Colloidal Silica Processing Aid Dramatically Reduces Cycle Time of Engineering Resins and Improves the Color Dispersion and part Dimensions With Huge Cost Savings to the Molders

Dr. Pravin L. Shah – Rheo-Plast Associates, Inc., and
Richard Oder – Energy Strategy Associates, Inc.

BACKGROUND

In a previous technical paper (See Plastics Technology November 2008, PP 51/52) we reported the effectiveness of ultra-fine amorphous synthetic colloidal silica particles - Nanosil ASD – to reduce the injection molding cycle time by 20% to 30% in polypropylene, unfilled and glass filled nylon 6 and nylon 66, PBT and ABS. We reported that the processing of Nanosil ASD is also accompanied by retention and even improvement of key physical properties like tensile strength and toughness. In the last twelve months we have made numerous successful commercial applications of the Nanosil ASD technology with large volume molders who have confirmed the significant cycle time reduction in multi-cavity molds as well the improvements in flow lines, part dimensions, product tolerances, and uniform surface of the molded parts.

OBJECTIVES

The objectives of this paper are as follows:

(1) Report the dramatic result of our new experimental work that shows very significant reduction of molding cycle time of six engineering plastics from 20% to 31 %, (2) Nanosil ASD works well in injection molding from processing melt temperature range of 100 C to 425 C without causing any degradation of the polymer melt, (3) Retention and improvement of key physical properties of the engineering plastics with Nanosil ASD, (4) Improvements in color dispersion and associated cost savings to use less amount of colorants, (5) Improved flow lines, good part dimensions, product tolerances, and improved surface, (6) Ease of handling and feeding the Nanosil ASD accurately to the molding machine with several options with proven technology, and (7) Illustrate substantial cost savings with Nanosil ASD in multi-cavity molding.

EXPERIMENTAL WORK – RESULTS AND DISCUSSION

Nanosil ASD processing aid is high-purity colloidal silica in the form of white free flowing powder. The spherical particles range from 0.02 to 0.55 microns (20 to

550 nanometers). Nanosil ASD is exclusively marketed and distributed by Energy Strategy Associates, Inc. located in Albany NY

FEEDING NANSOIL ASD POWDER

In this study, 0.8% Nanosil ASD powder was metered directly into the molding machine using a volumetric feeder along with each plastic resin. One can also tumble mix the Nanosil ASD powder with the resin for fifteen minutes if so desired.

Injection molding trial of each resin with 0.8% Nanosil ASD was performed on a 110 ton Cincinnati injection molding machine using an ASTM mold for making the tensile bars to measure the properties and to inspect the quality and dimensional stability of the molded parts.

RESULTS OF CYCLE TIME REDUCTION

Based on our extensive experience of running engineering plastics for molding applications, the molding machine was set at barrel temperatures close to the processing melt temperature shown in Table 1. Using our standard cycle time for each resin based on past experience, each resin was first run as control sample at optimum cycle time to produce the parts. Then 0.8% Nanosil ASD was metered into the machine as a next set of experiment to see if we can reduce the cycle time. The total cycle time in a molding operation consists of the holding time, ejection time, and the cooling time. As reported in our previous paper, it is best to work with the **cooling time to gradually reduce** it as the Nanosil ASD begins to work as a **heat sink to provide more effective cooling.**

Using this approach we obtained very dramatic results of reducing the cycle time for each resin as shown in Table 1. Please note that for Celcon resin, which is an aceatal copolymer resin, we were able to reduce the cycle time by 23% while the part geometry and the dimensions were unaffected. Similarly, as shown in Table 1, Nanosil ASD reduced the cycle time of 33% glass filled polycarbonate by 29%, a major cost savings for a molder. The results were even more dramatic for PPS (poly phenylene sulfide) to attain 31 % reduction in cycle time. PPS is a difficult resin to mold and parts often stick to the mold. The Nanosil ASD made it easier to mold and eliminate the sticking problem entirely while all the parts were very good in dimensions and tolerance limits.

Next we worked with Noryl which is a very popular material for the electronic components market and often very difficult to mold. We were able to reduce the cycle time of Noryl with Nanosil ASD by only 5%. HDPE resin on the other hand

offered excellent results with Nanosil ASD to provide 27 % drop in cycle time with very good part dimensions.

Poly Ether Ether Ketone, PEEK, is the most exotic and very expensive resin in the market today selling at close to $38/pound and it processes at very high melt temperature in the range of 380 to 410 C. We are very pleased to report that Nanosil ASD survived such harsh processing temperatures as 390 C (750 F) during the molding process and reduced the cycle time of PEEK by 22%. This is an enormous cost savings for a resin that costs close to $38-42/pound! The results of this study shows Nanosil ASD works very effectively at a processing temperature range from 100C to 425C with more than dozen commercial resins as reported in our study

EFFECT OF NANOSIL ASD ON THE PHYSICAL PROPERTIES

The physical properties of four engineering plastics reported in this work are shown in Table 2. As we can see, most of the properties of polyacetal, glass filled polycarbonate, PPS, and PEEK are retaining pretty much the same with Nanosil ASD compared to the control resin. There is some improvement in the tensile strength and flex modulus which means improved toughness is provided with Nanosil ASD working as a filler.

NEW SCIENTIFIC RESEARCH ON NANOSIL IN PROGRESS

At this point we feel that the Nanosil ASD appears to work as an effective processing aid to reduce the amount of cooling required during the molding process and thus allows one to reduce the cooling time and overall cycle time. We are doing additional research with Penn State University – Erie - School of Polymer Processing and Materials Science under the leadership of Prof. Jon Meckley to study the thermal effects inside the mold with different materials to fully understand the mechanism of Nanosil ASD as an effective heat transfer catalyst to reduce the cycle time. We expect to publish additional data in a few months to provide precise scientific thesis for this phenomenon of improved cooling and effective heat transfer with Nanosil ASD.

COMMERCIAL APPLICATIONS OF NANOSIL ASD AND ITS FEEDING OPTIONS

In the last twelve months we have found very good applications of the Nanosil ASD with several large volume molders across the country and some overseas locations to confirm our findings that the proper use of Nanosil ASD does in fact reduce the cycle time of many resins like PP, PC, PE, nylons, and PBT by 20% to 30%. In fact, some of the customers have demonstrated huge success of Nanosil

ASD with sixteen and thirty-two cavity molds with significant savings in cycle time.

At this point we have several options to introduce the Nanosil additive to a molding machine with any resin as briefly described below:

1. Tumble mix the Nanosil ASD powder with the resin for fifteen minutes and then feed the mix to the molding machine hopper. It does not create any dusting problem as the colloidal silica has a very good tendency to cling to the resin pellet. There is NO safety hazard in handling the Nanosil ASD additive in powder form.
2. Another option is to use a volumetric feeder at the feed throat to meter the exact amount of the Nanosil ASD powder for continuous large volume applications.
3. Many molders use a lot of different colorants that are added in liquid form or solid form. We have successfully demonstrated mixing of Nanosil ASD powder with liquid colorant by a reputed colorant manufacturer and the liquid mix was fed directly to the molding machine successfully. Many molders are able to lower the colorant amount in the product as Nanosil ASD disperses the color more effectively and this attribute of improved color dispersion often pays for the entire cost of Nanosil ASD. Many colorants cost in the range of $3 to $15 per pound and reducing the amount of the colorant is an added bonus a molder could enjoy working with the Nanosil ASD technology.
4. Energy Strategy Associates, Inc. is in a position to offer the Nanosil ASD in compounded pellet form with the desired resin as a carrier or a wax as a carrier depending on the customer needs.

EXAMPLE OF COST SAVINGS USING NANOSIL ASD

As reported in our earlier discussion, many commercial molders have been able to reduce the cycle time of their products made from PP and nylon materials with Nanosil ASD by 20% or more. Figure 3 shows a simple exercise how 20 % cycle time reduction can produce 1040 more parts per hour with a thirty two-cavity mold. Using a $20/hr current rate for machine hour rate in the US molding business, this would amount to a cost savings of eleven cents per part or **$110,000 per each million parts produced** with Nanosil ASD for a molder with large volume business. This is a huge cost saving to enable a molder to compete well in the global market by reducing the cost of production so substantially. The

cost of Nanosil ASD powder is only less than three cents per pound of resin at 0.8% level. A typical molded part may weigh 25 to 50 grams which amounts to approximately 10 to 20 parts per pound that would cost only three cents of the additive while the labor savings from the cycle time reduction are eleven cents per part for a multi cavity mold which well justifies the usage of the Nanosil ASD to attain very large cost savings in a high volume business set up to improve the productivity substantially.

CONLUSIONS

1. The results of our development work show that Nanosil ASD is very effective processing aid to reduce the cycle time for injection molding dozen different resins including many engineering plastics.
2. Nanosil ASD does not hurt any physical properties. It actually improves the strength and toughness in many cases as reported in our data.
3. Nanosil ASD can be used in processing temperature range of 100 C to 425 C causing no degradation of the polymer resin during molding.
4. Commercial molders will find this processing aid very easy to work with in terms of several feeding options and gain a significant cost savings by reducing the cost of production.
5. Significant cost savings have been realized in multi cavity production with nanosil ASD to reduce the cycle time for dozen different commercial resins and produce more parts per hour for single cavity mold to multi-cavity mold as shown in the example (Table 3).

Nanosil Cost Savings

Cost savings Estimate for Molders Using Nanosil ASD					
Table 3					
	Number of parts molded per hour on a commercial molding machine				
Material	**cycle time, se**	**Single cavity**	**four cavity m**	**16 cavity mo**	**32 cavity mold**
Polypropylen	**Cycle time**	**Parts/hr**	**Parts/hr**	**Parts/hr**	**Parts/hr**
control	30 sec	120	480	1920	**3840**
PP with 0.8%					
Nanosil ASD	24 sec	150	600	2400	**4880**
savings/hr		30 parts	120parts	480 parts	**1040 more parts**
With 32 cavity mold, Nanosil ASD produces 1040 more parts per hour					
Based on $20/hr rate of machine hour for molders, 20 % cycle time reduction can					
produce 1040 more parts per hour or approximately a savings of 10 cents per part					
For each million parts molded with Nanosil ASD the molder would save $110,000					

Effect of Nanosil ASD on the Physical Properties of Engineering Plastics						
Table 2						
Nanosil ASD in Celcon Polyacetal resin						
Material	**Tensile strength, psi**	**Elongation at yield, %**	**Flex Modulus 10E5 - Psi**	**Notched Izod ft.lb/in**	**HDT at 66 psi degrees F**	**MFI Gm/10 min**
Celcon M-90	8500	6	3.6	1.2	310	9
control	8500	6	3.6	1.2		
	8400	6	3.8	1.2		
	8600	6	3.7	1.2		
	8500	6	3.8	1.2		
Average value	**8500**	**6**	**3.7**	**1.2**	**310**	**9**
Celcon M-90 with	9100	6.5	3.8	1.2	310	9
0.8% Nanosil ASD	9500	6.5	3.9	1.2		
	9600	6.4	3.8	1.2		
	9400	6.5	3.9	1.2		
	9600	6.5	3.8	1.2		
Average Value	**9400**	**6.5**	**3.8**	**1.2**	**310**	**9**
Nanosil ASD in glass filled Polycarbonate - Hylex P10G33						
33 % glass filled PC	18000	3.3	10	2	305	7
	18500	3.2	10.2	2		
	18600	3.3	10.1	2		
	18400	3.3	10.1	2		
	18300	3.2	10.2	2		
Average Value	18300	3.3	10.1	2	305	7
PC with 0.8 %	19000	3	10.2	2	305	7
Nanosil ASD	18900	3	10.2	2		
	19100	3.1	10.2	2		
	19100	3.1	10.2	2		
	19000	3	10.1	2		
Average Value	19000	3	10.2	2	305	7
Material	Tensile Strength	% Elongation	Flex Modulus	Notched	HDT at 66 psi	MFI

	Psi	at yield	PSI	Izod - ftlb/in	F	gm/10 min
Nanosil ASD in Fortron PPS						
PPS 20386	12500	1	6	0.5	400	10
	12500	1	6.1	0.5		
	12400	1	6.1	0.5		
	12300	1	6	0.5		
	12600	1	6.2	0.5		
Average Value	12500	1	6.1	0.5	400	10
PPS with 0.8 %	13400	1	6.5	0.5	400	10
Nanosil ASD	13400	1	6.5	0.5		
	13500	1	6.4	0.5		
	13300	1	6.5	0.5		
	13500	1	6.5	0.5		
Average Value	13400	1	6.5	0.5	400	10
Nanosil ASD in	**Victrex PEEK**					
PEEK 450 G	14500	5	6	1.6	320	17
	14600	5	6	1.6		
	14500	5.2	6.1	1.6		
	14600	5.1	6	1.6		
	14500	5.1	6	1.6		
Average Value	14500	5.1	6	1.6	320	17
PEEK with	15600	6	7.1	1.6	320	17
0.8 % Nanosil ASD	15500	6	7.1	1.6		
	15500	6	7	1.6		
	15600	6	7.1	1.6		
	15500	6.1	7	1.6		
Average Value	15500	6	7	1.6	320	17

Effect of Nanosil ASD on Injection Molding Cycle Time			
Table 1			
Material	**Resin cost**	**Processing**	**% Reduction**
	$/pound	**melt temp, F**	**in Cycle Time**
Celcon Polyacetal	1.5	380	**23%**
33% Glass filled PC	2.8	560	**29%**
Polycarbonate			
PPS - Poly Phenylene	4.1	600	**31%**
Sulfide			
Noryl	4.25	590	**5%**
HDPE	1.1	425	**27%**
PEEK	38.5	750	22%