BNL- 63712
INFORMAL REPORT

THERMOPLASTIC ENCAPSULATION OF WASTE SURROGATES BY HIGH-SHEAR MIXING

P.R. Lageraaen
P.D. Kalb
B.R. Patel

DECEMBER 1995

Prepared by
Environmental & Waste Technology Center
Department of Advanced Technology
Brookhaven National Laboratory
Upton, NY 11973-5000

Prepared for
U.S. Department of Energy
Strategic Environmental Research and Development Program
and
U.S. Environmental Protection Agency
SERDP Project 387-EPA
Contract No. DE-AC02-76CH00016

ABSTRACT

Brookhaven National Laboratory (BNL) has developed a robust, extrusion-based polyethylene encapsulation process applicable to a wide range of solid and aqueous low-level radioactive, hazardous and mixed wastes. However, due to the broad range of physical and chemical properties of waste materials, pretreatment of these wastes is often required to make them amenable to processing with polyethylene. As part of the scope of work identified in FY95 "Removal and Encapsulation of Heavy Metals from Ground Water," EPA SERDP#387, that specifies a review of potential thermoplastic processing techniques, and in order to investigate possible pretreatment alternatives, BNL conducted a vendor test of the Draiswerke Gelimat (thermokinetic) mixer on April 25, 1995 at their test facility in Mahwah, NJ. The Gelimat is a batch operated, high-shear, high-intensity fluxing mixer that is often used for mixing various materials and specifically in the plastics industry for compounding additives such as stabilizers and/or colorants with polymers.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Brookhaven National Laboratory (BNL) has developed a robust, extrusion-based polyethylene encapsulation process applicable to a wide range of solid and aqueous low-level radioactive, hazardous and mixed wastes. However, due to the broad range of physical and chemical properties of waste materials, pretreatment of these wastes is often required to make them amenable to processing with polyethylene. As part of the scope of work identified in FY95 "Removal and Encapsulation of Heavy Metals from Ground Water," EPA SERDP#387, that specifies a review of potential thermoplastic processing techniques, and in order to investigate possible pretreatment alternatives, BNL conducted a vendor test of the Draiswerke Gelimat (thermokinetic) mixer on April 25, 1995 at their test facility in Mahwah, NJ. The Gelimat is a batch operated, high-shear, high-intensity fluxing mixer that is often used for mixing various materials and specifically in the plastics industry for compounding additives such as stabilizers and/or colorants with polymers.

Test objectives were to gauge the success of this process for mixing different waste materials with thermoplastics and to produce a molten product that can either be discharged directly into a waste container or can be fed to an extruder. In the latter case, the extruder would serve to further mix the materials, act as a melt pump for processing the materials through a die, and to create a continuous encapsulation process. For this test, a series of surrogate wastes including mixed incinerator ash, hearth ash, nitrate salts, sawdust and wood chips were mixed with pelletized virgin and recycled low-density polyethylene (LDPE), recycled flake high-density polyethylene (HDPE), recycled flake poly(ethylene terephthalate) (PET), or a combination of these polymers.

1. BACKGROUND

The BNL polyethylene encapsulation process utilizes a versatile, single-screw plastics extruder to melt and homogeneously mix waste materials with polyethylene. The molten mixture is then pumped through a die into a waste form container. Due to the inherent thermoplastic properties of polyethylene, cooling of the melt results in a solid monolithic waste form in which waste contaminants have been completely surrounded by a polymer matrix, i.e., microencapsulated. This process has been shown to be applicable to a wide range of waste types including aqueous evaporator concentrates (nitrates, sulfates, borates, chlorides, etc.), sludges, incinerator fly and bottom ash, contaminated soils, molten salt oxidation salt residuals, and ion exchange resins. However, many wastes require pretreatment to make them amenable to extrusion. This often includes drying for volume reduction and to remove residual moisture, and grinding to reduce particle size. Even with pretreatment, some waste materials are difficult to process with highly viscous molten polymers due to particle size, particle size distribution and/or density. For these materials, alternate processing techniques to extrusion or alternate processes that can be used in conjunction with extrusion are desired.

The use of extrusion for waste encapsulation is similar to routine compounding applications established in the plastics industry. The mixing or compounding of materials with polymers can be accomplished using extrusion, continuous mixing, and/or batch mixing. Each of these are proven technologies with merits for particular processing applications[1]. A high-intensity batch mixer was tested to assess its ability to mix various waste surrogates with several types of virgin and recycled thermoplastics. Test results will indicate if thermokinetic mixers may have application in conjunction with the BNL polyethylene encapsulation process or as a stand-alone waste encapsulation technique. When coupled with extrusion processing, the batch mixer would premix difficult to process waste materials with the thermoplastics, then discharge the molten plug into the extruder feed throat which would, in turn, further homogenize the mixture and continuously pump the material through a die.

High-intensity mixers operate with a powerful drive that is magnetically clutched to a single rotor mounted with staggered blades. The rotor revolves at high speeds (tip speeds up to 45 meters/sec) and produces a fast-paced mixing action resulting in thermokinetic heating of the batch without the use of an external heat source. Material impingement against the blades and the chamber wall provides the necessary mixing and dispersion of ingredients.

2. MATERIALS DESCRIPTION

2.1 Waste Surrogates

The wastes tested included surrogates of natural xanthate sorbents, hearth ash, nitrate salts and mixed incinerator ash obtained from the American Re-Fuel Incinerator located in Hempstead, NY. Sawdust and wood chips were used as the surrogates for xanthates which are natural sorbents currently being studied for the removal of heavy metals from groundwater. Hearth ash, retrieved from a household wood burning stove, is a surrogate for radioactively contaminated hearth ash resulting from the burning of wood contaminated by the Chernobyl nuclear accident. The nitrate salt surrogate was prepared at BNL and represents a high volume aqueous mixed waste generated at DOE's Rocky Flats Plant, Golden, CO. Nitrate salt surrogate composition data is shown in Table 1. The salt surrogate was previously formulated as an aqueous solution containing 35 weight percent solids and was dried in a rotary vacuum dryer to less than one percent moisture. The dried product was passed through a grinder to achieve a particle size distribution ranging from 250 to 2400 μm.

Table 1. Composition of nitrate salt surrogate used during thermokinetic mixer feasibility test

Compound	Formula	Target Composition
Sodium nitrate	$NaNO_3$	37.3
Potassium chloride	KCl	31.6
Sodium sulfate	Na_2SO_4	17.7
Calcium carbonate	$CaCO_3$	6.2
Sodium fluoride	NaF	5.2
Magnesium chloride	$MgCl_2$	2.0

2.2 Polymers

A number of thermoplastics, including both virgin and recycled resins, were obtained for this vendor test. The BNL encapsulation process has, to-date, focused on using an injection molding grade of virgin LDPE for waste solidification. However, a new initiative is focusing on determining the feasibility of using various grades of recycled resin for waste encapsulation. It is important to note that because of the broad range of rheological properties which vary with type and grade of plastic, substituting different polymers will impact encapsulation processing conditions. This is further complicated when considering recycled resins which are often heterogeneous, comprise a mixture of different resin grades, and contain additives such as colorants, fillers and/or stabilizers. Additives used to achieve particular characteristics for new plastic products will affect melt flow properties during reprocessing. Since processing parameters are dependent upon both the polymer and waste properties, it is necessary to conduct treatability studies to optimize processing conditions for different polymer and waste material combinations.

The recycled resins used during this vendor test were provided by plastic recyclers, as shown in Appendix A-1. The recycled LDPE was pelletized and co-mingled with a lesser quantity of linear low-density polyethylene (LLDPE). The actual mass fraction of LDPE and LLDPE was not known. The recycled PET was flaked and clear in color. The recycled HDPE was flaked detergent bottles in many colors, primarily different shades of blue and red.

3. EQUIPMENT DESCRIPTION

The Gelimat high-speed mixer tested is a one liter vessel consisting of a horizontal chamber with a central rotating shaft and staggered mixing blades at various angles. The shaft is driven by a magnetically clutched 30 hp motor that allows for nearly instantaneous engagement/disengagement. Although the mixer motor runs continuously, the rotor is protected with a safety interlock that ensures the charge and discharge ports are closed. Engaging and disengaging the rotor is accomplished by a remote control panel. The high speeds of the rotor (tip speed up to 45 m/sec) produce a fast-paced mixing action, short batch cycles, and kinetic heating of the batch materials. External heaters are not required, as the intense shearing converts mechanical energy into frictional heat in a thermokinetic heating process. Mixing and dispersion occurs as particles impact with the vessel walls, the rotor blades or with each other. This laboratory unit processed 150-250 gram batches in 20-40 seconds depending on the material properties.

4. PROCEDURE

Appropriate quantities of polymer and waste materials were pre-weighed to the desired waste loading, combined together and added to the mixing vessel through a top mounted charge port. For each run, the residence time and temperature were recorded. The temperature was monitored with a thermocouple that was mounted on the inside wall surface. The residence time was recorded by the operator who stopped and discharged each batch based on the sound emanating from the mixer and on previous experience with similar materials. A characteristic sound was heard when fluxing of the materials occurred. The processing time could also be determined by monitoring the wall temperature inside the mixer. The temperature initially remained at a constant value during the beginning of each cycle but then rapidly increased as the polymer melted and mixed with the waste material. When the temperature exceeded the polymer's melting point, the rotating shaft was disengaged and the molten materials were discharged onto a steel tray. The molten plug was then scooped into a 12.7 cm x 12.7 cm x 5.1 cm (5 in x 5 in x 2 in) mold and placed under a pneumatic compression press set to 95 psi. The product samples were maintained under compression for a short time (1-2 minutes), then released from the mold and allowed to cool in a water bath. Batch sizes ranged from 160 - 200 grams and produced mold samples with approximate dimensions of 12.7 cm x 12.7 cm x 2.0 cm (5 in x 5 in x 0.75 in).

5. RESULTS

A summary of the process data recorded during the vendor test is shown in Table 2. The experiments were sequenced by varying the type of binder and the waste-to-binder material ratio for each of the waste surrogates. A pure batch of polymer was processed between new waste/binder combinations in order to ensure that the mixing vessel was clean. Batch times ranged between 14-159 seconds and averaged 31 seconds for all runs conducted.

Sawdust was mixed with either virgin low-density polyethylene (VLDPE), recycled low-density polyethylene (RLDPE), recycled high-density polyethylene (RHDPE) or recycled poly(ethylene terephthalate) (RPET) for Batches 1-17. Surrogate waste loadings of 40, 50, 60, 65 and 70 weight percent sawdust with VLDPE were achieved. Higher sawdust loadings resulted in processing difficulties. Product from batches containing ≥60 wt% sawdust was flakey and the sawdust did not appear to be completely encapsulated. By comparison, a maximum waste loading of 50 wt% was achieved using a single-screw extruder at BNL. The low density of sawdust, approximately half the density of polyethylene, resulted in much larger volumes of sawdust than polyethylene on a weight basis. At higher loadings, the extruder was limited by insufficient polyethylene to convey the sawdust through the barrel. The kinetic mixer, on the other hand, was able to process higher loadings compared to extrusion but was ultimately limited by the ability of polyethylene to effectively wet and encapsulate the larger volume of sawdust.

Sawdust and wood chips are surrogates for xanthates which are currently being investigated under the EPA SERDP#387 as a sorbent material to remove heavy metals from ground water. Thermoplastic encapsulation is being investigated for solidification of these sorbents to minimize leaching of contaminants and provide long term stability under disposal conditions. The xanthates will be used as a column packing material through which contaminated water will be passed. As a result, sorbents contain a high degree of moisture that must be removed for successful extrusion processing. Experimental Batches 7 and 8 were conducted to ascertain the mixer's ability to tolerate waste streams with a high moisture content. All the water added for these batches was sorbed by the sawdust. Batch 7 contained 10% water (based only on the weight of sawdust, not the total batch weight) added to a 200 gram batch containing 60wt% sawdust/40 wt% VLDPE. Thirty percent water was added to a 200 gram batch containing 50wt% sawdust/50wt% VLDPE in Batch 8. The added water did not affect processing and in both trials produced a well-mixed final sample similar in appearance to previous dry samples at the same waste loading. Steam evolved during the processing cycle was vented through a pressure relief valve.

Two Batches (10 and 11) were processed with sawdust and RLDPE at a 50 wt% loading, chosen based on the success of processing sawdust with VLDPE at this waste loading. The product sample from Batch 10 did not appear to be well mixed and homogeneous. As a result, the blade speed was increased from 4800 to 6000 rpm for Batch 11 in an effort to achieve improved mixing. No observable improvements were found as both samples consisted of clearly visible areas of high polymer concentration. The RLDPE did not mix as well with the sawdust as the VLDPE, probably due to a higher melt viscosity (lower melt index) of the recycled material

Table 2. Summary of experiments conducted during Gelimat vendor test

RUN	POLYMER	WT%	WASTE	WT%	%WATER	BATCH WT. (g)	CYCLE (sec)	TEMP. (C)	RPM'S
1	VLDPE①	100	NA	NA	NA	180	17.3	134	4800
2	VLDPE	60	sawdust	40	NA	160	30.6	195	4800
3	VLDPE	50	sawdust	50	NA	160	35.4	215	4800
3a	VLDPE	50	sawdust	50	NA	160	34.8	210	4800
4	VLDPE	40	sawdust	60	NA	160	38.1	229	4800
5	VLDPE	30	sawdust	70	NA	160	43.3	211	4800
6	VLDPE	35	sawdust	65	NA	160	39.1	235	4800
7	VLDPE	40	sawdust	60	10	200	54.7	160	4800
8	VLDPE	50	sawdust	50	30	200	49.5	248	4800
9	RLDPE②	100	NA	NA	NA	160	36.0	256	4800
10	RLDPE	50	sawdust	50	NA	200	80.0	230	4800
11	RLDPE	50	sawdust	50	NA	200	30.0	284	6000
12	RHDPE③	100	NA	NA	NA	160	18.6	2??	6000
13	RHDPE	60	sawdust	40	NA	200	32.8	271	4800
14	RHDPE	60	sawdust	40	NA	200	26.2	280	5400
15	RPET④	100	NA	NA	NA	160	22.7	239	5400
16	RPET	100	NA	NA	NA	160	14.0	308	5400
17	RPET	60	sawdust	40	NA	200	31.8	296	5400
18	VLDPE	100	NA	NA	NA	160	16.4	205	5400
19	VLDPE	60	wood chips	40	NA	200	21.7	162	5400
20	VLDPE	50	wood chips	50	NA	200	29.5	227	5400
21	VLDPE	40	wood chips	60	NA	200	31.5	259	5400
22	RHDPE	100	NA	NA	NA	160	25.7	337	5400
23	RHDPE	60	wood chips	40	NA	200	44.5	294	5400
24	VLDPE	100	NA	NA	NA	160	17.6	184	5400
25	VLDPE	50	hearth ash	50	NA	200	14.0	220	5400
26	VLDPE	40	hearth ash	60	NA	200	14.1	212	5400
27	VLDPE	30	hearth ash	70	NA	200	18.3	234	5400
28	VLDPE RHDPE	15 15	hearth ash	70	NA	200	22.7	373	5400
29	RLDPE RHDPE	20 20	hearth ash	60	NA	200	18.3	286	5400
30	VLDPE	40	incinerator ash	60	NA	200	16.2	232	5400
31	VLDPE	30	incinerator ash	70	NA	200	17.2	238	5400
32	VLDPE RLDPE	20 20	incinerator ash	60	NA	200	15.3	259	5400
33	VLDPE RHDPE	20 20	incinerator ash	60	NA	200	22.0	374	5400
34	VLDPE	100	NA	NA	NA	160	15.9	171	5400
35	VLDPE	100	NA	NA	NA	160	14.0	153	5400
36	VLDPE	40	nitrate salt	60	NA	200	11.1	173	5400
37	VLDPE	40	nitrate salt	60	42	200	159.0	252	5400

①VLDPE: virgin low-density polyethylene; ②RLDPE: recycled low-density polyethylene
③RHDPE: recycled high-density polyethylene; ④RPET: recycled poly(ethylene terephthalate)

than that of the virgin polyethylene. The actual melt flow index (MFI) for RLDPE was not given by the supplier.

Batches 13 and 14 were processed with 40wt% sawdust/60wt% RHDPE at 4800 rpm and 5400 rpm, respectively. The mold samples were not homogeneously mixed, similar to the results for sawdust with RLDPE. Areas with high concentrations of polymer were clearly visible. The MFI for RHDPE, provided by the supplier, was 0.55 g/10 min. This is significantly lower than the MFI for the virgin polyethylene (i.e., is a more viscous melt) and explains why the RHDPE can not "wet" the sawdust as well as the VLDPE. A higher rotor speed or using a combination of RHDPE with a lower melt viscosity polymer may yield better results.

Processing RPET with 40 wt% sawdust (Batch 17) was not successful due to PET's higher melt temperature of approximately 220-250°C. Attaining this temperature during the batch experiment caused the sawdust to burn. This was observed on the inside of the mold sample after cutting the sample in half. The interior contained numerous voids, had a burnt odor and was similar in texture to a blackened styrofoam material.

Wood chips were successfully processed with VLDPE at waste loadings of 40, 50, and 60 wt% (Batches 19-21). Samples containing 60 wt% wood chips appeared to be more thoroughly and homogeneously encapsulated than the samples produced with 60 wt% sawdust. The wood chips were approximately the size of toothpicks but also contained some thicker, and longer pieces (up to 10 cm). The rotor blades were able to effectively shred the chips into smaller uniform lengths (approximately 1 cm), which can be easily seen in the final samples. Successful extrusion processing would require pretreating the wood chips to reduce the particle size. The kinetic mixer can tolerate a broader particle size range due to the high intensity mixing.

A waste loading of 40 wt% wood chips with RHDPE (Batch 23) did not produce a well mixed product. The results are similar to those obtained for mixtures of RHDPE and RLDPE with sawdust. The final sample reveals areas with high concentrations of wood chips and polymer. The performance of the recycled resins with sawdust and wood chips is dependent on the high melt viscosity of these resins under shear in the mixer.

Hearth ash was successfully mixed with VLDPE at waste loadings of 50, 60 and 70 wt% (Batches 25-27). Although the molten product was completely black, all samples appeared to be homogeneous, even at 70 wt%. Various blends of recycled resins as well as combinations of recycled resins with virgin polyethylene were mixed with hearth ash. A combination of 70 wt% hearth ash, 15 wt% VLDPE and 15 wt% RHDPE produced a well mixed product (Batch 28). The sample warped following removal from the mold, possibly due to the excessive temperature (373°C) attained during this run. A combination of 60 wt% hearth ash, 20 wt% RLDPE and 20 wt% RHDPE (Batch 29), also produced a well mixed product. Overall, the hearth ash was successfully mixed and encapsulated with VLDPE, and mixtures of VLDPE/RHDPE and RLDPE/RHDPE.

Similar to the results for hearth ash, mixed incinerator ash was successfully processed at waste loadings of 60 and 70 wt% with VLDPE, at 60 wt% with 20wt% VLDPE/20wt% RLDPE, and at 60 wt% with 20wt% VLDPE/20wt% RHDPE (Batches 30-33). All product samples molded readily and appeared well mixed. The incinerator ash was sieved at BNL prior to the vendor test for all particles greater than 2.380 mm primarily to remove nails, staples and other large fragments. This ash has been successfully processed at BNL by extrusion at waste loadings up to 70 wt%.

For Batches 36 and 37, the nitrate salt surrogate was mixed with VLDPE at a waste loading of 60 wt%. The salt was evenly distributed and appeared well mixed in the final mold sample. This surrogate has also been successfully processed by extrusion at this loading. Although starting with the same surrogate, the particles in the mold sample following processing in the kinetic mixer appear smaller than those in final waste forms generated by extrusion. As with the wood chips, the mixer apparently reduces the particle size of the waste material during mixing. For Batch 37, the salt surrogate was dissolved by adding 42% water to the mixture of 40 wt% VLDPE and 60 wt% nitrate salt. This test was not successful because the mixer was not leak proof, resulting in the majority of the surrogate waste solution dripping through the bottom discharge port. Since the mixer is not leak tight, it can only tolerate a high moisture content when sorbed by the waste materials. "Free" or aqueous liquids will leak from the vessel. However, the vendor representative indicated that the discharge port could be designed to be leak tight.

6. CONCLUSIONS

A high-shear, high-intensity (thermokinetic) mixer was tested and successfully processed a number of waste surrogates with virgin polyethylene, mixtures of virgin polyethylene with recycled high- and low-density polyethylene, and mixtures of recycled high- and low-density polyethylene. The mixer was able to encapsulate sawdust and wood chips with virgin polyethylene and produce a homogeneous product at a waste loading up to 60 wt%. Above this loading, the product became flakey and was not sufficiently encapsulated by the polyethylene. The low density of the wood surrogates limited the maximum attainable waste loading. The hearth and incinerator ashes were successfully processed at loadings up to 70 wt% with virgin polyethylene and 60 wt% with mixtures of virgin and recycled resins. Processing results with recycled polymers alone were not as effective as either recycled-virgin blends or virgin polymers alone. This was most likely due to the higher melt viscosity of the recycled resins, which impedes its ability to "wet" and effectively microencapsulate the waste materials.

Thermokinetic mixers have been proven to encapsulate waste surrogates with polyethylene on a batch basis. Compared with single-screw extrusion, thermokinetic mixing has certain advantages such as being able to process a broader particle size distribution including larger and finer particles and the ability to process wet materials. This would reduce the demand for waste pretreatment but not necessarily eliminate it. For example, pretreatment of the nitrate salt surrogate requires drying to less than two percent moisture and size reduction prior to encapsulation processing by extrusion. Experiments with the thermokinetic mixer show that it can tolerate larger particles than extrusion but may be limited with aqueous wastes. Pretreatment of the nitrate salt surrogate to make it amenable to processing with the high-intensity mixer may only require drying to approximately 20 percent moisture (i.e., a sludge) and limited size reduction. This would reduce the energy costs associated with waste pretreatment.

Two drawbacks of the high-intensity mixer are its batch operation and less precise control over melt and mixing parameters. Coupling of the mixer with a single-screw extruder may minimize limitations associated with each technique and enhance overall process capabilities. The thermokinetic processor can serve as an in-line pre-mixer for the extruder, in which the well-mixed molten product can be fed directly to the extruder feed throat. The extruder would serve to further homogenize the materials, act as a melt pump for processing the materials through a die and create a continuous encapsulation process.

7. REFERENCE

1. Patel, B.R., P.R. Lageraaen, and P.D. Kalb, "Review of Potential Processing Techniques for the Encapsulation of Sorbents in Thermoplastic Polymers," prepared for US DOE and US EPA Strategic Environmental Research and Development Program #387, Brookhaven National Laboratory, BNL-62200, August 1995.

Appendix A-1. Suppliers of recycled resin used during vendor test

Supplier	Resin Type	Resin Form
Mobil Chemical 500 East Superior Jacksonville, IL 62650	LDPE/LLDPE	pellet
Clearvue Resource Management Clearvue Polymers, Inc. Edson Street Industrial Park Box 8 Amsterdam, NY 12010	HDPE	flake
WTE Recycling 136 Fuller Road Albany, NY 12205	PET	flake

Appendix A-2. Laboratory Data Sheets from Vendor Test of Draiswerke Gelimat Kinetic Mixer

Laboratory Test of Draiswerke Gelimat Kinetic Mixer

~~July~~ APRIL 25, 1995

①

Polymer	%	Weight (g)	Waste	%	Weight (g)	% Water	Weight	Residence Time	Temperature	RPM's
VLDPE	100	180 g	NA	—	—	—	—	17.3 sec	134°C	4800

Comments: RUN VLDPE TO CLEAN MACHINE

Too much material to press into our small 2" square mold.

②

Polymer	%	Weight	Waste	%	Weight	% Water	Weight	Residence Time	Temperature	RPM's
VLDPE	60	96 g	SAWDUST	40	64 g	—	—	30.6 sec	195°C	4800

Comments: 160g Total, temp. in mixer stays const. at approx. 80°C for most of the time, then in the last few seconds it shoots up rapidly. David Rice, operator, runs the machine and stops a run based on the noise it makes

③

Polymer	%	Weight	Waste	%	Weight	% Water	Weight	Residence Time	Temperature	RPM's
VLDPE	50	80 g	SAWDUST	50%	80 g	—	—	35.4 sec	215°	4800

Comments: 160g total mix

melt temp. 180°C : temp of molten plug discharged from mixer taken w/ thermocouple

Laboratory Test of Draiswerke Gelimat Kinetic Mixer Paul [illegible]

~~July~~ 25, 1995
APRIL

④

Polymer	%	Weight (g)	Waste	%	Weight (g)	% Water	Weight	Residence Time	Temperature	RPM's
VLDPE	40	64g	SAWDUST	60	96 g	–	–	38.1 sec	229°C	4800

Comments: ≈ ~~71 Amps~~

molten plug = 195°C . use Draiswerke 5×5 mold. This mold w/ approx. 200g of material make a mold sample that is 5'×5"× ≈0.5" thick. This mold sample didn't come out complete, one of the corners was flakey.

③a

Polymer	%	Weight	Waste	%	Weight	% Water	Weight	Residence Time	Temperature	RPM's
VLDPE	50	80	sawdust	50	80	–	–	34.8 sec	210°C	4800

Comments: use larger Draiswerke mold. ~95 or 90 psi compression molder, 5"×5" mold.
Ram is 1.75" diameter

⑤

Polymer	%	Weight	Waste	%	Weight	% Water	Weight	Residence Time	Temperature	RPM's
VLDPE	30	~~[illegible]~~ 48g	Sawdust	70	112g	–	–	43.3 sec	211	4800

Comments: Sample is flakey, ~~and~~ made a poor sample after molding . mold sample has broken and flakey corners

Laboratory Test of Draiswerke Gelimat Kinetic Mixer (RL)
~~July~~ 25, 1995
APRIL

(6)

Polymer	%	Weight (g)	Waste	%	Weight (g)	% Water	Weight	Residence Time	Temperature	RPM's
VLDPE	35	56g	sawdust	65%	104g	—	—	33.1 sec	235°C	4800

Comments: 160g total Temp ~ 99°C then shoots up to 235°C
waste form didn't come out very well. Mold sample is flakey + has broken corners.

(7)

Polymer	%	Weight	Waste	%	Weight	% Water	Weight	Residence Time	Temperature	RPM's
VLDPE	40	80g	SAWDUST	60	120g	10%.	12g	54.7 sec	160°C	4800

Comments: 200g total + 10% moisture (of sawdust only) [12g H_2O], sample should have been run a little longer
mold sample is not complete and has flakey + broken edges and corners.

(8)

Polymer	%	Weight	Waste	%	Weight	% Water	Weight	Residence Time	Temperature	RPM's
VLDPE	50	100g	SAWDUST	50	100g	30%	30g	49.5 sec	248°C	4800

Comments: temp ~ 107°C shot up to 248°C, steam was still evolving before placing in mold. Steam also evolving from mixer (not much though). Very nice mold sample.

50% VLDPE / 50% sawdust makes best sample

Laboratory Test of Draiswerke Gelimat Kinetic Mixer (PL)

~~July~~ 25, 1995
APRIL

(9)

Polymer	%	Weight (g)	Waste	%	Weight (g)	% Water	Weight	Residence Time	Temperature	RPM's
RLDPE	100	160 g	–	–	–	–	–	36.0 sec	256 °C	4800

Comments: 160g total. Temp. 102°C → 256°C

(10)

Polymer	%	Weight	Waste	%	Weight	% Water	Weight	Residence Time	Temperature	RPM's
RLDPE	50	100g	Sawdust	50	100g	–	–	1:20 sec	230 °C	4800

Comments: Sample appeared dry, it didn't seem to mix as well. We'll try another run at a higher rpm. The sample also doesn't appear to be homogeneous.

* Polymer + sawdust are not well-mixed in mold sample.

(11)

Polymer	%	Weight	Waste	%	Weight	% Water	Weight	Residence Time	Temperature	RPM's
~~HDPE~~ RLDPE	~~100%~~ 50	~~100g~~ 100g	Sawdust	– 50%	100g	–	–	30 sec	284 °C	6000

Comments: Temp.

Sample must have burned. Smoke poured from mixer. We could smell the burnt sawdust. The molten sample flowed very well under compression that it formed flash on the bottom of the mold.

* Polymer + sawdust are not well-mixed in mold sample.

Laboratory Test of Draiswerke Gelimat Kinetic Mixer (R)

~~July~~ APRIL 25, 1995

(12)

Polymer	%	Weight (g)	Waste	%	Weight (g)	% Water	Weight	Residence Time	Temperature	RPM's
RHDPE	100	160g	—	—	—	—	—	18.6 sec	2??°C	~~4800~~ 6000

Comments: 160 g total, smoke came from machine (residual soap?) ⇒ sure smelled like it.

(13)

Polymer	%	Weight	Waste	%	Weight	% Water	Weight	Residence Time	Temperature	RPM's
RHDPE	60	120 g	sawdust	40	80 g	—	—	32.8 sec	271 °C	4800

Comments: 200g total. Temp. - 103°C → 271°C

Smoke came from machine, same as before?

*Polymer + sawdust not well mixed in mold sample

(14)

Polymer	%	Weight	Waste	%	Weight	% Water	Weight	Residence Time	Temperature	RPM's
RHDPE	60	120g	sawdust	40	80 g	—	—	26.2 sec	280°C	5400

Comments: 200g total. Temp: 103°C → 280°C, sample appeared flakey prior to testing

*Polymer + sawdust not well mixed in mold sample

Laboratory Test of Draiswerke Gelimat Kinetic Mixer (R)

~~July~~ APRIL 25, 1995

(15)

Polymer	%	Weight (g)	Waste	%	Weight (g)	% Water	Weight	Residence Time	Temperature	RPM's
R PET	100	160 g	—	—	—	—	—	22.7 sec	237 °C	5400

Comments: 160 g. Temp: 110 °C → 237 °C

- Product looks molten, milky white. Should be run a little longer. Compression sample has flakes in it. Motor is more noisay than on other runs. Product sunk in water bucket

(16)

Polymer	%	Weight	Waste	%	Weight	% Water	Weight	Residence Time	Temperature	RPM's
R-PET	100	160 g	—	—	—	—	—	14 sec	308 °	5400

Comments: 160 g. ~~Temp 104~~ → Temp. started increasing immediately.

Product sunk in water bucket.

(17)

Polymer	%	Weight	Waste	%	Weight	% Water	Weight	Residence Time	Temperature	RPM's
R-PET	60	120 g	Sawdust	40	80 g	–	–	31.8 sec	296 °C	5400

Comments: 200 g sample. Product was smokey, cools quickly. Product sample floated in cooling water buckets

Check sample, look for voids on inside.

* After cutting mold sample in half, the interior is full of voids, looks like Bar-None Candy Bar. Similar to foam. It also smells burnt

Laboratory Test of Draiswerke Gelimat Kinetic Mixer (PL)

~~July~~ 25, 1995
APRIL

(18)

Polymer	%	Weight (g)	Waste	%	Weight (g)	% Water	Weight	Residence Time	Temperature	RPM's
V-LDPE	100	160g	—	–	—	—	-	16.4 sec	205°C	5400

Comments: Total wt. 160g.

(19) *

Polymer	%	Weight	Waste	%	Weight	% Water	Weight	Residence Time	Temperature	RPM's
V-LDPE	60	120g	wood chips.	40	80g	–	-	21.7 sec	162°C	5400

Comments: Total. wt. 200g. Product looks well mixed. Wood chips seem to be very well broken up.

* mold sample looks very good

(20)

Polymer	%	Weight	Waste	%	Weight	% Water	Weight	Residence Time	Temperature	RPM's
VLDPE	50	100g	Wood Chips	50	100g	—	-	29.5 sec	227°C	5400

Comments: Total. wt. 200g. Product looks well mixed

* mold sample looks very good

Laboratory Test of Draiswerke Gelimat Kinetic Mixer (PL)

~~July~~ 25, 1995
APRIL

(21)

Polymer	%	Weight (g)	Waste	%	Weight (g)	% Water	Weight	Residence Time	Temperature	RPM's
VLDPE	40	80g	Wood Chips	60	120g	–	–	31.5 sec	259°C	5400

Comments: 200g total; Temp: 105°C → 259°C

* Mold sample looks very good. The mixer worked better when using 60% woodchips than with 60% sawdust.

(22)

Polymer	%	Weight	Waste	%	Weight	% Water	Weight	Residence Time	Temperature	RPM's
R-HDPE	100	160g	–	–	–	–	–	25.7 sec	337°C	5400

Comments: 160g total, clean mixer, product discharged was smokey. Smelled like detergent

(23)

Polymer	%	Weight	Waste	%	Weight	% Water	Weight	Residence Time	Temperature	RPM's
R-HDPE	60	120g	Wood Chips	40	80g	–	–	44.5 sec	294°C	5400

Comments: 200g total, not noisy. Material did not make much noise as it was fluxing. Product was smokey, odor had detergent smell.

* Mold sample is not well-mixed. Areas w/ high concentrations of sawdust are clearly visible

Laboratory Test of Draiswerke Gelimat Kinetic Mixer (PL)

~~July~~ 25, 1995
APRIL

(24)

Polymer	%	Weight (g)	Waste	%	Weight (g)	% Water	Weight	Residence Time	Temperature	RPM's
VLDPE	100	160g	–	–	–	–	–	17.6 sec	184°C	5400

Comments: 160g total, clean mixer for next run.

(25)

Polymer	%	Weight	Waste	%	Weight	% Water	Weight	Residence Time	Temperature	RPM's
VLDPE	50	100g	Hearth Ash	50	100g	–	–	14.0 sec	220°C	5400

Comments: 200g total, Temp. 106°C → 220, prod. sample sunk in H_2O bucket

* mold sample looks good

(26)

Polymer	%	Weight	Waste	%	Weight	% Water	Weight	Residence Time	Temperature	RPM's
VLDPE	40	80g	Hearth Ash	60	120g	–	–	14.1 sec	212°C	5400

Comments: 200g total, Temp: 106 → 212°C. Prod. sunk in H_2O bucket

+ mold sample looks good.

Laboratory Test of Draiswerke Gelimat Kinetic Mixer (R)

~~July~~ 25, 1995
APRIL

(27)

Polymer	%	Weight (g)	Waste	%	Weight (g)	% Water	Weight	Residence Time	Temperature	RPM's
VLDPE	30	60g	Hearth Ash	70	140g	—	—	18.3 sec	234°c	5400

Comments: 200g total, 106°C → 234. Sample sunk in H_2O bucket. No problems processing.
Can probably go higher.
+ mold sample is not complete. One corner is missing, although the sample looks well mixed

(28)

Polymer	%	Weight	Waste	%	Weight	% Water	Weight	Residence Time	Temperature	RPM's
VLDPE RHDPE	15 15	30g 30g	HEARTH ASH	70	140g	—	-	22.7 sec	373°C	5400

Comments: 200g total, 15% VLDPE / 15% RHDPE / 70% Ash.
Prod. was smokey.
+ mold sample is wavy and has bumpy surface. It worked but didn't make a perfect mold sample.

(29)

Polymer	%	Weight	Waste	%	Weight	% Water	Weight	Residence Time	Temperature	RPM's
RLDPE ~~VLDPE~~ RHDPE	20 20	40g 40g	Hearth Ash	60	120g	—	—	18.3	286°c	5400

Comments: 200g total, 106°c → 286°C

+ mold sample looks pretty good. materials seem to be well-mixed.

Laboratory Test of Draiswerke Gelimat Kinetic Mixer

~~July~~ APRIL 25, 1995

(PL)

(30)

Polymer	%	Weight (g)	Waste	%	Weight (g)	% Water	Weight	Residence Time	Temperature	RPM's
VLDPE	40	80g	INCINERATOR ASH	60	120g	—	—	16.2 sec	232°C	5400

Comments: 200g total, 107°C → 232, Prod. is well-mixed

+ mold sample looks great. Materials are well mixed.

(31)

Polymer	%	Weight	Waste	%	Weight	% Water	Weight	Residence Time	Temperature	RPM's
VLDPE	30	60g	INCINERATOR ASH	70	140g	—	—	17.2 sec	238°C	5400

Comments: 106 → 238°C
prod. is well-mixed

+ mold sample looks good + well mixed. Although, one corner is missing

(32)

Polymer	%	Weight	Waste	%	Weight	% Water	Weight	Residence Time	Temperature	RPM's
R-LDPE V-LDPE	20 20	40g 40g	INCIN. ASH.	60	120g	—	—	15.3 sec	259°C	5400

Comments: 107°C → 259°C
200g total

+ mold sample looks great, well-mixed. This worked very well.

Laboratory Test of Draiswerke Gelimat Kinetic Mixer (R)
~~July~~ 25, 1995
APRIL

(33)

Polymer	%	Weight (g)	Waste	%	Weight (g)	% Water	Weight	Residence Time	Temperature	RPM's
R-HDPE V-LDPE	20 20	40 40	INCINERATOR ASH	60	120g	–	-	22.0 sec	374°C	5400

Comments: 200g total.

+ mold sample appears well-mixed but is bent + curvy. This may have been caused by removing ~~it~~ it from the compression molder too soon or by odd cooling behavior of mixtures of HDPE + LDPE.

(34)

Polymer	%	Weight	Waste	%	Weight	% Water	Weight	Residence Time	Temperature	RPM's
VLDPE	100%	160g	–	–	–	–	–	15.9 sec	171°C	5400

Comments: Clean mixer 107→171°C
prod. is slightly dark.

(35)

Polymer	%	Weight	Waste	%	Weight	% Water	Weight	Residence Time	Temperature	RPM's
VLDPE	100	160 g	–	–	–	–	–		153°C	5400

Comments: Clean mixer again. Prod. sample disposed.

Laboratory Test of Draiswerke Gelimat Kinetic Mixer (PL)
~~July~~ APRIL 25, 1995

(36)

Polymer	%	Weight (g)	Waste	%	Weight (g)	% Water	Weight	Residence Time	Temperature	RPM's
VLDPE	40	80g	Nitrate salt	60	120g	—	—	11.1 sec	173°C	5400

Comments: Very quick run. ~~Fast sample disposed~~

salt taken from container labelled batch #7

+ mold sample seems well mixed. In comparison w/ waste forms from extrusion w/ 60 wt% salt, the mixer seemed to break up the salt to a smaller particle size. The extrusion sample seems to have more PE on the surface layer covering any exposed salt.

(37)

Polymer	%	Weight	Waste	%	Weight	% Water	Weight	Residence Time	Temperature	RPM's
VLDPE	40	80g	Nitrate salt	60	120g	42%	50g	2min 33 sec.	252°C	5400

Comments: wet nitrate surrogate, water dripping out bottom.

108°C →

1:45 sec increase rpm to 5950 rpm.

+ mold sample is ok but run didn't work very well.

Polymer	%	Weight	Waste	%	Weight	% Water	Weight	Residence Time	Temperature	RPM's

Comments: