Novel technology: magnetic fluids that separate plastics II

Bruno van Wayenburg rounds off his 2 part feature outlining a new patent - pending approach to magnetic fluids, which use permanent magnets, and can be applied to applications such as the recycling of plastics and metals, and refining diamonds.

Frustrated

Unlike his Greek colleague, Rem never had his eureka moment, but in 2004 he realised there was another way. Rem calculated a magnetic field with a strength that decreases exponentially as the distance from the magnet increases. This results in an exponential decrease in the attractive force and consequently, a change in effective density, so that each type of material can find its own level of equilibrium in the magnetic liquid. This has the advantage that a large number of components of different densities can be accurately separated from each other in a single process.

Rem calculated a configuration of magnets that would produce such a field. Magnet manufacturers Bakker Magnetics, who specialise in the manufacture of complex magnet systems, then produced the configuration for the research group. Creating the experimental magnet plate was not a simple task. Its main ingredient is a set of extremely powerful permanent iron-neodymium-borium magnets.

"The field strength just above the magnets is 1 tesla, which is pretty strong for a permanent magnet," Rem says. The magnets are mounted in a 'frustrated' configuration, which means that they are out of balance and subject to large forces acting between them. It is a good thing that the whole assembly is covered by a steel plate to protect researchers from being hit by any magnet fragments that may become detached from the main mass. In addition the plate screens the assembly from curious gazes, as the magnet configuration calculated by Rem is a secret.

"Our patent application mentions something like 'any person trained in the art is capable of creating such a field', but in practice it is not quite that simple," Rem admits with a smile.

Test rigs

The only thing left to do at this stage is to construct a working separation plant.

Rem: "The separation principle itself works all right, but the trick is to get the materials into the separator in an orderly and effective fashion, allow them just enough time to get separated, and then extract them without disturbing the separation process."

The speed and size of the machine, and consequently, the cost of the separating process, are crucial elements in an industry processing tonnes of material for just a handful of euros, and having to do it quickly and with the smallest possible plant.

Two test rigs have now been set up. One of these is used to separate metal particles and consists of a conveyor belt running across the magnetic plate. The magnetic liquid (which in this case is pitch black due to the much higher concentration of iron oxide particles) sits stationary over the magnetic plate, like some weird outsize blob of ink, while below it the conveyor belt moves along, bringing in the metal particles.

Once inside the liquid, the various metal particles float at different levels, so horizontal separator louvres can lift them out.

"This demonstrates the viability of the principle," Rem says, "but we don't believe it is suitable for large-scale or high-speed applications."

Contaminants

Erwin Bakker recently tested a different configuration that might serve as the basis of a continuous process for separating plastics.

This time the liquid runs across the magnet in a continuous flow containing shreds of plastic to which contaminants in the form of glass, grit, and metal have been added. The contaminants sink to the bottom, whereas the particles of plastic are carried away by the magnetic liquid to be strained off later.

The liquid is reused, and in a future version the extracted plastic particles as well as the contaminant sediment could be collected by a conveyor belt in a fully continuous process.

"I have run this set-up for up to ten minutes, and it worked perfectly," Bakker says. He has undertaken a little market research to assess the economic possibilities of his technique. Including the 15,000 tonnes collected in the Netherlands, the worldwide annual pet recycling figure comes to 750,000 tonnes, which in view of the current typical processing cost of a few dozen euros per tonne would be a useful market.

Another sector appealing to the researchers is recycling the many different kinds of plastics used in motorcars (8,000 tonnes each year in the Netherlands alone; 400,000 tonnes worldwide).

"A typical car contains six different types of plastic, apart from rubber and fabrics. For all the different makes together, the number of plastics is about twenty," Rem says.

Density separation by means of magnetic fluids can provide the required resolution to separate all these different types of plastic in a single process step. Most current techniques use a separate step for each different component.

As for separating (non-ferromagnetic) metal ores or recycled metals, the outlook is less favourable. These materials are heavier and would require a magnetic liquid of much higher concentration, which in a pure form would be rather expensive. Since a small portion of the liquid will inevitably be lost, the cost will also be higher.

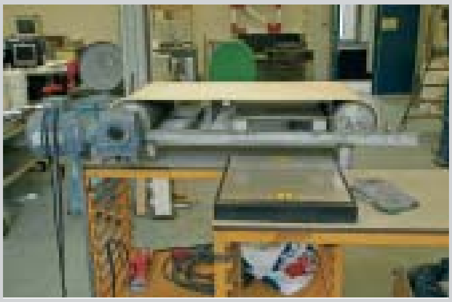
Diamond

A possible niche application might be the refining of diamonds. A South African colleague of Rem, who also worked for the De Beers diamond company, asked the Delft team whether they knew of a separating method for the final stages of the company's production process, in which the diamonds are separated from the extracted ore.

Rem: "In this case, the economic as well as the physical prerequisites are very different from those of plastics. This is a process in which you want to end up with the full 100 percent of the diamonds, and the collected material has to be 100 per cent pure."

In addition, De Beers intends to fully automate the process, since the number of people working in the diamond production facilities is kept to a bare minimum to reduce the risk of theft.

Test set-up of an inclined conveyor belt carrying a large blob of magnetic fluid, used for separating different types of metal.



The 2 litre blob is held in place by a heavy permanent magnet located directly below the belt. The magnet consists of nine poles and weighs about 120 kilograms.

As the conveyor belt carries the metal particles into the blob of magnetic fluid, the lighter particles will start to float, while heavier particles will remain lying on the belt.

A separator vane inserted into the fluid down to 2 cm above the belt is used to separate the floating particles from those lying on the belt. The heavier particles move under the vane and drop off the end of the belt. The lighter particles float over the vane to hit a V-shaped ridge that carries them away to the side of the belt.

The metal particles are extracted in two flows, one in the centre, and one along the edge.

Separated particles of aluminium and copper.

This test set-up devised by doctoral student Erwin Bakker was used for separating shredded PET from contaminants such as grit, glass, and metals. This test set-up also uses a magnetic fluid, but this time the fluid moves along with the PET particles. The contaminants remain behind at the bottom of the container. The PET particles are extracted by a screen

Kimberlite diamond ore

Rem: “On the other hand, cost is not a primary issue.”

The separation technique developed by the Delft team appeared to be the most promising, both regarding separating effectiveness and suitability for automation, but even so there was no response when Rem asked his colleague for a test sample of diamonds.

“We never heard again from them,” Rem says, laughing, “but we still needed something to experiment with.”

Air bubbles

The plastics and recycling industries on the other hand showed much more interest.

“One manufacturer even asked us how many square metres of his factory floor he would have to keep free for installing a separator unit this summer. Mind you, not as a test unit, but for full production use,” Rem recalls.

Unfortunately, things are not that simple. Before a separating process can be standardised and left to run routinely, a lot of things have to be done. The flow properties of the fluid need to be better understood, and Rem plans to bring in his colleagues at the TU Delft Fluid Dynamics department at the faculty of Applied Physics.

Rem: “The fluid cannot remain stationary, since you want to separate any particles that are stuck together. On the other hand, you want to prevent turbulence, as that might jeopardize the separating process.”

Even air bubbles, which can easily remain attached to the flat shreds of plastic, would upset the apple cart, but stirring or heating the mixture might offer a solution there.

The group intends to set up standard procedures for as many applications as possible, and document what the losses are in terms of raw materials and magnetic fluid, as well as how pure the end product is.

“We intend to keep the physics as simple as possible in order to better understand why our optimisation cannot be improved upon,” Rem outlines the programme, “and we would be very happy indeed if we were to have a prototype in a year’s time.” •

About the Author:
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