Recommendations for Flow and Weld Line Mitigation using Aluminum Pigments

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Introduction

Over the past several years, extensive research has been applied to explore flow and weld line mitigation for injection molding applications. Flow and weld lines are a common aesthetic challenge, when using special effect pigments. The use of metallic pigments can enhance visible lines that were not noticeable in chromatic pigmented parts. The focus of our research is to explain the appearance of flow and weld lines when using metallic pigments, determine if these lines could be mitigated with aluminum pigment technology, make suggestions on formulations to reduce line visibility, and propose processing conditions that could improve part appearance.

Although visual similarities exist in the appearances of flow and weld lines, the reasons for their formation differ. The injection molding process demonstrates some unique orientation of aluminum flakes within the part. Further investigation reveals that when an injection molded part is cross sectioned, three various orientations of flake layers are exposed. The flakes near the mold surface are oriented nearly parallel to the mold surface and often provide a bright flake appearance. Below this layer, the flakes in the body have a very random distribution and produce a dull color; yet, at the core of the part there is a fountain flow of aligned flakes. This orientation in the mold makes areas that are die cut, or have trimmed gates, lack brightness, which creates further tool design challenges.

Weld Lines are formed when two or more molten polymer flows meet during the injection molding process. This can occur when a polymer flow splits to go around an interruption (e.g., a post that forms a hole) and then rejoins, or when polymer melt fronts meet, from multiple injection points. A visible weld line is observed, due to a combination of two factors. First, during injection, the metallic pigments do not tend to travel in the flow front as quickly as the polymer, resulting in a greatly reduced concentration of pigment at the point where the flow fronts meet. This lack of pigmentation appears as a darker, non-metallic line. Secondly, the pigment flakes adjacent to the flow front tend to orientate differently than those in the main body of the polymer flow. The general flake orientation near the surface is parallel to the surface of the mold, while at the flow front, the flakes are more perpendicular in orientation. Therefore, the dark edges of the flake pigment are seen at the area adjacent to the weld line, rather than the bright reflective face. This has the effect of making the weld line even more visible as a dark line.

Flow Lines can occur where the mold design causes abrupt changes to the flow path of the polymer during injection. These changes in flow path could be at mold gates, at areas with a difference in thickness, or where the polymer flow experiences a sudden change in direction. Such changes in polymer flow result in changes in the orientation of the pigment, and with high aspect ratio, flake pigments, this is observed as visible flow lines, since the edges, rather than the surface of the pigment, are seen. Flow lines are the contrast between the brighter flake face and darker flake edge.

Recommendations for Reducing Flow and Weld Line Visibility

The most important factor is to first determine whether the defect is caused by a weld or flow line. The mitigation of each is different and, in some cases, opposite. This makes finding a solution for visible marks difficult, because there is no solution that reduces both at the same time. The most dramatic of these opposing causes is concentration. The absence of pigmentation at low loading for a weld line makes it more noticeable than at higher concentrations. A flow line at low concentrations is much less noticeable than at higher concentrations, where the bright face to dark edge effect is enhanced. The following recommendations are based on studies of metallic molded parts in specially designed flow and weld line tools.

Size of Metallic Pigment

In general, the larger the size of the metallic pigment, the less visible the flow and weld lines become. This is partly due to the lower opacity of large particles; but, there is also a more random orientation of large particles, during the molding process, than with smaller particles.

Addition Level of Metallic Pigment

In transparent or semi-transparent polymers, when metallic pigments are used at a low addition level, the weld line is very visible because of the lack of pigmentation. When higher addition levels are used, more aluminum pigment is found in the weld line area, reducing the visibility of the weld line. However, as the addition level of pigment is increased, the effects related to the differences in orientation of the pigment, at the weld line, become more visible. Flow lines are less apparent when low addition levels of aluminum pigment are used and become more noticeable as the addition level is increased.

The optimum addition level for reducing the visibility of flow and weld lines is a balance of the amount sufficient to fill in the weld line lack of pigmentation, but low enough to not show orientation contrast at the weld line and flow line areas. The opacity level is judged by doing a metallic loading ladder from lowest to highest, with several steps, to determine the optimum point. This optimum level will change with each grade of aluminum pigment, due to variations in hiding power. Silberline is able to offer guidance on choosing the correct pigment for your application.

Pigment Geometry

Traditional metallic pigments, called **Cornflakes,** are very thin, with wide particle size distribution. The orientation of these thin particles, during injection molding, will produce visible flow and weld lines. If the cornflake pigment contains a large amount of fine particles, this will result in a higher definition of flow and weld lines. **Lenticular**, or **Silver Dollar** type pigments, are thicker than cornflakes, with a narrower particle size distribution. This technology was anticipated to have improved flow and weld lines, due to a reduced amount of fines and less orientation. This concept was proven to be incorrect, because the silver dollar flakes were brighter than cornflakes, so the bright-to-dark contrast is more visible. **Spherical** pigments were expected to have improvements to flow and weld lines, due to the lack of a dark edge area. The low opacity of these pigments does provide good flow line resistance; however, weld lines are very noticeable because of the lack of pigmentation at the flow fronts. The correct hiding power seems to have a greater mitigation effect for flow and weld lines than the shape of metallic pigment.

Chromatic Pigment with Aluminum

The use of chromatic pigments, in combination with aluminum pigments, can provide color combinations that are much less noticeable in flow and weld lines than aluminum pigments, only. It was originally expected that darker colors, such as blue and black, would best hide these lines, but further investigation revealed that these colors made the contrast between dark lines and bright flakes more noticeable, at equal chromatic hiding power. At equal hiding power, yellow and red were better for mitigating flow and weld lines. The balance of chromatic-to-aluminum flake is also important. As the aluminum flake loadings increase, the ability of the chromatic pigment to mask flow lines goes down. Weld lines are not noticeable at very low concentrations because the chromatic pigment fills in the absence of pigmentation at the weld line; but, as the pigment level increases, the contrast of bright flakes can overshadow the chromatic hiding power. The use of a black pigment on a weld line can make it worse, because it makes the dark line (from the absence of aluminum pigment) more apparent.

Molding Conditions

The use of an optimum metallic formulation, in combination with proper molding conditions, can help make improved quality parts. There are processing variables that can be changed to make some improvements, but some of these may increase the overall cycle time. The speed of injection and the injection pressure have the greatest overall effect; a combination of fast injection speed and high injection pressure is recommended. The limit of fast injection and high pressure occurs when marks at gate, caused by jetting, are found. The increase in stock temperature, to make the polymer more easily injected to fill the part, seems to be better for flow lines, but weld lines appeared to become worse. The mold temperature can be slightly increased to show some improvement, but is limited, because at higher mold temperatures the lines can become more visible.

Masterbatch/Compound Production

The processing of metallic effect pigments for masterbatch should be carried out with minimal shear, to avoid damaging the pigments. Any pigment damage will result in a much darker/greyer color, since the flakes are either folded, or pieces are broken from the edges. This will also make the flow and weld lines more visible, since there will be a larger number of small particles present. Metallic pigment damage is usually only seen in the compounding processes, and little damage generally occurs in the injection molding process, unless abrasive fillers are included in the polymer. If pigment damage is seen to be a problem, then using a lenticular, or Silver Dollar, type will help, since this type of pigment is thicker and more robust. It is, therefore, less likely to be damaged, folded, or broken during higher shear extrusion.

Tooling Design

Any changes that can be made to the mold tool design to reduce flow and weld lines, or move them to areas where they will not be visible on the final article, are recommended. Mold flow analysis is useful for new tool design or modifications. Single injection points are advisable, with large gate areas located away from the surface that will be visible on the finished part. If producing large particles with many injection points, the use of sequential or cascade gating may reduce weld lines. This is popular in long, thin sections, such as car bumpers. The use of texture on the surface of the part also reduces the flow and weld line appearance. Ideally, the use of a metallic effect as a design feature should be included at the earliest possible stage, so that the mold tool can be properly designed.

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This 2012 edition supersedes all previous editions.