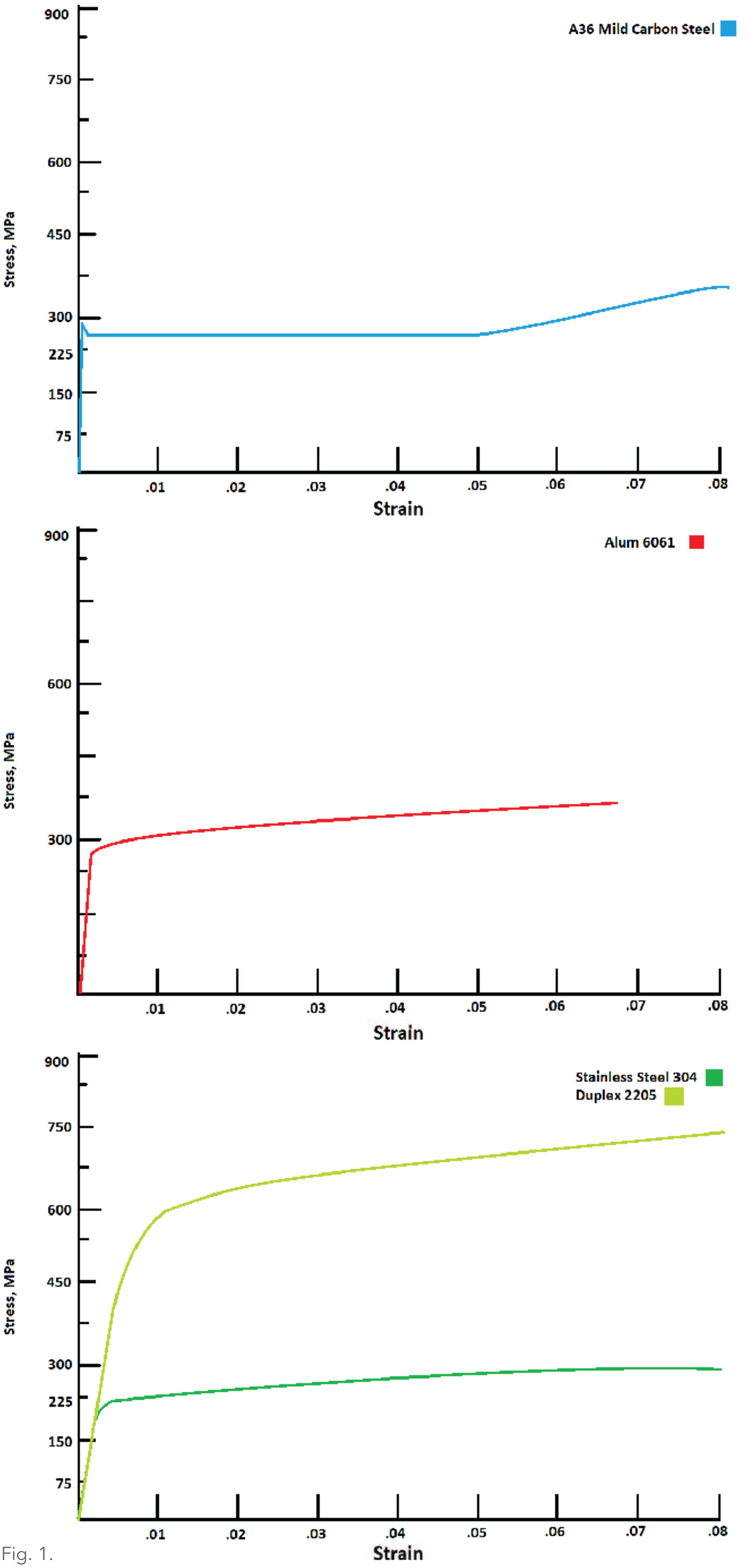
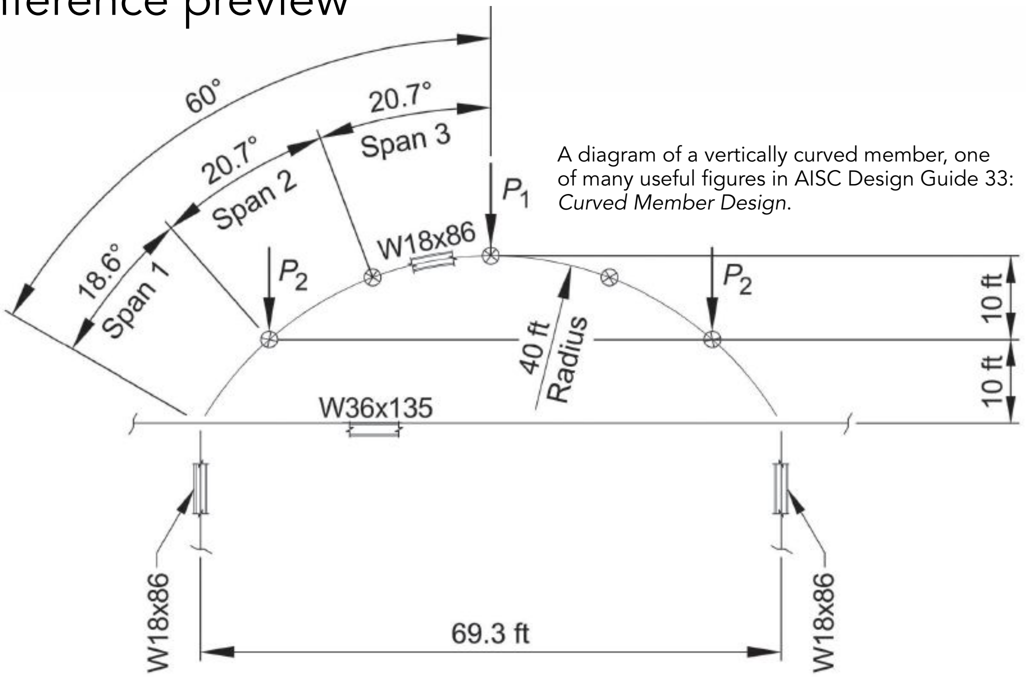


Fig. 1.



A diagram of a vertically curved member, one of many useful figures in AISC Design Guide 33: *Curved Member Design*.

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Consult the Guide

AISC Design Guide 33: *Curved Member Design* (**aisc.org/dg**) provides solid guidance on these considerations through equations and tables showing the maximum strain magnitude a member can undergo before the quality of the curve becomes questionable due to impending overstraining and undesirable changes in the material's mechanical and physical properties. Simply put, the more severe or tighter a bend's radius and resulting curvature, the greater amount of stress the inner and outer extreme fibers undergo. And once the bending forces are released, residual stresses persist throughout the cross section, mechanically increasing the member's hardness and strength. And this can cause a loss in ductility and formability. The good news is that structural steel can be taken pretty far into the plastic range before serious strain hardening takes place, and this can be seen in the stress-strain curve where the line appears to plateau (Figure 1, previous page); this is why it is easily curved when compared to other stainless steels and aluminum.

At the end of the day, curving steel, given the factors that need to be considered and the balance of pushing a member to its limits while still maintaining its strength in integrity, is itself an extreme process. And resources such as Design Guide 33 and the members of AISC's Bender-Roller Committee—who are happy to answer your questions (and are all listed at **aisc.org/benders**)—can provide a better understanding of the bending-rolling process and help you optimize your next curved steel project. ■

*For a more in-depth look at the bending-related characteristics of different types of metals and a deep dive into their atomic-level properties, check out the session "Extreme Steel Bending: A Focus on Materials" at NASCC: The Steel Conference, taking place April 12–14 in Charlotte. You can learn more about the conference and register at **aisc.org/nascc**.*

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