Autodesk® Moldflow® Insight 2012

AMI Birefringence Analysis

Revision 1, 22 March 2012.

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Birefringence analysis produces two classes of results.

- **Refractive index** results show the change (from the nominal value) of the refractive index as a result of part stresses. These results are computed using a stress result (either at the end of packing or after warpage) and the optical properties of the material.
- **Phase difference** and **retardation** results show the difference between horizontally-polarized and vertically-polarized light as it passes through the part from the specified direction. This difference can be expressed as an absolute distance (“phase difference”) or as a fraction of wavelength (“retardation”).

All Birefringence results require a 3D Warp analysis.

Birefringence analysis

Birefringence results are generated from the stress results produced by a 3D Warp analysis.

Setting up a Birefringence analysis

To produce birefringence results, set up a standard Warp analysis sequence, and select **Birefringence analysis if material data includes optical properties** in the Fill+Pack process settings.

Additionally, you must choose a material with measured optical properties (refractive index, stress-optical coefficients, viscoelastic retardation spectrum).

TIP: The optimal number of mesh layers through the thickness is at least 10 for birefringence results.

About Birefringence

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The refractive index of a transparent material is a dimensionless property which specifies the factor by which light slows down as it travels through the material. For most materials the refractive index is independent of the direction of travel and polarization of the light. However, stress can alter the refractive index of a material. If the stress is different in different directions then the material's refractive index may depend on the polarization of the incident light. This phenomenon is known as birefringence.

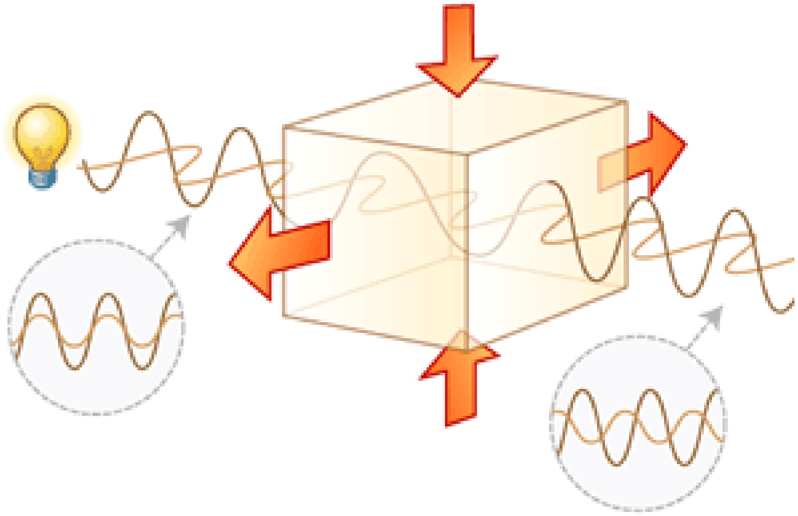

Figure 1: Birefringence in a transparent material caused by stress. Horizontally- and vertically-polarized light travels at different speeds through the material and emerges out of phase.

NOTE: Some crystals have a natural optical axis and exhibit birefringence even when not under stress. Crystalline birefringence is less important than stress birefringence in thermoplastic analysis because most plastics are amorphous.

Stress birefringence

In amorphous materials, the refractive index for light polarized along an axis varies proportionally to both the linear stress in that axis and the transverse stress perpendicular to that axis. These proportions are called the stress-optic coefficients and are a property of the material type.

Visual effects of birefringence

Birefringence leads to two different visible effects, depending on the orientation and polarization of the incident light and the principal stress directions in the material. Both effects are generally undesirable in parts that are intended for optical purposes.

Retardation

Normal light is unpolarized, which is to say that it contains multiple beams, polarized in all possible directions perpendicular to the direction of travel. When light enters a birefringent material, it decomposes into component beams polarized along each of the principal stress directions. Each of these beams experiences a different refractive index and so emerges from the material having traveled at different speeds. When the components are recombined they are out of phase. This phase difference is sometimes known as retardation. The transmitted beam may consequently have a different polarization direction (or distribution of polarization directions) than the incident beam. If the light was initially polarized, or is subsequently polarized, then its components may destructively interfere, leaving alternating bands of darker and lighter transmission. This effect is visible by placing the material between two crossed polarizing filters.

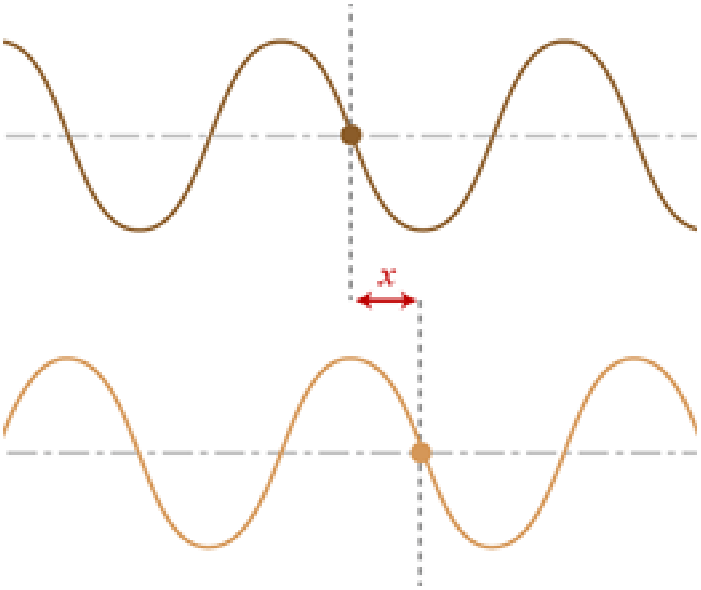

Figure 2: Retardation. Horizontally and vertically-polarized light waves emerge offset by a distance *x*. This can be expressed absolutely as a length, or as a fraction of a wavelength (one quarter of a wave, or 90°).

Double images

If the light's direction of travel is not parallel to one of the principal stress directions then one polarized component beam (the “extraordinary” beam) may refract even if the incident light is normal to the material surface. When it emerges from the material the beam is offset from the other (“ordinary”) beam, leading to double images.

About birefringence

In situations where the light traveling through a transparent part is already polarized, the magnitude of retardation may matter less than the direction of the principal axis of optical orientation. For example, if the expected polarization direction is along a principal axis of optical orientation then double images will not occur.

Finding the optical orientation of an analysis

1. Create a custom birefringence result **Results tab > Plots panel > Custom**.
2. Choose a **Birefringence** plot type.
3. Choose **Retardance Tensor**.
4. Select a direction for the light's origin.
5. Click **OK**.
6. Change the plot properties (right-click on the plot name in the Study Tasks pane and select **Properties**).
7. On the **Methods** tab, select **Tensor principal vector as darts**.
8. On the **Tensor** tab, select one of the three principal directions.

   Choose a direction according to the optical orientation you want to see.

Direction	Meaning
First principal	Direction of greatest refractive index change
Second principal	Direction of second-greatest refractive index change perpendicular to first principal direction
Third principal	Direction of least refractive index change

NOTE: For some materials, the direction of greatest refractive index change may be in the direction of flow. For other materials, the direction may be perpendicular to the flow under the same processing conditions.

Spectrum correction factor for birefringence results

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Birefringence simulations use a **spectrum correction factor** that modifies the influence of viscoelastic deformations on the birefringence results.

The default value for the spectrum correction factor is 1, but you may adjust it to suit your situation. Typically, the value should be a positive number between 0.2 and 2.

Autodesk Moldflow have performed experimental observations of birefringence using specific materials, and as a result have adjusted the spectrum correction factor for those materials to provide more accurate birefringence results. If the default value of the spectrum correction factor is not 1, this indicates that the material you have selected is one of the materials that Autodesk Moldflow have adjusted.

Spectrum correction factor for birefringence results

Birefringence simulations use a spectrum correction factor that modifies the influence of viscoelastic deformations on the birefringence results.

Adjusting the spectrum correction factor

Adjust the spectrum correction factor to achieve more accurate birefringence results.

1. Select **Home tab > Molding Process Setup panel > Select Material**.
   The **Select Material** dialog appears.
2. Choose a material with measured optical properties (refractive index, stress-optical coefficients, viscoelastic retardation spectrum).
3. Click **Manufacturer** and select the manufacturer of the required material.
4. Click **Trade name** and select the trade name of the required material.
5. Click **Details**.
   The **Thermoplastics materials** dialog appears.
6. Select the **Optical Properties** tab and locate the **Spectrum correction factor** field.
7. Enter a value into the Spectrum correction factor field.
8. Click **OK**.

Improving birefringence accuracy with the spectrum correction factor

If you have optical birefringence measurements from your own moldings, you may adjust the spectrum correction factor for the specific material you have used in order to obtain more accurate simulation results.

1. Select a few typical moldings where the birefringence (retardation or the phase shift) of the moldings has been measured and the processing conditions are known and well defined.
2. Measure the birefringence in a few characteristic points on the moldings.
3. Run a 3D Warp analysis for the parts using the spectrum correction factor of 1.0.

   NOTE: Select the **Birefringence analysis if material data includes optical properties** option in the Fill+Pack process settings page when you are setting up the 3D Warp analysis. This ensures that the birefringence results will be generated.

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4. Compare the simulated birefringence results with your experimental molding results.
   - If the simulated birefringence results are over-predicted compared to the experimental results, decrease the spectrum correction factor to values less than 1, for example 0.4 to 0.8.
   - If the simulated birefringence results are under-predicted, increase the spectrum correction factor to values greater than 1, for example 1.2 to 1.6.
   - If the simulated birefringence results are similar to the experimental birefringence results, use spectrum correction factor values close to 1, for example 0.8, 0.9, 1.1 and 1.2.
5. Once you have adjusted the spectrum correction factor value, run the 3D Warp analysis again.
6. For each value of the spectrum correction factor calculate the residual mean square error or RMS: $R M S = \sum i = 1 N (R i , m e a s u r e d - R i , p r e d i c t e d) 2 N$ where *N* is the total number of birefringence measurements, and $R i , m e a s u r e d$ and $R i , p r e d i c t e d$ are correspondingly the retardations measured and predicted for the point *i*.
7. Plot the graph of RMS versus the spectrum correction factor.
   The minimum point on the graph corresponds to the optimal spectrum correction factor for the particular material grade.
8. Add the material data to your personal database and enter the optimum value of the spectrum correction factor.
9. You should use this new material data for future birefringence analyses.