31D07

CAE Analyses of the Syringe Barrel Injection Molding

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1. Introduction

The cavity filling analyses were performed for the new design of the 3cc Syringe Barrel using polypropylene PF-091, and the new nucleated polypropylene PF-533. These analyses have been performed for different processing conditions as well as various wall thickness designs with PF-091. However, for the new material PF-533, only the original wall thickness design has been studied at two different processing conditions for comparison purpose. This study was conducted to investigate the optimum part design and processing condition for two different materials.

2. Molding Constraints

In order to illustrate the relationship between the melt temperature and the flow stresses, analyses were performed at two different processing conditions.
These are listed below :

Processing Condition 1 (PC1) : Mold Temp. = 30 C, Melt Temp. = 240 C
Processing Condition 2 (PC2) : Mold Temp. = 30 C, Melt Temp. = 260 C

Processing condition 1 (PC1) represents the typical lower range of melt temperature used for PF-091, while processing condition 2 (PC2) reflects the upper range based on field test. The actual polymer temperature will probably fall within this operating window. This 20 C range in melt temperature was selected because flow stresses in the part are significantly influenced by temperature and to gain a better understanding of the window of operating conditions.

The injection time selected (0.5 sec.) was based on optimizing the flow stresses in the part. However, for comparison, the results for a 1.0 sec. injection time are also analysed for the original wall thickness design using both materials. The terminology used for the Syringe Barrel is defined in Figure 1.

3. Analyses using PF-091

Four different wall thickness designs were analyzed using PF-091 in order to reduce the flow stress levels in the barrel. Table I shows the nominal wall thicknesses in the different areas of the barrel, the part volumes and the relative increase in material utilization for each design.

TABLE I

NOMINAL WALL THICKNESSES (in.)

AREA	DESIGN 1	DESIGN 2	DESIGN 3	DESIGN 4
TIP	0.040	0.040	0.040	0.040
ROOF	0.035	0.035	0.035	0.040*
COLLAR	0.025	0.025	0.030*	0.030
UPPER BARREL	0.030	0.035*	0.035	0.040*
LOWER BARREL	0.037	0.042*	0.042	0.047*
FLANGE	0.060	0.060	0.060	0.060

Note : Numbers with * indicate changes in wall thickness from the previous design.

PART VOLUME (cm^3)

DESIGN	VOLUME	% CHANGE
1	2.10	---
2	2.35	+ 12%
3	2.38	+ 13%
4	2.64	+ 26%

3.1 Design 1

Design 1 represents a design with wall thicknesses per the original part drawing. Flow stresses in the part are shown in the figures 2 and 3 for PC1 and PC2, respectively. Areas which are black in these figures denote stresses which are above the degradation level for PF-091(250,000Pa) and are generally unacceptable except in confined regions such as the gate. Light to dark pink areas denote high stresses which are acceptable in small areas but tend to cause radiation embrittlement, bowing and/or warpage in large areas such as the barrel. Areas shown in the blue to red range have flow stresses that are relatively low and are generally acceptable. Figure 2 indicates that the flow stresses in the upper barrel are above the degradation level for PF-091.

Flow stresses for a 1.0 sec. injection time have also been shown in figures 4 and 5, at the two different processing conditions. These figures indicate that the flow stresses in the upper barrel are extremely high due to the polymer cooling off rather excessively, causing it to be more viscous than for the shorter 0.5 sec. injection time (shown earlier in figures 2 and 3). The minimum temperature of the polymer at the end of fill cycle and the injection pressure for two different processing conditions are presented in Table II.

3.2 Design 2

Design 2 represents a design with the upper and lower barrel wall thickness increased by 0.127㎜(0.005 inches) from Design 1. The flow stresses in the part for this design have been shown in figure 6 for PC1.

TABLE II

Analysis Results (Injection Time = 1.0 sec.)

Material	Molding Constraints	Average Stress	Injection Pressure	Minimum Temperature
		Pa	MPa	C
PF-091	PC1 (240 C)	211,784	51	198
	PC2 (260 C)	185,244	45	209
PF-533	PC1 (240 C)	195,672	47	202
	PC2 (260 C)	168,522	41	215

3.3 Design 3

Design 3 represents a design with the wall thickness in the collar increased by 0.127 ㎜(0.005 inches) from Design 2 in order to reduce the flow stresses in this area. As shown in figure 7, the flow stresses in the collar are now lower and confined significantly from Design 2 to Design 3.

3.4 Design 4

Design 4 represents a design with the wall thicknesses in the roof and the upper and the lower barrel increased by 0.127㎜(0.005 inches) from Design 3 in order to further reduce the stresses in the upper barrel. As shown in figure 8, the flow stresses in the upper barrel are now much lower than before and well within acceptable limits.

The maximum and average flow stresses, injection pressures and maximum and minimum temperatures for each design at a 0.5 sec. injection time are presented in Table III for PC1.

TABLE III

Analysis Results (Processing Condition 1)

Mold Temp. = 30 C
Melt Temp. = 240 C
Inj. Time. = 0.5 sec.

Design	Maximum Stress	Average Stress	Injection Pressure	Maximum Temperature	Minimum Temperature
	Pa	Pa	MPa	C	C
1	472,496	210,542	50	242	229
	(429,086)	(195,271)	(46)	(241)	(229)
2	487,756	190,243	41	242	229
3	403,862	188,047	38	241	229
4	416,774	172,542	32	241	230

Note : Numbers in( ) indicate the values for PF-533.

4. Analyses using PF-533

Cavity filling analyses have also been performed on the barrel using the new nucleated polypropylene PF-533 for the original wall thickness design. Figures 9 and 10 show the flow stresses at a 0.5 sec. injection time when processed at PC1 and PC2, respectively. The flow stresses are slightly lower with the new material compared to those obtained using PF-091(see figures 2 and 3). As figure 9 shows, flow stresses are still quite high in the upper barrel (near degradation) for the lower melt temperature(240 C). From figure 10 it appears that the flow stresses are within acceptable limits at the higher melt temperature (260 C).

Figures 11 and 12 show the flow stresses at a 1.0 sec. injection time for PC1 and PC2, respectively. As can be seen in these figures, flow stresses in the upper barrel at a 1.0 sec. injection time are much higher than those obtained at a 0.5 sec. injection time (figures 9 and 10). However, the stresses obtained with the new material are lower than those obtained with PF-091 (see figures 4 and 5). Figure 12 indicates that the flow stresses in the upper barrel may be acceptable when processed at the higher melt temperature, but are quite high in the lower half of the barrel.

5. Results and Conclusions

- Design 1 (original design) develops extremely high flow stresses in the upper barrel with PF-091 processed at PC1. However the flow stresses are possibly acceptable when processed at PC2 for this wall thickness design at a 0.5 sec. injection time, although there is a slight risk of bow/warpage.
- The most desirable design is probably Design 3 in terms of material utilization and reduced flow stresses in the part, when processed at 260 C. At a melt temperature of 240 C, Design 4 may be a safer design.
- Regardless of melt temperature or material, the flow stresses developed at a 1.0 sec. injection time are much higher than those developed at a 0.5 sec. injection time. This is because the polymer cools off to a greater extent at the end of the injection cycle, causing it to become more viscous.
- The new material PF-533 provides slightly lower flow stresses in the part than those predicted using PF-091, for given processing conditions.

6. References

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3. V.W. Wang, K.K.Wang, C.A. Hieber, J. Polym. Eng., **7**, 1, 1986
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6. MOLDFLOW Design Philosophy

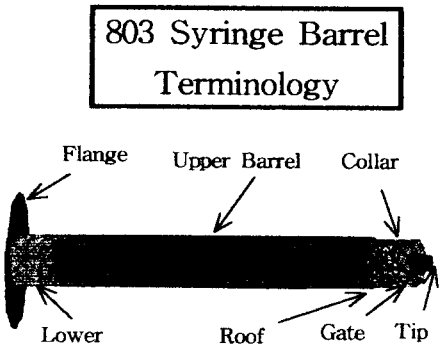


Fig.1

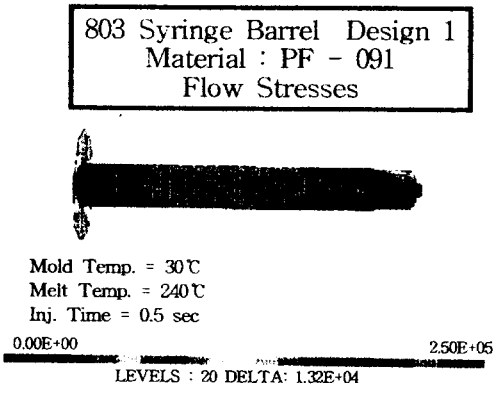


Fig.2

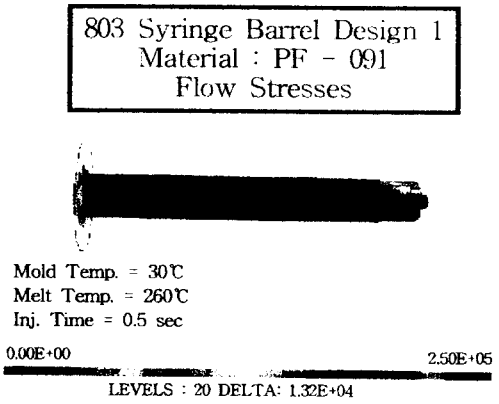
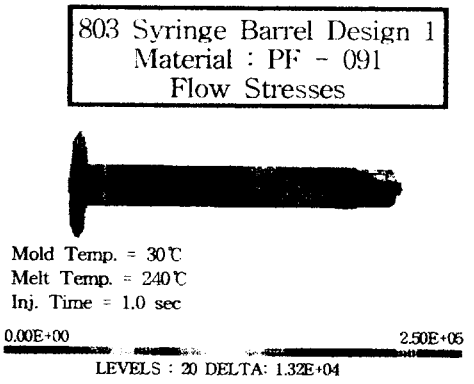


Fig.3



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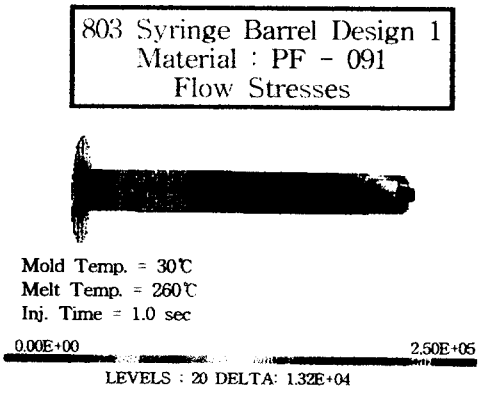
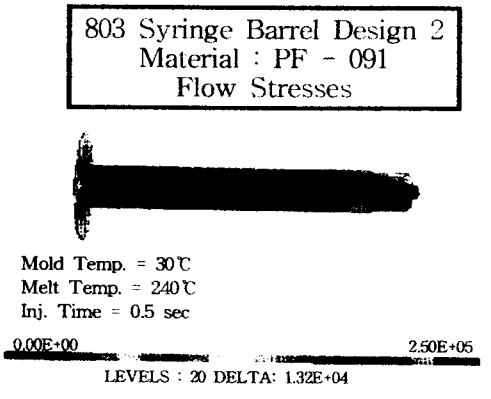


Fig.5



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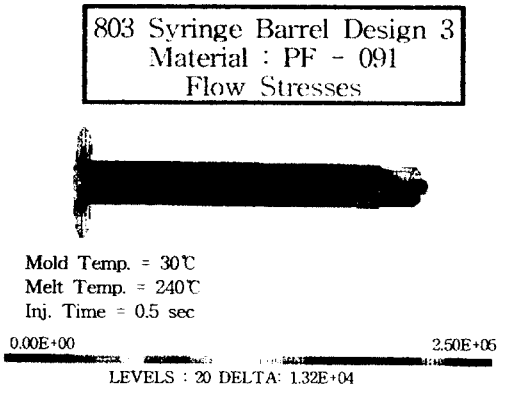


Fig.7

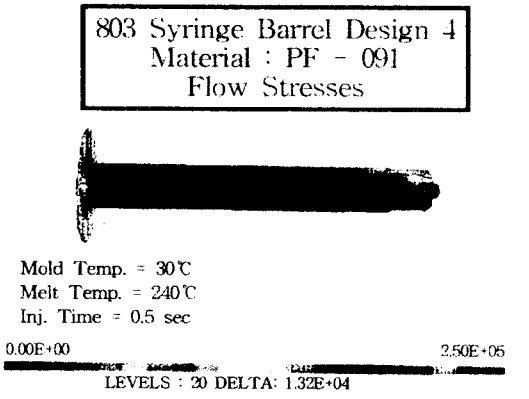


Fig.8

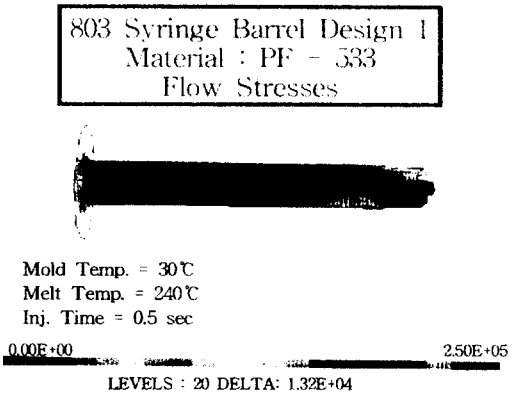


Fig.9

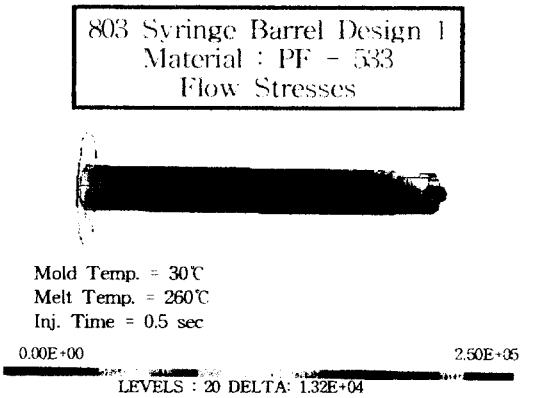
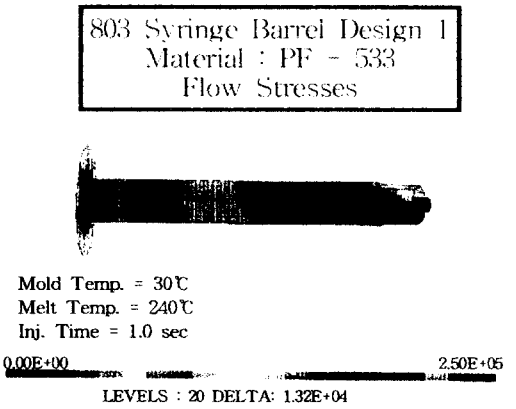


Fig.10



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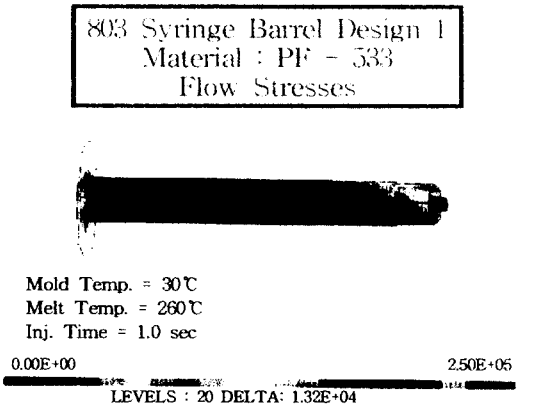

Fig.12