THE EFFECTS OF RUNNING DIFFERENT BARREL TEMPERATURE PROFILES FOR VARIOUS RESINS

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Abstract

Differences in solids conveying, screw pressure profile generation, output, motor energy required, will vary between resins, barrel temperature profiles, and resin preheat temperatures, on a single stage low compression barrier screw design.

Introduction

Barrier screw designs can be run on many different resins, using many different barrel temperature profile settings. This paper will explore the processing differences on four different resins, running (3) different barrel temperature profile settings for each resin. The same barrier screw design will be used for all the resins being processed under all the processing conditions.

Equipment

The extruder used for this study was a 50.8mm (2.0”) diameter x 25:1 hydraulically driven extruder with four; air-cooled barrel temperature zones and one heat only die zone. It is equipped with a Vickers MHT 70 hydraulic motor. Figure 1 shows the extruder with (10) melt pressure transducers located every 2 L/D down the axial length of the barrel to record internal barrel pressures during each extrusion test.

The extruder was also equipped with a 50mm wide x 1 mm thick ribbon die. A 20/40/20 screen pack was used with a breaker plate for each resin trial run. The barrel used was a one-piece barrel design that has the feed port machined directly into the extrusion cylinder with a water-cooled feed block the clamps over the feed end of the barrel.

A Conair dryer was used to preheat each resin to the required 65°C temperature during each resin preheat trial run.

A low shear, low compression barrier screw with mixer was used for all testing. This screw was specifically designed as a general-purpose extrusion barrier screw, capable of running all of the resins used in this study.

A (20) channel Fluke Data Acquisition System was used to acquire all data from each of the extrusion runs. It will be referred to as NetDAQ.

Resins

Four resins were used for this study.

- HDPE (.45 MI) ExxonMobil HD 7845.30
- PP (2.1 MI) ExxonMobil 9852E21
- LDPE (.7 MI) Dow 170A
- PS (1.5 MI) Dow Styron 685D

Experimental Procedure

Each of the four resins was extruded with the same low compression barrier screw design, with three different barrel temperature profile settings. Resin was processed with the feedstock at ambient temperature, and also preheated to 65°C.

For each test, the barrel, screw, screen pack, and die were completely cleaned. The die and barrel were pre-heated for one hour prior to each output test. Steady thermal conditions were then assumed to prevail throughout each of the eight twenty-four minute tests, for each resin tested. The feed block temperatures were kept between 40°-42° C for each of the resins run in this study.

The four resins were run under three different barrel temperatures profile settings. The first barrel temperature profile used was a “flat” type barrel temperature profile, meaning all the four barrel zones were set at the same temperature, along with the single die zone. The second barrel temperature profile that was used was a “ramped” type barrel temperature profile, meaning the barrel temperature settings increased from the feed section out to the die zone. The third barrel temperature profile used was a "hump" type barrel temperature profile, meaning the barrel temperature settings were cooler at ends of the barrel, the feed section and discharge sections; and hotter in the middle barrel zones. See Chart 1 for the barrel temperature profiles run on each particular resin. Note, that the same barrel temperature profile settings were also run on the 65 C resin preheat temperature feedstock, as well as the ambient temperature resin feedstock.

Each resin test included screw speeds of 25, 50, 75, and 100 rpm. Three one-minute ribbon samples were taken at each screw rpm, and then averaged, to calculate a total screw output rate. The barrel pressure immersion probes, screw speed and hydraulic motor pressures, used to calculate motor power requirements; were all monitored and recorded at one-second intervals on the NetDAQ. The same above procedure was also used for all the preheated resin runs.

All the data were then extracted from the NetDAQ and compiled with a spreadsheet program.

Presentation of Data and Results

Regarding the HDPE trials with ambient temperature resin feedstock: The hump type barrel temperature profile had a greater output at 50, 75 and 100 screw rpm than the ramped and flat barrel temperature profiles. The ramped type barrel temperature profile had the poorest output across all the four screw speeds recorded. See Figure 2 for the HDPE screw outputs at ambient temperature.

Regarding the HDPE trials with a 65°C resin preheat: The hump type barrel temperature profile had more output at 75 and 100 screw rpm than the ramped and flat barrel temperature profiles. The output was the same at 50 screw for both the humped and flat temperature profiles. The output for the hump and flat were greater at all screw speeds as compared to the ramped barrel temperature profiles for the preheated HDPE. The screw output was greater across most of the screw speeds for the preheated HDPE trials as compared to the ambient temperature trials. See Figure 3 for the HDPE screw outputs for the 65°C resin preheat temperature.

The axial barrel pressure profiles for HDPE at 50 and 100 screw rpm, for ambient temperature feedstock are shown in Figure 4. The HDPE trials also had on the average a greater output per Kw, for all the barrel temperature profiles, on the preheated runs versus the ambient temperature runs at 100 screw rpm, as shown in Figures 14 and 15.

Regarding the PP trials with ambient temperature resin feedstock: The hump type barrel temperature profile had a greater kg/hr output at 50, 75 and 100 screw rpm than the ramped and flat barrel temperature profiles. The ramped type barrel temperature profile had the poorest output across all the four screw speeds recorded. See Figure 5 for the PP screw outputs at room temperature.

Regarding the PP trials with a 65°C resin preheat: The hump type barrel temperature profile had more output at 50, 75, and 100 screw rpm than the ramped and flat barrel temperature profiles. The output was the same at 25 screw for both the humped and flat profiles. The output for the hump and flat were greater at all screw speeds as compared to the ramped barrel temperature profiles for the preheated screw trials. The screw output was greater across all screw speeds for the preheated PP trials as compared to the ambient temperature trials. See Figure 6 for the PP screw outputs for the 65° C resin preheat temperature.

The axial barrel pressure profiles for PP at 50 and 100 screw rpm, for ambient temperature feedstock, are shown in Figure 7. The PP trials also had on the average about the same output per kW on the room temperature runs, for all barrel temperature profiles, versus the preheated runs, at 100 screw rpm, as shown in Figures 14 and 15.

Regarding the LDPE trials with ambient temperature resin feedstock: All the barrel temperature profiles, flat, ramped, and the hump; had equal output all four screw rpm, in both the ambient temperature trial and the 65° C preheated trials. The preheated resin trial had slightly more output across the entire screw speed range, than the ambient temperature trial. See Figures 8 and 9.

The axial barrel pressure profiles for LDPE at 50 and 100 screw rpm, for ambient temperature feedstock, are shown in Figure 10. The LDPE trials also had a higher on average output per kW on the room temperature runs, for all barrel temperature profiles, versus the preheated runs, at 100 screw rpm, as shown in Figures 14 and 15.

Regarding the PS trials with ambient temperature resin feedstock: The hump and flat type barrel temperature profiles had the same output across all four screw speed ranges. The flat and hump profile also had more output than the ramped barrel temperature profile. The ramped type barrel temperature profile had a lower output at 50, 75, and 100 screw rpm. See Figure 11 for the PS screw outputs at ambient temperature.

Regarding the PS trials with a 65°C resin preheat: The hump and flat type barrel temperature profile had more output at 50, 75 and 100 screw rpm than the ramped barrel temperature profiles. The output was the same at 25 screw for both the humped and flat profiles. The screw output was greater at 50, 75, and 100 screw rpm for the preheated PS trials as compared to the ambient temperature trials. See Figure 12 for the PS screw outputs for the 65°C resin preheat temperature.

The axial barrel pressure profiles for PS at 50 and 100 screw rpm, for ambient temperature feedstock are shown in Figure 13. The PS trials also had on the average a greater output per kW, for all the barrel temperature profiles, on the preheated runs, versus the ambient temperature runs.

Discussion of Data and Results

Screw outputs were affected significantly according to the barrel temperature profile being run with HDPE, PP, and PS resins, on the same barrier type screw design. The LDPE resin was the only resin that was not affected by the different barrel temperature profiles that were run in this study. The hump and flat barrel temperature profiles had the greater outputs over the ramped profiles, with the hump type barrel temperature profile achieving the best output results on the PP and HDPE trials. The differences in output was not significant between the flat and hump profiles when running the PS. Screw outputs were also greater running the 65°C preheat temperature for all barrel temperature profiles when running HDPE, PP, PS, and LDPE, over the ambient temperature feedstock.

The Kg/hr/kW were up when running went up when running the 65°C preheated HDPE and PS. The Kg/hr/kW for PP remained about the same when comparing the room temperature trials and the preheat trials. The LDPE showed a decrease in Kg/hr/Kw in the preheat data as compared to the ambient temperature data.

Screw pressure profile generation, for the hump type barrel temperature profile was measured to be greater in the feed end of the barrier screw, indicating better solids conveying and screw output, for HDPE, PP, and PS.

Conclusions

1. A hump type barrel temperature profile will yield greater screw output, on low compression barrier screw designs, when running HDPE, PP, and PS by increasing coefficient of friction between the barrel wall and the resin early in the feed section of the screw. The screw pressure profile charts in this study confirmed this.

2. Resins preheat temperatures for HDPE, PP, and PS will yield greater output per kW of the drive, over ambient temperature resin in this study.

3. Modified barrel temperature profiles may be needed to improve the overall output and feeding for the particular resin being extruded.

4. Proper temperature profile will also reduce screw and barrel wear.

References

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2. W. Smith, L. Miller, T. Womer, R. Sickles, *An Experimental Investigation Into Solids Feeding Characteristics of a Single Piece barrel Vs a Two Piece Barrel Configuration,* ANTEC 2007
3. C. Chung, *Extrusion of Polymers*, Hanser Publishers, NY, 2000
4. Z. Tadmor and I. Klein, *Engineering Principles of Plasticating Extrusion*, Reinhold, NY, 1970

Material = HDPE					
Trial Type	Zone 1	Zone 2	Zone 3	Zone 4	Die 1
1A - Flat Profile	182	182	182	182	182
2A - Ramped Profile	166	171	177	182	182
3A - Hump Profile	177	216	199	182	182

Material = PP					
Trial Type	Zone 1	Zone 2	Zone 3	Zone 4	Die 1
1A - Flat Profile	193	193	193	193	193
2A - Ramped Profile	177	182	188	193	193
3A - Hump Profile	191	232	218	193	193

Material = LDPE					
Trial Type	Zone 1	Zone 2	Zone 3	Zone 4	Die 1
1A - Flat Profile	182	182	182	182	182
2A - Ramped Profile	166	171	177	182	182
3A - Hump Profile	177	216	199	182	182

Material = PS					
Trial Type	Zone 1	Zone 2	Zone 3	Zone 4	Die 1
1A - Flat Profile	199	199	199	199	199
2A - Ramped Profile	182	188	193	199	199
3A - Hump Profile	188	221	210	199	199

Chart 1-Processing Temperatures

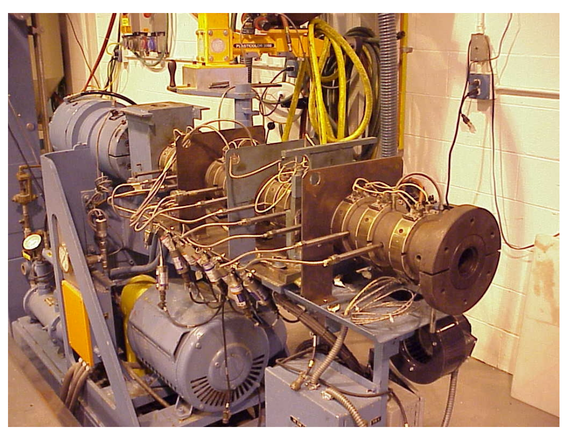

Figure 1-50.8mm x 25:1 Topflight Extruder

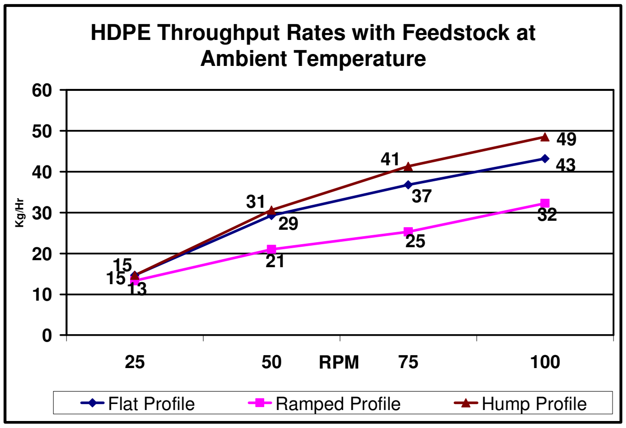

Figure 2: Throughput Rates of HDPE at Ambient Temperature

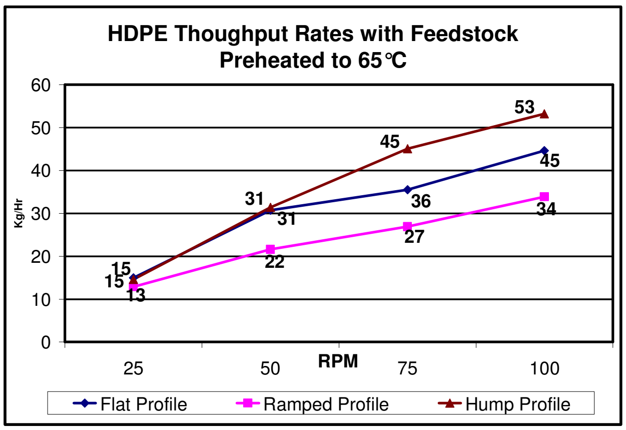

Figure 3: Throughput Rates of HDPE Preheated to 65°C

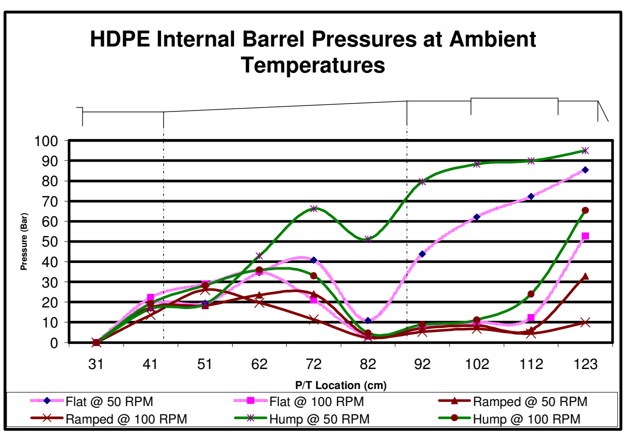

Figure 4: HDPE Internal Barrel Pressures at Ambient Temperatures

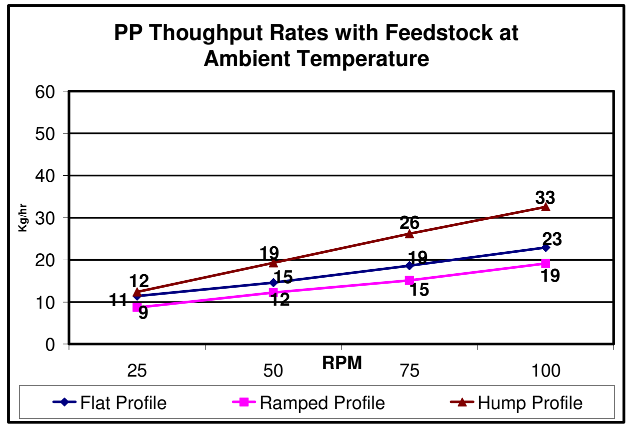

Figure 5: Throughput Rates of PP at Ambient Temperature

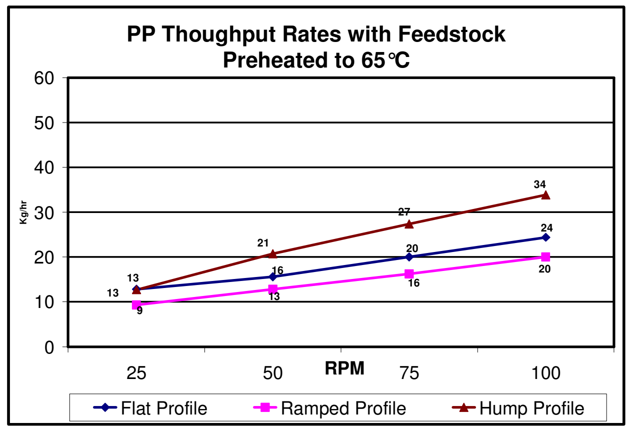

Figure 6: Throughput of PP Preheated to 65°C

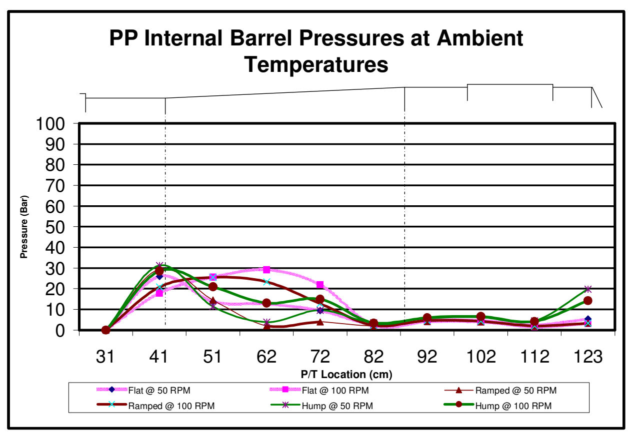

Figure 7: PP Internal Barrel Pressures

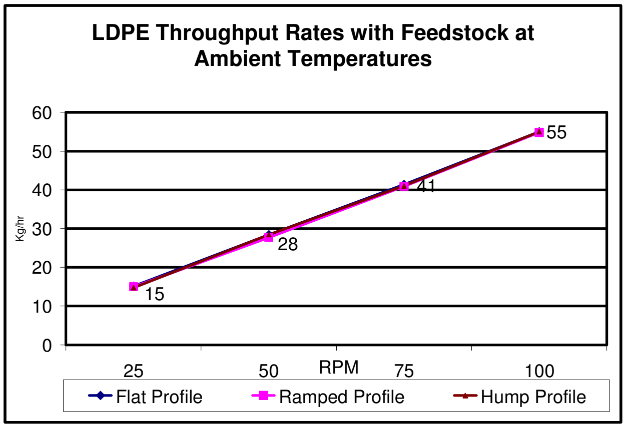

Figure 8: LDPE Throughput Rates with Feedstock at Ambient Temperature

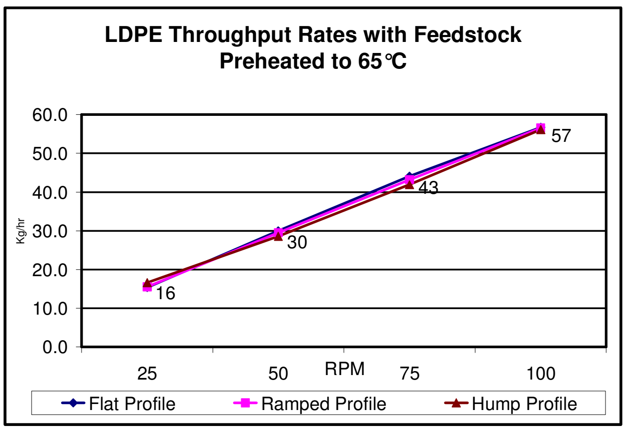

Figure 9: LDPE Throughput Rates with Feedstock Preheated to 65°C

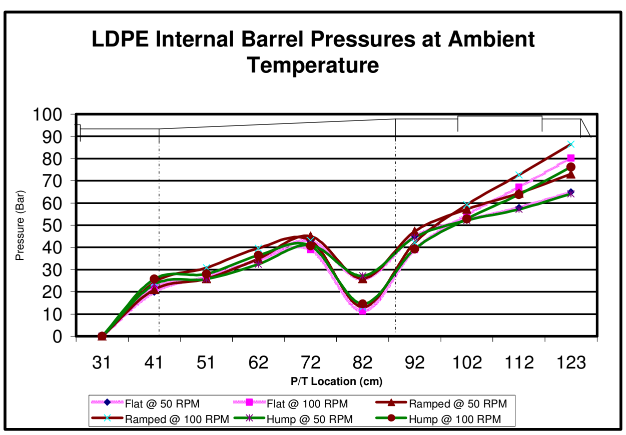

Figure 10: LDPE Internal Barrel Pressures

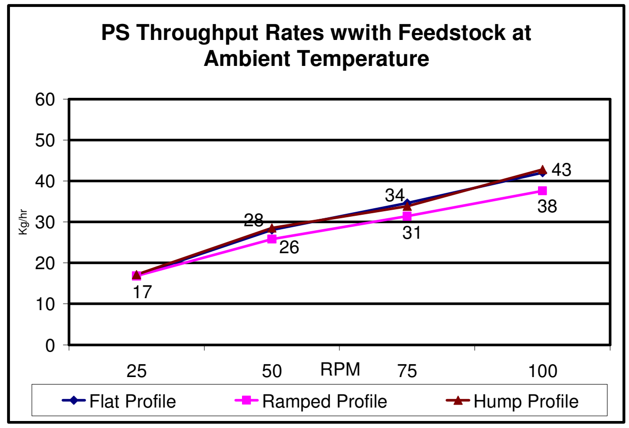

Figure 11: PS Throughput Rates with Feedstock at Ambient Temperature

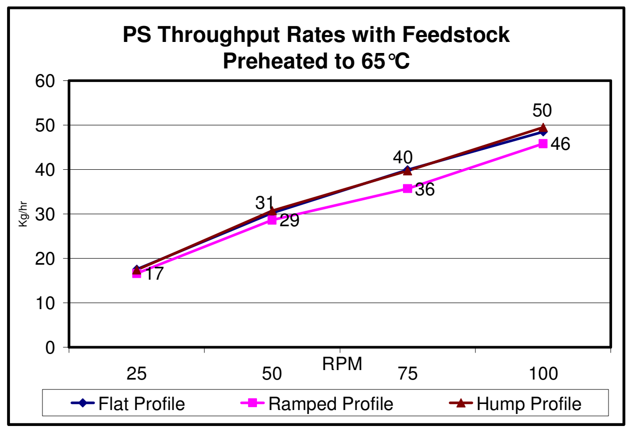

Figure 12: PS Throughput Rates with Feedstock Preheated to 65°C

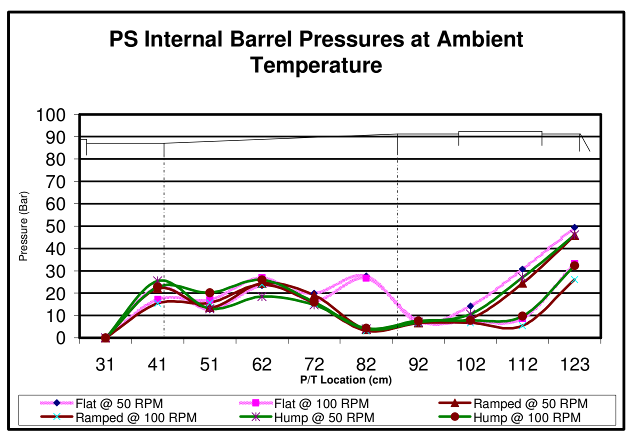

Figure 13: PS Internal Barrel Pressures

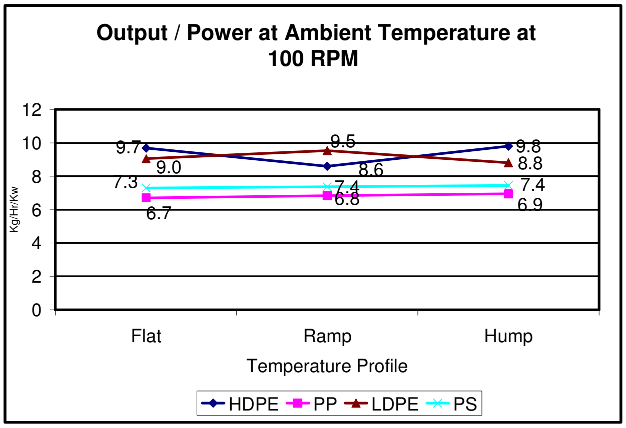

Figure 14: Output / Power at Ambient Temperature at 100RPM

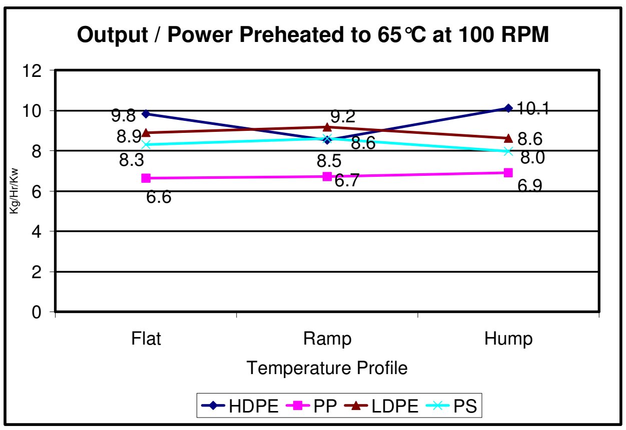

Figure 15: Output / Power Preheated to 65° Temperature at 100RPM