A Magnetic Approach to Multi-Material Plastic Scrap Recovery

by
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To produce the most cost effective designs, leading edge manufacturers and designers are turning to multi-material injection molding, overmolding, profile co-extrusion, sequential 3-D and multi-layer blow molding. Among the many benefits this extraordinary design freedom provides are parts consolidation, consumer appeal, reduced assembly cost, consistent functionality, fewer SKUs, lower inventory costs and the best total cost. However, with the advantages come challenges.

One problem multi-material processors face is separating and recovering valuable mixed resins. With the notable exception of household consumer products, the vast majority of plastic polymers are simply discarded due to a lack of acceptable recycling techniques.

For many years, experts have recognized the need for a solution to the problems with multi-material plastic scrap recovery. Over time, many flawed attempts have been made to better recycle these mixed plastic components. These include, but are not limited to, gravity and electrostatic separation. Limited success has also been achieved in recycling of post consumer waste. Nevertheless, these failed efforts were not brought about from a lack of trying. This led some experts, including those at Eriez Magnetics®, an Erie, Pa.-based world authority in magnetics, vibratory and inspection applications, to begin to look at the plastic itself for the answer, rather than the recycling process.

To produce an effective separation process, Eriez conjectured that it was necessary to re-engineer the plastic to be separated. Using the time-tested method of magnetic separation to reclaim products, Eriez® invented an innovative, new process that involves manipulating the magnetic susceptibility of plastic polymers through the use of additives. In 2005, the company patented this procedure as its *PolyMag® Process.*

The innovative *PolyMag®* magnetic separation process achieves a high degree of separation purity. It has even demonstrated the ability to separate a thin layer of EVOH barrier resin from multi-layer HDPE blow moldings, delivering a clean PE regrind.

Materials

In multi-material molding, Thermoplastic Elastomers (TPEs) are frequently co-molded with other resins to deliver special material characteristics. These unique properties include flexibility, soft touch or non-slip finishes. Prominent examples of these types of products include toothbrushes, appliance knobs, power tool housings, garden tool handles, casters and automotive interior components.

Designers choose TPEs for vital gasket and sealing performance. Applications include pump housings, vinyl windows, automotive cowl vents and HVAC dampers or transportation body and glazing seals. Dual-durometer blow molded air intake ducts are a good example of a product in which both rigid and flexible materials are combined into complicated molded shapes for under-the hood applications.

The market data proves the prevalence and growth of TPEs. Last year, the global market for these Thermoplastic Elastomers was approximately 2.15 million tons with a projected annual growth rate of 6.4%. (1) The transportation segment accounted for 40% to 50% of TPE sales. (2)

Waste Reduction Separation Techniques

The standard method for scrap recovery, currently utilized by the most advanced companies in the world, requires a band saw and extensive manual labor. This costly and contaminant-prone method not only requires a great deal of time, but also places employees at risk of serious injuries. Add to this escalating resin prices and there is a special urgency to recycle these mixed plastic resins.

The development of Eriez' *PolyMag Additive and Process* enables the automated separation of mixed resins. With *PolyMag,* molders can now easily recover their scrap materials, without cross contamination, and use these materials for new parts.

Magnetic Separation

Magnetic separation is an effective, high capacity process that is well suited for separating granular and powder materials. It is based on the ability to attract a particular material exhibiting magnetic susceptibility and then physically segregate it from particles that are non-magnetic or particles that have a different susceptibility. Magnetic susceptibility is an innate property of a material. This is the most important parameter to consider when addressing the characteristics of magnetic separation.

Polymers do not exhibit a natural magnetic susceptibility. Thus, when Eriez® began developing *PolyMag*, company experts knew they had to create a material that incorporated separation characteristics into its design.

It is known that particles subjected to a magnetic field will respond in a particular manner that can be classified in one of four ways: ferromagnetic, paramagnetic, diamagnetic or non-magnetic. Materials that have a very high magnetic susceptibility, and are strongly induced by a magnetic field, are ferromagnetic. Materials that have a low magnetic susceptibility and a weak response to a magnetic field are termed paramagnetic. Materials with a negative magnetic susceptibility are termed diamagnetic and, for all practical purposes, are non-magnetic. Non-magnetic materials do not react to a magnetic field.

Ferromagnetic and, to a lesser degree, paramagnetic materials become magnetized when placed in a magnetic field. The amount of magnetization induced on the particle depends on the mass, magnetic susceptibility and the intensity of the applied magnetic field. The induced magnetization of a particle, M, can be expressed as follows in Figure One:

Figure One

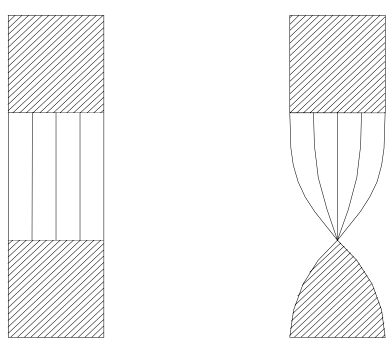
$$M = mXH$$

Where M is the mass of the particle, X is the specific magnetic susceptibility, and H is the applied magnetic field intensity.

A separation process depends upon the ability to make one type of particle move relative to another by applying an external force. In the given case, a magnetic force is applied that is sufficient to move particles of high magnetic susceptibility relative to all of the other material. Similarly, particles exhibiting a low magnetic susceptibility (i.e., paramagnetic materials) can be moved relative to non-magnetic particles. The force acting on the particle must be quantified.

The magnetic force acting on a particle relies upon the induced magnetization, M, and the field gradient. The magnetic field gradient refers to the rate of change or the convergence of the magnetic field strength. In Figure Two, Case A has a uniform pattern of flux lines without gradation. A magnetic particle entering this field will be attracted to the lines of flux and remain stationary without migrating to either pole piece. Case B shows a converging pattern of flux lines displaying a high gradient. As these lines pass through a smaller area, there is a significant increase in the magnetic field intensity. A magnetically susceptible particle entering this field configuration will be attracted to the lines of flux and migrate to the region of highest flux density. This occurs at the tip of the bottom pole piece. In simplified terms, the magnetic field intensity holds the particle while the magnetic field gradient moves the particle.

Figure Two



$\frac{dH}{dx} = 0$ $\qquad$ $\frac{dH}{dx} > 0$

From the earlier equation for magnetization, the magnetic attractive force acting on a particle is the product of the particle magnetization and the magnetic field gradient and can be expressed as:

Figure Three

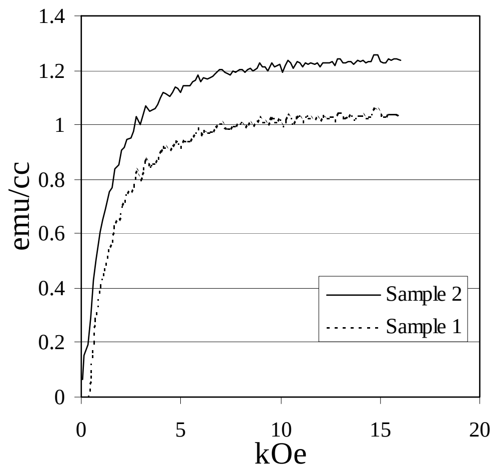
$$Fm = m\chi H \frac{dH}{dx} \text{ or } M \frac{dH}{dx}$$

dH/dx is the magnetic field gradient

For a fixed magnetic field strength and gradient, relative particle motion can only be attained through a difference in magnetic susceptibility. This means that achieving separation of a mixture of polymers requires the susceptibility of one type of plastic be substantially different from the other.

Magnetic susceptibility is determined from the initial slope of the response curve and is reported as emu/cc·kOe. Using this procedure, the response curves for plastics containing different amounts and/or types of additives can be determined. As shown in Figure Four, the magnitude of the susceptibility can be adjusted by varying the amount of additive. Given an appropriate magnetic field and gradient, it is evident that a separation can then be achieved based on the difference in magnetic susceptibilities. The susceptibility can be altered through the addition of magnetic materials at various points in the manufacture of the polymer or the end product.

Figure Four



PolyMag manipulates the magnetic susceptibility of the polymer. It goes right to the basis of the problem by creating a material that encompasses separation characteristics directly into the molding material. The first step is to include the additive, typically at 1% by weight, using a standard additive feeder located below the material hopper. This imparts a low level of magnetic susceptibility to the resin, without materially affecting the molded part properties. The pelletized additives consist of a specially prepared iron oxide or a magnetically susceptible stainless steel and a low molecular weight wax based carrier so it is compatible with a wide range of plastics.

These additives, available in black and light gray colors, are easily pigmented for high appearance applications. Furthermore, the additives have received a favorable review by the FDA for inclusion in food contact plastics.

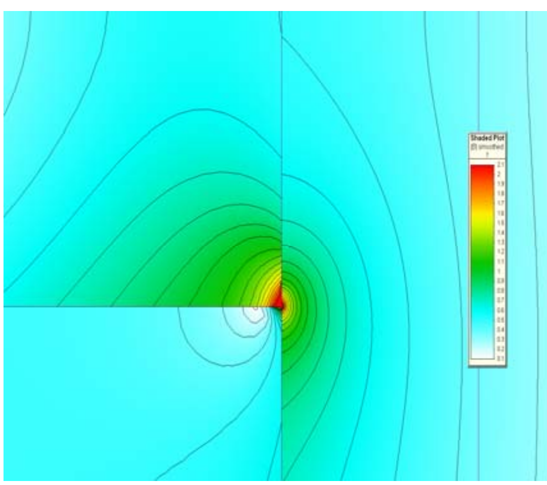
An unexpected use for much higher concentrations of these additives is to impart "metal detectability" into plastic and rubber articles. This allows parts or pieces that can potentially contaminate food products to be detected, located and isolated using standard metal detectors. Mike Mankosa, Eriez' Vice President of Operations, explains "Incorporating the FDA-compliant *PolyMag Additives* enables manufacturers to offer plastic and rubber detectable products that are ideal for food contact applications where product purity and safety is crucial. Examples of such products include gaskets, seals, o-rings, scrapers, gloves, scoops, shovels, spatulas and buckets."

Separation Process

After incorporating the additive in one of the multi-material resins, the mixed resins can be separated by Eriez' extremely powerful *PolyMag* Rare Earth Magnetic Roll Separator. This permanent magnet circuit generates a high gradient with a peak magnetic field strength of 2.4 Tesla (24,000 gauss). Developing a very powerful magnetic roll is critical. This allows the processor to use a very small amount of additive to minimize resin properties changes. Figure Five shows the axisymetric gradient plot of this powerful permanent magnetic roll.

<u>Figure Five</u>

Steel Disc Air

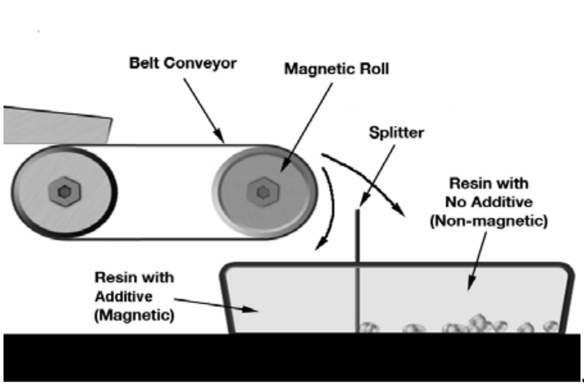


RE Magnetic Disc

In the separation process, scrap that occurs from start-up waste, process variations, sprues and runners, edge trim or design changes is easily ground or pulverized into particles using a standard plastics granulator or pulverizer. The plastic regrind is ready for vacuum conveying and automatically runs through the magnetic separator.

The mixed regrind particles containing the additive are evenly distributed onto a thin (.25mm) Kevlar belt by an electromagnetic vibratory feeder. To obtain optimum separation results, Eriez recommends that users place a shallow or monolayer of the mixed particles on the belt. The belt then carries the mixed particles over the magnetic roll. The regrind without the additive follows its natural trajectory dropping into the front discharge bin of the separator. The particles containing the additive cling to the belt as it passes around the magnetic roll. These particles fall into the rear discharge bin as the belt moves away from the magnetic roll as illustrated in Figure Six

Figure Six



The end result is a high percentage of resin separation--automatically without the cost of salvage labor and the ergonomic risks of cutting, peeling and sawing.

Diverse products and processes have different results, but if the part regrind has distinct particles of each resin, it can be separated with *PolyMag*®. When chemically bonded materials with a high percent of surface contact are used, it may not be possible to completely break apart all of the regrind into the distinct materials using a coarse regrind. To avoid this issue, Eriez suggests using smaller granulator screen openings ranging from 3mm to 8mm to separate the bonded particles. It is also possible to run the material in a two or three roll separator utilizing the lower level of magnetic susceptibility of the bonded particles to deliver exceptional purity.

The process has even demonstrated the ability to remove a 0.1mm EVOH barrier resin from 2.5mm thick multi-layer blow molded containers. In this case the additive was included in the EVOH resin. The trim and scrap was pulverized to liberate the EVOH particles. The separator provided “clean” polyethylene without the diminished weld line strength, gels and the moisture problems of regrind that contains this common barrier resin. This offers the molder substantial resin savings and improved product quality.

Separation Process Variables

The *PolyMag* separator has three basic process variables: vibratory feeder rate, belt speed and the splitter position. A splitter position further from the magnetic roll will result in a higher purity “non-magnetic” fraction, while a position closer to the roll improves the “magnetic” fraction purity. The belt speed is optimized based on the particle size of the regrind or pulverized resins.

The separator also utilizes a static eliminator bar to minimize static cling on the belt. The distance of the eliminator bar above the belt is adjustable to deliver proper functionality with different regrind burden depths.

For applications that demand an especially high level of purity, separators are available with two or three rare earth magnetic rolls, belts and feeders. They are arranged in a cascading fashion to enable automated separation of the particles with varying levels of paramagnetic susceptibility.

The *PolyMag* separator is designed for either centralized or automated press or extruder side operation. For automated machine side operation, scrap is put into a granulator and the regrind is vacuum conveyed to the magnetic separator. The mixed resins are separated and the “clean” regrind is vacuum conveyed to proportioning valves where it is blended with virgin resins. Here, the material is recovered without any salvage labor, and typically used within the same lot of resin. This also offers material consistency and lot traceability.

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John Collins is the market manager for plastics and PolyMag Processing at Eriez in Erie, Pa. Prior to this position, he was manager of the PolyMag Div. Eriez is recognized leader in advanced technology for magnetic, vibratory and metal detection applications. The company’s magnetic lift and separation, metal detection, materials feeding, screening, conveying and controlling equipment have application in the plastics, process, metalworking, packaging, recycling, mining, aggregate and textile industries. For more information, call toll-free in the U.S. and Canada at (888) 300-(ERIEZ) 3743 or (814) 835-6000. For online visitors, go to www.eriez.com or send email to eriez@eriez.com