Figure – Warpage Measurement

A Study on the Effect of Nan-O-Sil ASD on Cooling Time Reduction

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Abstract

A cooling time study was performed to show the benefits of the Nan-O-Sil ASD additive. Through the use of an infrared camera, the part's temperatures can be examined. The part's warpage was also measured and compared to the neat resin for each material. The materials used in this study were PP, PBT - 33% glass-filled, Nylon 6/6 – 33% glass-filled, ABS, and HDPE.

Through the use of the Nan-O-Sil silicon dioxide additive, cycle time can be reduced by as much as 70% in semi-crystalline materials.

Introduction

A common goal in Injection Molding is to reduce cycle time as it can save a company both time and money. Cooling time is typically the only phase of the injection molding cycle that has any amount of time that can be reduced. However, big reductions in cooling time could have an unwanted effect on a part's dimension.

In this study, the temperature of the parts as well as warpage was measured to determine how well the Nan-O-Sil ASD additive could reduce the cooling time. A cooling time study was used to compare the neat resin to the resin with the Nan-O-Sil ASD. Several materials were run at the same cooling time to evaluate different combinations of materials.

An infrared camera was used to measure the part's temperature at each run. In order to determine if cooling time could be reduced sucessfully, the part's dimensions were recorded and averaged for each cooling time. A graph was created from this data to show the differences.

There were five materials used in this study. The semi-crystaline materials were Polypropylene (PP), Polybutylene Terephthalate (PBT), Nylon 6/6, and High Density Polyethylene (HDPE). The only amorphous material was Acrylonitrile Butadiene Styrene (ABS).

Statement of Theory and Definitions

A year ago we reported research data showing that very small amounts of ultra-fine silica, Nan-O-Sil ASD, can reduce injection molding cycle times by 20% to 30 % in PP, nylon, PBT, and ABS [i]. These results have since been confirmed in numerous commercial applications. The cycle time reductions have been demonstrated in 16 and 32 cavity molds along with other benefits such as reduced flow lines, improved color dispersion, and improved dimensional stability of PP, nylon and various glass-filled polyamides and other engineering plastics [ii].

Nan-O-Sil ASD is a high purity, amorphous, colloidal silica in the form of a white powder. The spherical particles range from 0.02 to 0.55 microns (20 to 550 nanometers). Energy Strategy Associates, Inc exclusively markets Nan-O-Sil ASD.

Description of Equipment and Process

The molding machine used in this study was a Husky Hylectric 90. The mold selected for this study was the Drawer mold. This mold was selected because the wall thickness varied in the part.

The PP material used was A. Schulman PP 3479-01. The PBT is 33% glass-filled resin, – Ticona Celenex 3309 HR. The nylon is Teknor 133GNT001, a 33% glass-filled resin. The ABS is SABIC (GE) Cyclolac GPM 5500-2502.

The part temperature was taken with the FLIR A-20 infrared camera. The data obtained from this camera was manipulated by MATLAB 2009a and software developed at Penn State Erie. A fixture was developed to ensure the parts orientation was consistent.

The parts warpage was measured with the OGP Avant 400 CFOV optical measuring device.

The nano-composite additive used in this study was Nan-O-Sil ASD, an ultra fine, high purity, amorphous colloidal silicon dioxide powder.

Application of Equipment and Process

The Nan-O-Sil ASD powder was hand mixed to 0.8% in the lab prior to running. For the hygroscopic materials, smaller batches were mixed during the process and brought to the molding machine when needed.

An optimum process was set for each material with 0.8% Nan-O-Sil ASD. The neat resins were run with the same process, although there was some adjustment for shot size.

The mold was run for 10 minutes to make sure it was in temperature equilibrium. The cooling time was set to 90s and six parts were molded. Data collection started on the seventh. Three parts were collected and infrared pictures were taken of each. The parts free fell from the mold and were collected by a gloved hand and placed into the fixture.

After the three samples were collected, the cooling time was dropped to 60s and three more samples were collected and measured in the same fashion. This was repeated for cooling times of 45s, 30s, 25s, 20s, 15s, 10s, and 5s. Between cooling time changes, six parts were run between the 90s, 60s, and the 45s cooling times. Four parts were run between the other cooling times.

The parts were stored in a climate controlled room to condition for a later measurement. The parts were then measured between two walls (Error: Reference source not found).

The data from the part measurements was placed into an Excel spreadsheet for each material. On each spreadsheet, the neat resin was compared to the Nan-O-Sil ASD.

Presentation of Data and Results

The part used in this study was a utility drawer. It has a main wall thickness of 1.524 mm with a front of 2.54 mm. The part can be seen in Error: Reference source not found. For each material, the temperatures for all cooling time results are scaled to the highest temperature seen in the 5s run. The elapsed time from ejection until the parts were placed in the fixture was around 4s.

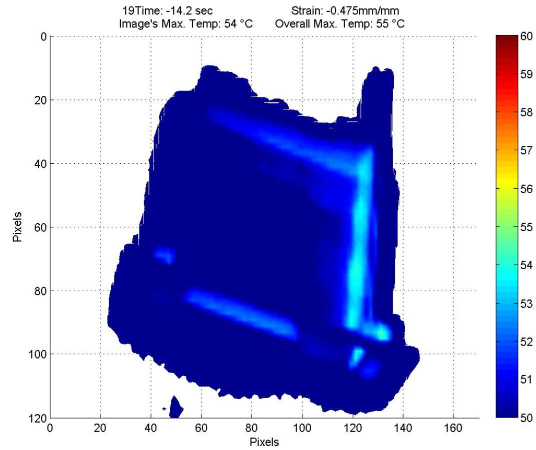

Figure - Neat PP @ 90s Cooling Time

The first material to be examined was PP at a cooling time of 90s. The temperature of the part can be seen in Figure . The part has a maximum temperature of 54°C and is fairly cool on the bottom floor of the drawer.

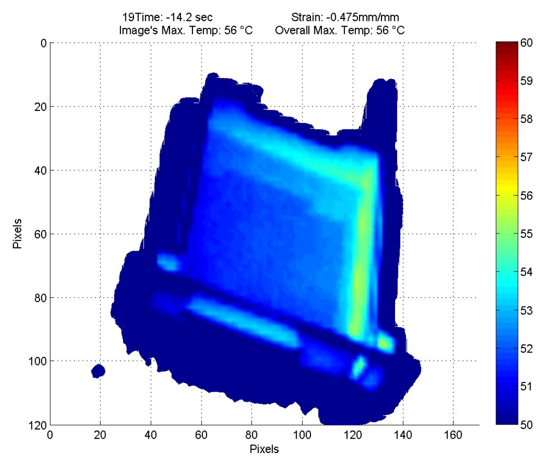

Figure - Nan-O-Sil ASD PP @ 90s Cooling Time

The same part with Nan-O-Sil ASD in PP can be seen in Figure . The maximum temperature is 2°C higher than the neat resin at 90s (Figure). Compared to the neat resin, the Nan-O-Sil ASD is warmer in the bottom of the drawer.

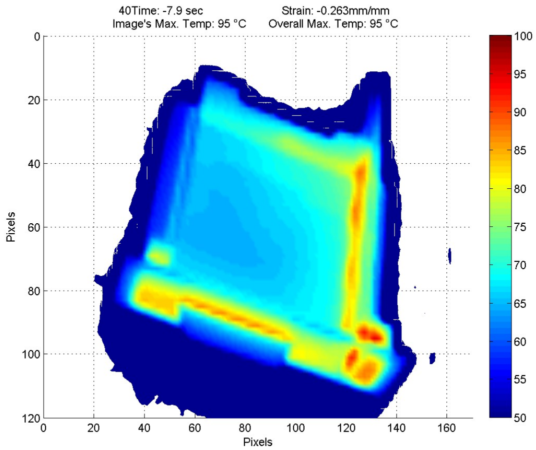

Figure - Neat PP @ 15s Cooling Time

The maximum temperature at a cooling time of 15s for PP is 95°C (Figure). It is 41°C higher than at a cooling time of 90s.

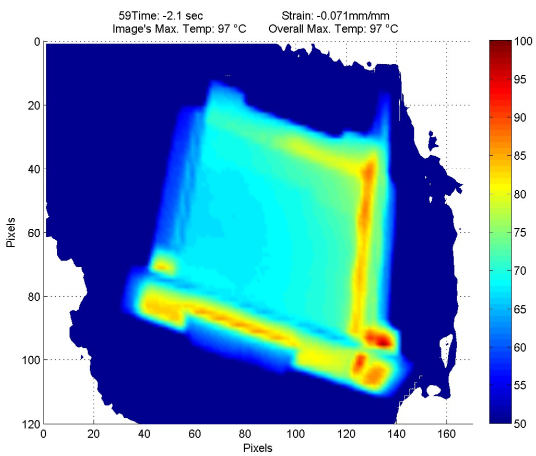

Figure - Nan-O-Sil ASD PP @ 15s Cooling Time

The same part with Nan-O-Sil ASD in PP at a cooling time of 15 s can be seen in Figure . The maximum temperature is 2°C higher than the neat resin at 90s (Figure). Compared to the neat resin, the Nan-O-Sil ASD is warmer in the bottom of the drawer.

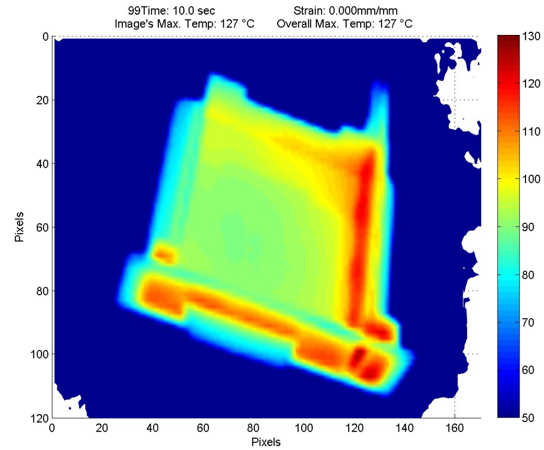

Figure - Neat PBT @ 15s Cooling Time

The maximum temperature at a cooling time of 15s for neat PBT is 127°C (Figure).

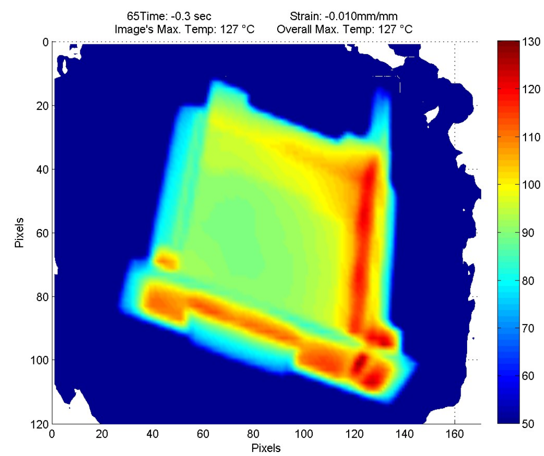

Figure - Nan-O-Sil ASD PBT @ 15s Cooling Time

In Figure , the maximum temperature is 127°C. This is the same as the neat PBT part. The temperature distribution on the bottom of the shelf is the same as the neat part.

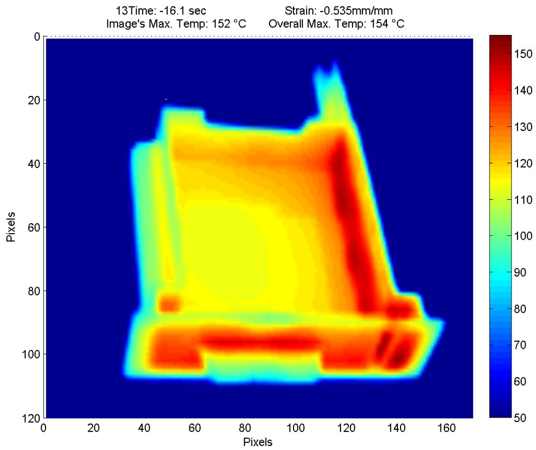

Figure - Neat Nylon @ 15s Cooling Time

The maximum temperature at a cooling time of 15s for neat Nylon is 152°C (Figure).

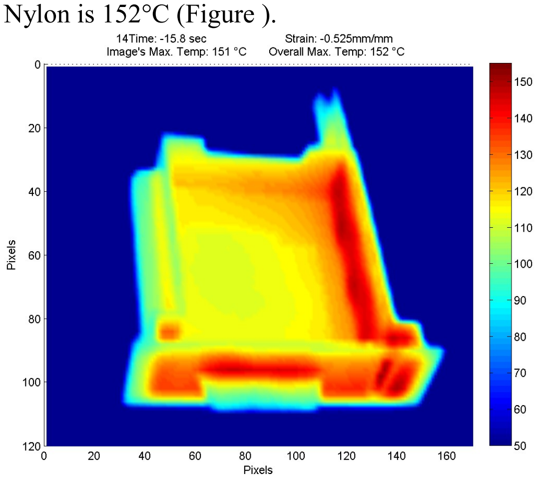

Figure - Nan-O-Sil ASD Nylon @ 15s Cooling Time

In Figure , the maximum temperature is 151°C. This is 1°C below the neat Nylon part. The temperature distribution on the bottom of the shelf is warmer than the neat part.

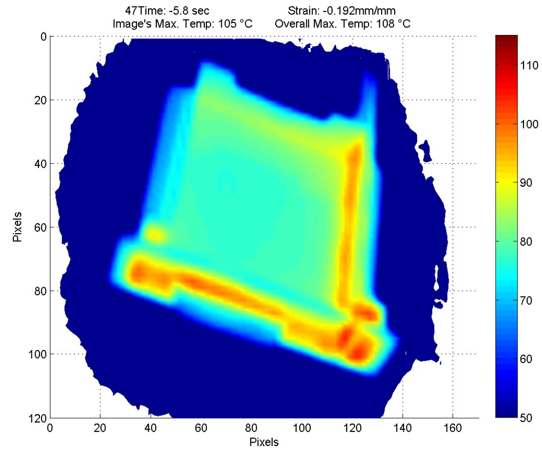

Figure - Neat ABS @ 15s Cooling Time

The maximum temperature at a cooling time of 15s for neat ABS is 105°C (Figure).

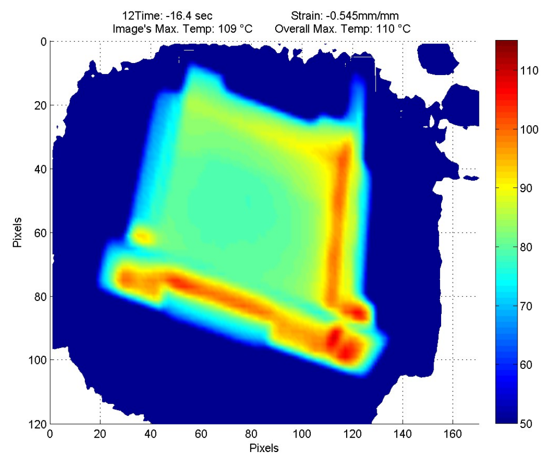

Figure - Nan-O-Sil ASD ABS @ 15s Cooling Time

In Figure , the maximum temperature is 109°C. This is 4°C above the neat ABS part. The temperature distribution on the bottom of the shelf is warmer than the neat part.

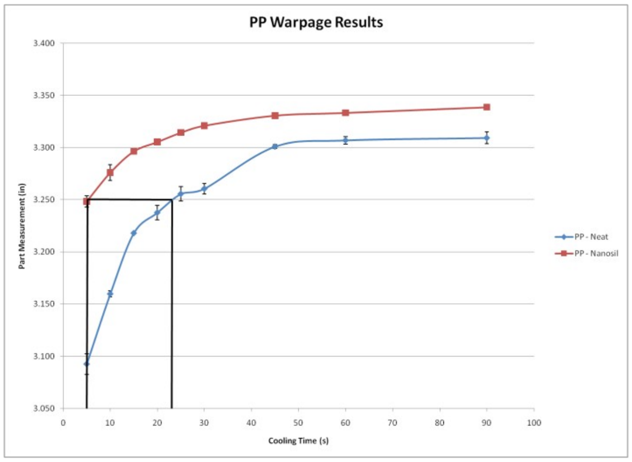

Figure - PP Warpage Results

The warpage results were generated from part measurements. The measurements were taken in the center walls of the drawer (Error: Reference source not found). The parts were allowed to condition for several weeks. The cooling times ranged from 5s to 90s. Y-Error Bars are based on the standard for each set of measurements. Since the part warps toward the center of the drawer, a smaller warpage measurement indicated more warpage.

The neat resin shows more warpage than the Nan-O-Sil ASD (Figure). The black lines show the potential cooling time reduction. If the part's dimension is acceptable at 22s in the neat PP resin, the cooling time can be reduced to 5s with the Nan-O-Sil ASD. This is a reduction of 77% from the neat resin.

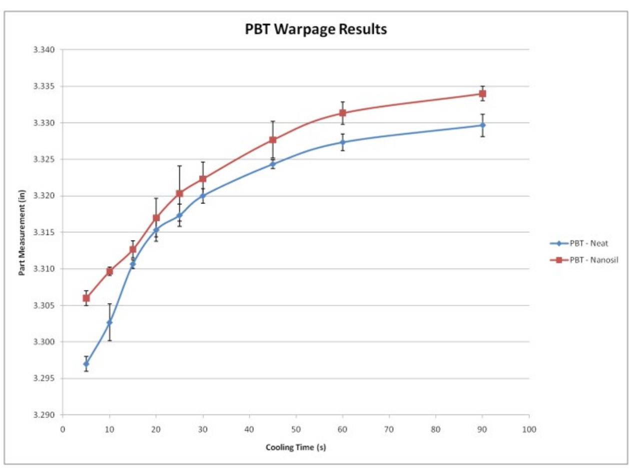

Figure - PBT Warpage Results

The neat resin shows more warpage than the Nan-O-Sil ASD (Figure). If the part's dimension is acceptable at 13s in the neat 33% glass-filled PBT resin, the cooling time can be reduced to 4s with the Nan-O-Sil ASD. This is a reduction of 70% from the neat resin.

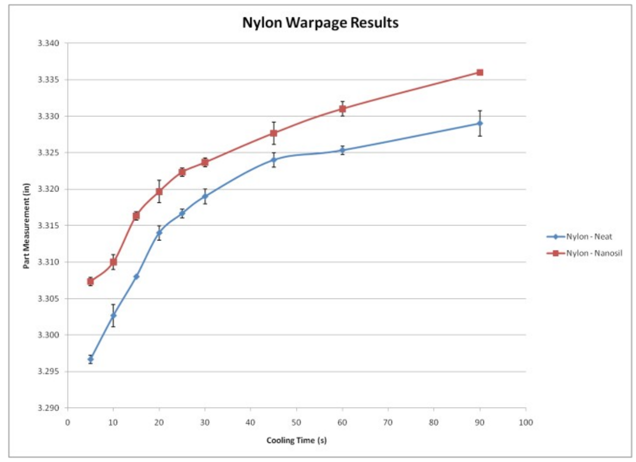

Figure - Nylon Warpage Results

The neat resin shows more warpage than the Nan-O-Sil ASD (Figure). If the part's dimension is acceptable at 15s in the neat 33% glass-filled Nylon resin, the cooling time can be reduced to 5s with the Nan-O-Sil ASD. This is a reduction of 67% from the neat resin.

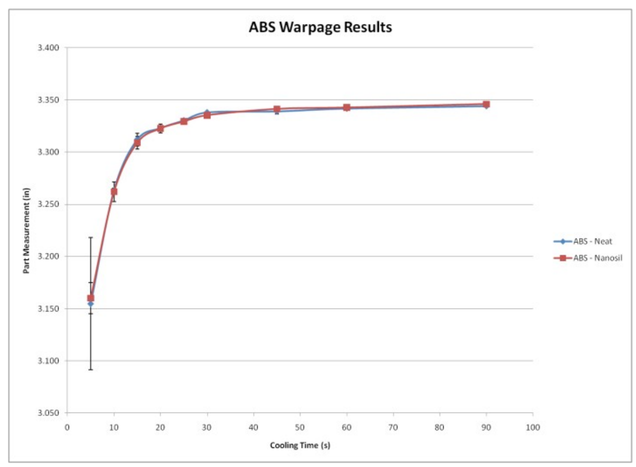

Figure - ABS Warpage Results

The neat resin shows the same warpage as the Nan-O-Sil ASD (Figure). This shows that the addition of Nan-O-Sil ASD to ABS has no effect.

Interpretation of Data

Several molding trials had shown that the addition of Nan-O-Sil ASD shortened cycle time. These trials had shown the promise of cooling time reduction, but the mechanism for the reduction in cooling time was unknown.

The original hypothesis was that the Nan-O-Sil ASD additive would absorb the heat and cool the parts more quickly or help transfer the heat to the mold easily. The infrared pictures showed a different outcome.

The temperatures of the Nan-O-Sil ASD parts are generally 1°C to 4°C higher than the neat resin parts. When looking at the bottom of the drawer, the Nan-O-Sil ASD also shows a higher temperature. It would be expected that the parts, at a higher temperature, would warp more than the cooler neat parts. The results showed that the addition of Nan-O-Sil ASD made the parts more dimensionally stable.

Preliminary DSC and SEM work show that there is less crystallinity in the PP parts. It is possible that the Nan-O-Sil ASD acts like a nucleating agent. It could create more individual crystals, but not as much total crystallinity as the neat resins. More tests need to be performed to confirm this hypothesis. This would explain why there is little effect on the ABS parts.

The addition of Nan-O-Sil ASD in the resin shows some significant reductions in cooling time. Several case studies have shown the same thing. PP shows the most reduction. It is the most crystalline of the polymers.

Future Work

More work needs to be done on the DSC and SEM to verify the preliminary results already run.

Since ABS was the only amorphous material run in the experiment, there is interest in seeing if Nan-O-Sil ASD affects other amorphous materials. Polycarbonate and PMMA may be tested with the Nan-O-Sil ASD.

Conclusions

Significant reductions in cooling time can increase a company's profits. The addition of Nan-O-Sil ASD has shown a significant reduction in cooling time. In PP, it is 77%. In glass-filled PBT, it is 70%. Glass-filled Nylon has a 67% reduction. ABS shows no reduction in cooling time. The most likely cause of the reduction may be because the Nan-O-Sil ASD acts like a nucleating agent. The Nan-O-Sil ASD may also inhibit polymer chain movement, just like a filler.

Acknowledgements

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Key Words: Nan-O-Sil ASD, Infrared, IR, Injection Molding, Cycle Time Reduction

References

i. Sherman, Lilli, “Plastics Technology”, November 2008

ii. Naitove, Matthew H., “Plastics Technology”, December 2009