

Visual Defects Due To Metal Flake Orientation

Executive Summary

Molded parts containing reflective, flake-shaped fillers can show visible light-and-dark streaks when filler orientation changes across the surface. These changes are often most noticeable near weld or knit regions, where converging flow fronts disturb the preferred in-plane alignment of the flakes.

Autodesk Moldflow Insight 2027.1 introduces the **Metal flake reflection indicator**, a grayscale surface result for 3D Flow analyses. The result converts the predicted orientation state at each surface node into a scalar value from 0 to 1. Higher values indicate regions more likely to appear bright when viewed from above with a direct light source; lower values indicate regions with greater risk of a dark appearance from this viewing angle.

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Introduction

Metallic finishes rely on thin reflective flakes dispersed in the polymer. When most flakes lie approximately parallel to the visible surface, their reflected response tends to be bright and comparatively uniform when viewing from directly in front of the surface. Where the flakes rotate away from the surface plane, the reflected response changes and the region can appear darker than its surroundings.

Flow-front interactions are an important source of this orientation change. At weld lines and knit regions, two flow fronts meet and the local deformation history can rotate flakes out of the surface plane. The resulting orientation discontinuity may be seen as a dark streak, black line, or localized dark patch. Sometimes, these visual defects become more pronounced at particularly viewing angle (relative to the position of the light source).

Cosmetic defects are often identified only after tooling and molding trials. A simulation-based indicator allows teams to identify earlier surface regions with high contrast risk, relate those regions to the filling pattern, and compare alternatives such as gate location, fill balance, and process settings.

Modeling

Metal flake reflection indicator

The Metal flake reflection indicator is a simplified measure of the light intensity reflected by a population of metal flakes near the part surface. It captures the effect of flake orientation on relative light-and-dark contrast without requiring the user to define a particular light source position or viewing direction.

For one reflective flake, let $\mathbf{p}$ be the unit vector normal to the flake surface, $\mathbf{s}$ the unit vector toward the light source, and $\mathbf{v}$ the unit vector toward the viewer. A simplified orientation-dependent color intensity is proportional to the product of the two directional projections:

$$C(\mathbf{p}) \propto (\mathbf{p} \cdot \mathbf{s})(\mathbf{p} \cdot \mathbf{v})$$

The indicator adopts a fixed reference condition in which the lighting direction and viewing direction coincide with the local outward surface normal $\mathbf{n}$. This removes the need to select a specific lamp and camera arrangement:

$$C(\mathbf{p}) \propto (\mathbf{p} \cdot \mathbf{n})^2$$

Under this assumption, a flake whose normal is aligned with the local surface normal contributes a larger value, while a tilted flake contributes a smaller value. The calculation therefore provides a consistent relative measure of orientation-driven reflected intensity under the adopted reference condition.

A molded material contains many flakes with different orientations. Averaging the single-flake intensity over the local flake population gives the indicator:

$$I = \langle (\mathbf{p} \cdot \mathbf{n})^2 \rangle = \mathbf{n} \cdot \mathbf{A} \cdot \mathbf{n}$$

Here the bracket $\langle \rangle$ denotes the average over local flake population and $\mathbf{A} = \langle \mathbf{p}\mathbf{p} \rangle$ is the second-order orientation tensor which is already computed in injection molding simulations. The scalar I ranges from 0 to 1. In the default result plot, higher values represent a greater reflected-intensity response under the reference condition, while lower values represent a weaker response. Abrupt spatial changes indicate areas where neighboring regions may show visible contrast.

Result interpretation

Indicator value	Orientation meaning	Expected visual tendency
Near 0	Flakes contribute little reflected intensity under the reference condition.	Darker in the default indicator plot.
Intermediate	Mixed or transitional orientation response.	Intermediate grayscale; often outlines a contrast transition.
Near 1	Flake normals are strongly aligned with the local surface normal.	Brighter in the default indicator plot.

The essential diagnostic is spatial contrast. Abrupt changes or localized bands indicate a potential appearance transition. The plot should be interpreted as a relative map rather than an exact prediction of final color or luminance.

The Metal flake reflection indicator provides a practical assessment of potential appearance variations caused by metal-flake orientation.

- The result is orientation based and is not photorealistic.
- The indicator assumes that lighting and viewing directions coincide with the local surface normal. Actual appearance also depends on real lamp and viewing positions, surface finish, pigment formulation, flake optical properties, and processing variation.
- The result should be interpreted as relative severity and location information, not as a guaranteed prediction of final color or luminance.

Implementation and Use

Calculation conditions

The result is available for 3D Flow analyses of thermoplastic and thermoset materials. It is produced only when all the following conditions are satisfied:

- Filler orientation analysis is enabled for the material by selection of the fiber orientation option.
- The qualifying filler is flake-shaped, with an aspect ratio less than 1.
- The filler description is recognized as a reflective filler type.

For materials with multiple fillers, the implementation uses the available combined filler description and the average aspect ratio.

After a qualifying analysis is completed, the **Metal flake reflection indicator** appears with the other analysis results. The surface contour uses values from 0 to 1 and a grayscale palette to emphasize orientation-driven contrast.

Improving the result

The quality and interpretability of the Metal flake reflection indicator depend on the accuracy of the predicted filling pattern, material characterization, and mesh resolution. The following practices can help improve the reliability of the results:

- Ensure filling pattern and weld-line locations are representative.
- Review material and process inputs when the predicted orientation appears nearly random or inconsistent with observations.
- Use a realistic flake aspect ratio. Predicted contrast increased as aspect ratio was reduced from 0.5 to 0.1 and below.
- Use a finer surface mesh where narrow streaks or sharp orientation changes are expected.

Case Study

Molded part

The case study examines a vacuum swivel coupling. The molded part has a glossy metallic surface, but fine dark lines are visible near one of the openings. These localized lines interrupt the otherwise uniform appearance and provide the target defects for comparison with the simulation results.



Figure 1. Molded vacuum swivel coupling and observed dark-line location.

Simulation results

A CAD model was created from measurements of the molded part. The actual material and processing conditions were not available. For demonstration purposes, a Polyoxymethylene (POM) material containing aluminum flakes was selected, and the analyses were performed using automatic filling and packing processing conditions. The part was approximately 100 mm long and was initially meshed with a nominal element size of 1.8 mm, resulting in approximately 1.84 million elements.

The fill-time result plotting in Figure 2 shows that, near the opening where the dark lines were observed, the polymer approaches and fills the region from three sides, forming a C-shaped filling pattern. The meeting of these flow fronts produces a complex local flow history that can change the orientation of the metal flakes.

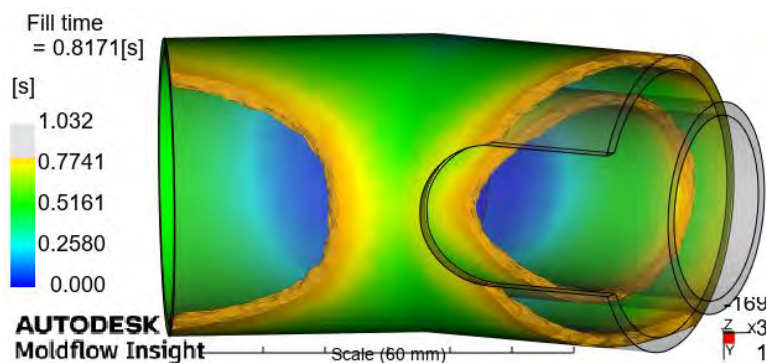


Figure 2. Predicted filling pattern for the vacuum swivel coupling.

With the material's default filler aspect ratio of 0.5, the Metal flake reflection indicator remains relatively dark over most of the surface, with values generally between 0.4 and 0.5, as shown in Figure 3. At this aspect ratio, the filler shape is relatively close to spherical, and

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the predicted orientation is close to random. As a result, the indicator provides limited contrast and does not clearly distinguish the observed dark-line pattern.

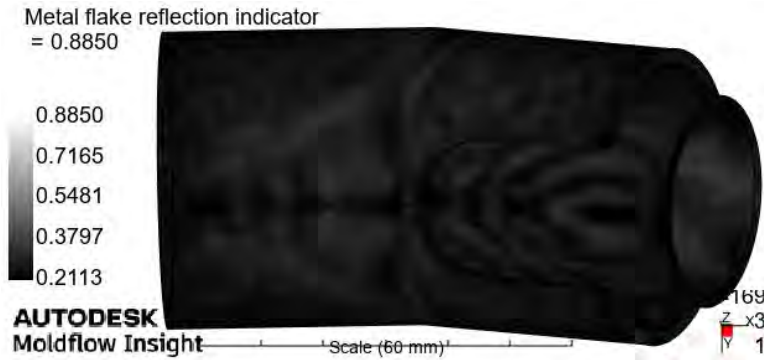


Figure 3. Metal flake reflection indicator for the vacuum swivel coupling, using filler aspect ratio of 0.5.

When the filler aspect ratio is reduced to 0.1, the Metal flake reflection indicator clearly reproduces the dark-line pattern observed on the molded part. The predicted pattern consists of one longer central line and two shorter lines branching toward the sides, forming an arrow-like shape, as shown in Figure 4. The location and overall pattern correspond well with the visible defect near the opening.

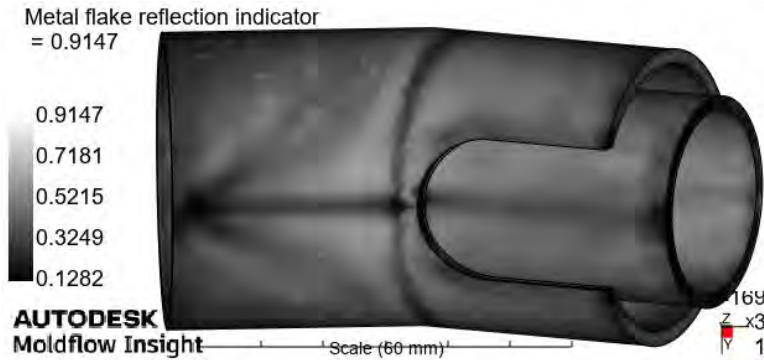


Figure 4. Metal flake reflection indicator for the vacuum swivel coupling, using filler aspect ratio of 0.1.

The reflection-indicator pattern is consistent with the fiber-orientation result shown in Figure 5. The displayed orientation component is in the z-direction, which approximately follows the local surface-normal direction in the circled region. Higher orientation values indicate a greater alignment of flake normals with the z-direction, while lower values indicate less alignment. Some areas show less alignment in the normal direction than the surrounding surface, corresponding to the dark-line pattern in the reflection-indicator result. Because the part surface is curved and the orientation components are reported in the global coordinate system, the two shorter branches are less pronounced in the orientation plot. The surface-based reflection indicator makes the complete defect pattern easier to identify.

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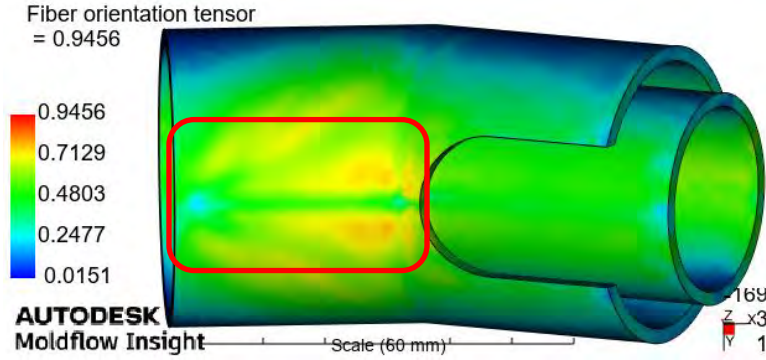


Figure 5. Fiber orientation for the vacuum swivel coupling, using filler aspect ratio of 0.1.

The dark lines on the molded part are very thin. To resolve these narrow features more clearly, a refined mesh was generated using a nominal element size of 0.45 mm, resulting in approximately 5.45 million elements. The refined model provides greater spatial resolution in the defect region and improves the ability of the indicator to represent the narrow dark lines, as illustrated in Figure 6.

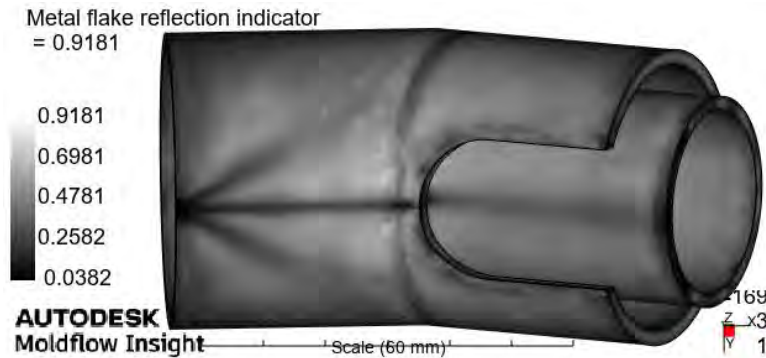


Figure 6. Metal flake reflection indicator for the vacuum swivel coupling, using a fine mesh.

Conclusions

Autodesk Moldflow Insight 2027.1 introduces the Metal flake reflection indicator for qualifying 3D Flow analyses with fiber orientation enabled. The indicator is derived from a simplified color-intensity relationship using the reference assumption that the viewing and lighting directions coincide with the local surface normal. Averaging the reflected response of individual flakes gives $I = \mathbf{n} \cdot \mathbf{A} \cdot \mathbf{n}$, which is evaluated at cavity surface nodes.

The Metal flake reflection indicator is derived from the Fiber orientation result. Although fiber-orientation plots can be used to investigate the source of cosmetic defects, their interpretation can be challenging on complex geometries because they are displayed in a single Cartesian coordinate system. By projecting the orientation state onto the local part surface normal, the Metal flake reflection indicator provides a more intuitive, surface-based representation that makes defect patterns easier to visualize and interpret.

The indicator provides a relative map for comparing designs and assessing the risk of cosmetic defects. It is not intended to reproduce the photorealistic appearance of a molded part under specific lighting and viewing conditions.

In the vacuum swivel coupling case study, the predicted dark region corresponded to the observed defect location near one of the coupling openings. The study also showed that filler aspect ratio and surface-mesh resolution strongly influenced the predicted contrast.

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