Understanding material **anisotropy**

It is critical to always be aware of how material anisotropy might affect a design. A case in point is how anisotropy played a part in an individual getting injured when he tried to loosen the internal stirring ball of a spray-paint can by rapping the bottom of the can on a door jamb.

The impact point coincided with the welded seam going along the side of the can and the resulting compression effect caused added tensile stress across the seam. The fracture thus initiated at the seam and, counter-intuitively, traveled around the circumference of the can body just above the junction with the can bottom — not, as-to-be expected, along the path of the side-weld seam where there are the greatest stresses. The can bottom suddenly separated from the body, releasing the internal pressurized gas, and propelling the can like a rocket into the person's face.

Material anisotropy was the significant factor in determining the fracture path. The body is made from rolled steel sheet which then is rolled into the can's cylindrical shape. Problems arise because during hot rolling of the steel ingots, the alignment of impurity inclusions produces considerably lower fracture toughness in the rolling direction of the sheet during manufacture.

Strength anisotropy can also be seen in vacuum-formed polyethylene drinking cups. The cups can be easily torn along the axial direction, but they are much more difficult to tear in the circumferential direction. Vacuum forming stretches the plastic sheet and aligns polymer chains along the vertical direction in the cup. Bonding between atoms along the chain length is much greater than the bonds between adjacent chains, which accounts for the formed cup's anisotropic strength behavior.

In these examples, the simple article shape allows the straightforward illustration of the effects of material-strength anisotropy. But, such anisotropy also occurs more subtly in complex shapes. For example, alignment of inclusion impurities during hot forging (such as in some car and railroad wheels, or in wrenches and hammers) leads to increases in toughness and fatigue strength along the direction of metal flow and lowers values transverse to the metal flow. Similar strength anisotropy is seen in extruded material. Designers can take advantage of this process effect by ensuring that, in the part application, critical stresses occur along directions of significant metal flow, but not in the transverse direction.

Complex injection-molded plastic parts also have anisotropic-strength properties for the same reason as do plastic drinking cups. Polymer-chain alignment happens during material flow in injection molding, and the degree of such alignment will be particularly high in regions that undergo large section reductions. Plastic hinges, for example, are produced by increasing the polymer flow through very-thin rectangular sections. These sections can tolerate much higher bending stresses along the direction of flow than can sections that undergo little polymer flow.

The pertinent lesson is that because strength anisotropy accompanies nearly every production process and material, it is prudent to consider the effects of a material's directional variations on a design. This is a good step toward increased product quality and decreased liability. *— Howard A. Kuhn*

Howard A. Kuhn is an Adjunct Professor at the **Univ. of Pittsburgh, School of Engineering** and Director of Technology at **The Ex One Co.** He spends the rest of his time consulting.

WHAT'S THIS?

When you see a code like this, take a photo of it with your smart phone (iPhone 3G-S gives best results) and, using software from *www.neoreader.com*, you will be connected to relevant content on *machinedesign.com*

Edited by **Leslie Gordon**