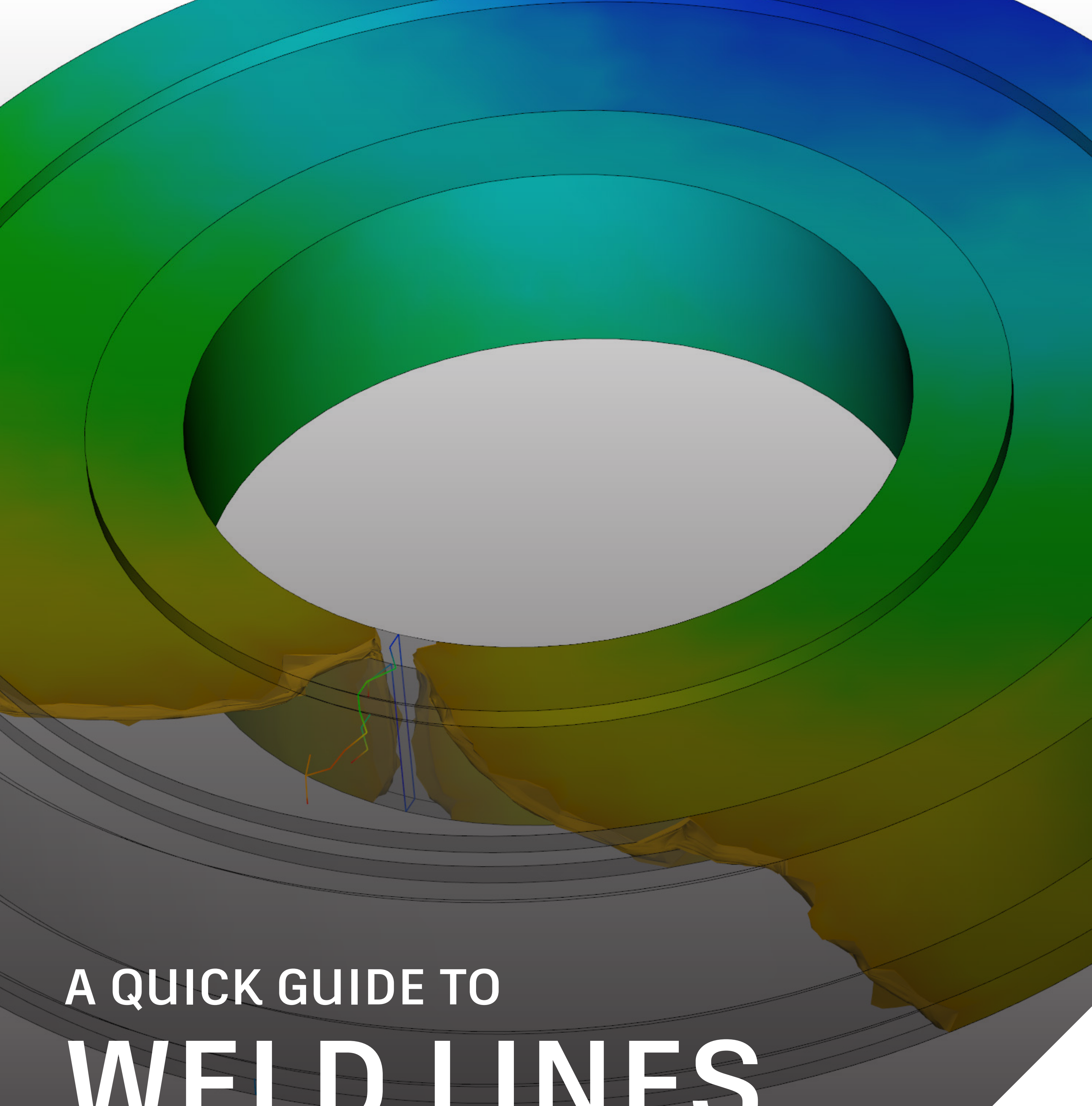

A QUICK GUIDE TO

WELD LINES

AUTODESK

A Quick Guide to Weld Lines

Drawing the Line

How to manage weld lines in molded plastic parts

Weld lines are a kind of Achilles heel of plastics. Unless you are manufacturing an extremely simple part with one gate and a unidirectional flow front, your part will have weld lines. Which means engineers need to know how to account for this phenomenon in an efficient way.

Weld lines represent the region where two separated melt fronts recombine. They may be separated by an obstacle, such as a core pin, or by a geometric feature, such as a boss or change in thickness. Weld lines can also happen when the part requires multiple injection locations or when jetting occurs due to an unrestricted gate injecting at a relatively high velocity.

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How weld lines affect plastic parts

Engineers care about weld lines because they can compromise the function of the part as well as its appearance.

Functionally, weld lines cause severe reductions in material strength. To complicate matters, the relationship between the weld line and the potential point of failure is not intuitive. You may see a line at the top of the part but the actual weakness may occur elsewhere. After the weld line forms, it can shift due to how the part is injected or the pressurization in certain gates.

Cosmetically, weld lines produce visible surface defects that degrade the part's perceived value with potential customers. These defects are especially noticeable in plastics with metallic pigment, because the additional reflections draw our attention. Even if a part's interior strength is not critical to its performance, weld lines will cause it to be rejected.

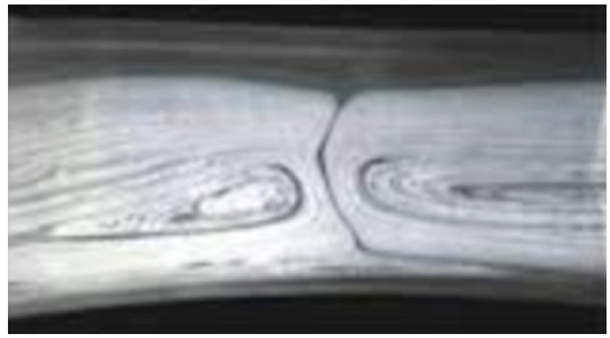

Figure 1:
Cross section of weld line under electron microscope. When flow fronts meet and don't move, insufficient polymer chain mixing significantly reduces material strength. In plastics with added fiber, this problem is only compounded.

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Differentiating weld and meld lines

Weld lines form in two ways, each of which affects the loss of strength that may occur.

1. Cold or butt weld line. In this case, separated flow fronts moving from opposite directions meet and rapidly immobilize. This typically happens with a dual-gated part, where the two fronts meet at the end of fill. The result is a concrete weld line without much polymer mixing. Poor bonding at this interface seriously affects part strength.

2. Hot, streaming, or meld lines. When flow fronts traveling in the same direction are separated by an obstacle (or multiple gates) and recombine, the result is more polymer mixing than with a cold weld line. While this is not ideal, the loss of strength is not as severe.

   In general, the angle between the flow fronts is what separates a weld line from a meld line. Within Autodesk Moldflow software, for example, a plane angle less than 140° is classified as a weld line and an angle greater than 140° is a meld line.

Factors that affect weld line strength

Many factors determine the strength of the weld line (compared to the bulk material). The three most important are:

1. Poor bonding. The quality of polymer bonding at the interface depends on both the process and the material, both of which affect the meeting angle. The thickness of the part may also play a role. In any case, when polymer mobility is poor where flow fronts recombine, it is up to the secondary polar bonds to hold the two sides together. These bonds can be anywhere from 10 to 50 times weaker than the chain bonds, resulting in a precipitous drop in material strength.

2. Orientation. Fountain flow orients polymer chains or fillers (fibers) perpendicular to flow where the two fronts meet. This is the opposite of what is needed for a strong part. If a crack propagates at this point, the strength of the plastic or its fillers is effectively neutralized by orientation.

3. V-notches. Injecting into a very cold mold or improper venting may result in notches. These are created when compressed gases are trapped where the flow fronts meet. Notches not only reduce cross-sectional thickness and area but also act like a stress amplifier.

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Testing weld line strength

The foundation of any simulation is real-world test data. For weld lines, tensile testing helps establish how much strength is lost when weld lines occur.

By comparing "pull apart" test results from a specimen with no weld lines to one with a single weld line, researchers can compute the ratio of difference in tensile strength, also called "weld line retention." In other words: how much of the bulk material's strength is retained when a weld line occurs? Retention values for a wide range of material types and amounts of filler are well established by research.

These tests reveal the importance of mitigating weld lines. If engineers are designing a part assuming 100% material strength and a weld line delivers only 20%, this is a critical issue for the design team to resolve in order to avoid catastrophic failure.

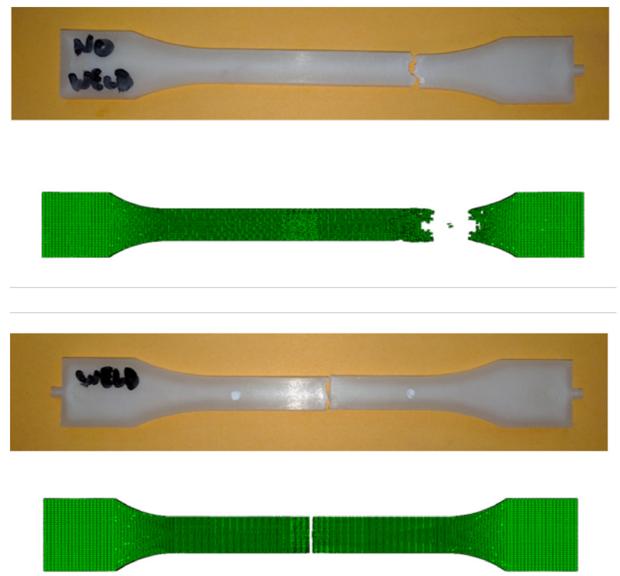

Figure 2:
Using simulation software greatly improves the accuracy of predicting weld line location and strength for injection molded plastic parts.

Managing weld lines

Predicting where weld lines occur and how weak they will be is the key to mitigation. While weld lines can't be avoided entirely, engineers may be able to change process settings to move the lines to a less critical area of the part. Changing the gating can also be used to reduce the loss in strength, transforming what would have been a weld line into a more tolerable meld line.

The challenge predicting weld lines is that they are extremely condition-dependent. Retention values reflect a specific set of conditions, and will change according to the design of the part and how it is processed. This is where Moldflow Insight software comes into play. It features three important capabilities, all of which can improve the accuracy of weld line prediction:

1. 3D weld surfaces. The ability to examine 3D weld surfaces allows engineers to see where weld lines occur and what is happening beneath the surface. The software shows where the initial formation occurs and how it is likely to move within the part. Seeing both of these points makes it easier to characterize the strength of the surface and differentiate weld lines from meld lines.
2. Fiber orientation. Models for short and long fibers allow Moldflow software to simulate all mesh types using a similar fiber orientation model. The software can differentiate between shorter (< 1mm) and longer fibers (>1mm) as well as simulate fiber breakage. All of these features improve the ability to predict weld line strength accurately.
3. Processing effects. Processing determines the temperatures and pressures at which separated flow fronts meet. Moldflow software simulates melt/mold temperature, hold/pack pressure and time, and injection pressure and time, all of which helps determine molecular mobility.

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Understanding the workflow

One way to manage weld lines in injection molded plastic parts is to combine Moldflow Insight software with Autodesk Helius PFA (progressive failure analysis) software.

The workflow starts with a designed CAD model of the part. Within Moldflow, engineers can run a cool, fill, and pack simulation to visualize weld lines two ways. The first is a 2D representation of the surface formation, which shows where weld lines will likely be visible on the part. The second is the 3D representation, which shows both the formation and movement of the weld line.

At this point, as-manufactured results are taken into account for a nonlinear finite element analysis using Helius PFA software. Data about warpage, residual strains from processing, and fiber orientation as well as weld lines and anisotropic material properties can be mapped directly between the two applications. All of this data enables a more realistic structural simulation of the part within Helius PFA software, as opposed to using guesswork with knockdown factors.

Engineers can then use Helius PFA software to predict the strength reduction of each weld line point. The strength prediction model in PFA depends on the temperature history, pressure history, and meeting angle of each weld line, all of which is taken from the Moldflow simulation. Tools within Helius PFA also allow engineers to consider how much fiber orientation and the weld surface contribute to strength reduction.

The end result is a more accurate prediction of weld line location and strength for both filled and unfilled parts, which sets the stage for adapting part design and processing accordingly.

Learn more now

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