Rock & Roll

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by ROB VAN DEN BERG

Five hundred tonnes of glass, 1 million tonnes of plastic, 14 million tonnes of building and demolition waste, 7 million tonnes of household waste, 3 million tonnes of packaging, 3.5 million tonnes of paper and board, and 300,000 old cars. All part of the annual harvest of waste materials in the Netherlands. Optimal processing is still lacking for quite a few of these waste streams. Take scrap metal from cars, for instance. It contains bits of copper and aluminium that cannot be separated. At present, processing this waste stream still costs money, but given an effective separation method, the job would be profitable. The fundamental research into the motional behaviour of waste particles by Dr Liesbeth Beunder of the Delft Faculty of Applied Earth Sciences has yielded a wealth of practical knowledge.

The Netherlands is doing fine and it shows in the quantity of waste we produce which is keeping pace with our national income. Although government policy gives priority to the prevention of waste streams, recycling options are gaining in importance. In many cases manufacturers are responsible for the removal of their products once they have reached the end of their useful lives. The cost of removal is included in the price of the product so the polluter pays even though the manufacturers pass on the cost to consumers. And it would appear that by now we have become used to the handful of extra guilders we have to pay for household appliances for the cost of disposing of them and the three hundred guilders extra we pay on a new car as a contribution towards scrapping it at some future date.

Purity

But there’s more to it than that. One way or another the materials suitable for reuse must be recovered from the waste streams. Although recycling and separation techniques have improved immensely over the past few years, the purity of the materials recovered in this way still cannot match that of the original raw materials obtained directly from the source. Evidently, the simple application of the chemical, physical, and mechanical techniques developed for the extraction of minerals does not suffice. Primary materials (such as ores) and secondary materials (such as scrap metal from cars) are simply too little alike. Primary materials contain relatively few components, they are granular in nature, and they are relatively fine after release from the matrix. The size of the particles is of the order of magnitude of dozens of micrometres. The secondary scrap metal from cars that emerges from the shredder on the other hand, is a couple of centimetres in size and has a large variety of shapes. To separate the various materials into their more or less pure forms is not so simple. The Delft Faculty of Applied Earth Sciences has been successfully
researching this field for some years. Recently a patent was granted for a method to separate different plastics, and for a new method to extract metal particles from a waste stream. The Delft scientists have applied every conceivable principle to separate waste materials: differences in particle size, specific mass, magnetic and electrical properties, etc.

**Virgin territory**

Through his contacts with the non-ferrous processing industry, Prof. Ir. Wijnand Dalmijn knew that the industry had problems separating various non-ferrous metals. This was caused by the large variety in shape of scrap metal particles. He found a willing audience at the department of Environment, Energy, and Process Innovation of tno in the city of Apeldoorn. The institute was prepared to invest money in fundamental research to find a solution to the problem. Four years ago, doctoral student Liesbeth Beunder received a research grant to look into the available options for separating waste materials on an industrial scale, based on differences in shape. In other words, can the problems caused by differences in shape be turned into an advantage?

Beunder: ‘It was a promising field, and it was largely virgin territory, promising rich pickings. Secondary materials practically always retain the typical shape they receive during the production process. Pieces of glass will be flat, and copper wire will be long and thin, extremes of shape you won’t find in primary materials.’

Separation based on differences in shape can take many forms. One is to use a stack of identical sieves. The more elongated particles will take longer to fall through the stack. However, the most obvious way is probably to separate particles based on their behaviour when in motion. This principle was introduced in the late nineteen-fifties for the extraction of raw materials, e.g. to separate lignite from xylite. The long, tough fibres of the incompletely carbonised fossil vegetation remains proved to be easily separable by using an inclined conveyor belt. The lignite rolls off the belt much faster.

**Marbles**

Even so, there are more problems to solve. Granted that flat particles will slide and perfectly round marbles will roll, but any other shape in between will do a bit of both, or bounce downwards. The experience with metal scrap is that it will either slide or bounce. The «normal», classic motion equations we were taught at school apply only to ideal bodies, and do not account for bouncing. So Beunder first had to try and understand the mechanics of irregularly shaped particles. In doing so she followed in the footsteps of Galileo who was the first to conduct a systematic study of particles moving along an incline. She also spent hours watching the way in which balls of aluminium foil and pebbles descended.

Beunder is quick to add: ‘At least I had a video camera.’ And she needed it too, for any particle that is not a perfect sphere will move quite erratically.

Beunder: ‘Once a certain speed is exceeded, the rotation can no longer keep up, and the particle will start to bounce. My video recordings showed that a bouncing
particle will always be faster to arrive at the bottom than its sliding counterpart, although rolling is still the fastest method. In order to verify my observations, I calculated the motion of (regular) polygonal cylinders.

Each time one of these rolling particles hits one of its corners against the slope, it loses a little energy. In fact, this is a type of friction. Once this had become clear, she was able to adapt the model to include a description of the motion of irregular polygons. She then proceeded to introduce a shape factor, a new parameter linked to the number of angles of the particle. The standard deviation from this shape factor for each particle became a measure of its lack of symmetry. Together with the coefficient of friction, the shape factor provided sufficient information to describe the bouncing motion.

Beunder: ‘Based on the model, and given certain incline conditions, I was able to predict when particles would start to bounce or slide. To separate the particles, we somehow had to find a way to use the big difference between rolling/bouncing and the much slower sliding motion. I discovered that I could make a particle bounce or slide at will by changing the roughness properties of the surface.’

In order to test the ideas in an experiment, a rotating cone separator was developed. The basic idea behind the device is simple. Feed the particles into the top of the (truncated) cone. As a particle is slower to move down the incline, it will be carried further along by the rotating cone. Fast particles will be affected hardly at all by the rotating motion of the cone. By fitting a number of splitters at the lower end of the cone, fast particles can be separated from slow particles.

**Vibrating trough**

Before a working prototype could be created, a number of problems had to be solved.

‘Feeding the particles required a special solution’, Beunder explains. ‘It has to be done in such a way as to ensure that they all enter the cone in the same way. We started with a simple vibrating trough, but that did not work. In the final design, the particles drop onto a wheel rolling along the cone wall at a right angle. The wheel holds back the particles entering the cone until the cone surface carries them off.’

Any particles that fail to move down the incline are intercepted by a kind of scraper device after they have made a full turn. However, the scraper will also catch any particles that just happened to land on a rough or flat side, preventing them from rolling. If these were to be fed back into the machine, they would still end up in the right containers. Beunder carried out a series of experiments using «model particles» and was able to simulate these closely using a model. Even a simulation of the second chance effect proved a perfect match with reality. The real test of course lay in the processing of actual waste streams. For this purpose, a long series of experiments was conducted to determine the best surface, rotation speed, and orientation of the device for each type of material. Finally, using the optimum settings, residue material from a car wreck shredder plant was used. The residue had been obtained from a U.
S. company that had shown an interest in the method.
The scrap contained stones (!), metal parts, and wires.
Beunder’s method was able to recover 70% of the latter
fraction, and almost 90% of the stones. The stone
fraction is still too polluted to be used for road building,
but it is a definite step in the right direction. A step that
did not go unnoticed. A Swedish company was so
impressed with the results she had achieved that it
commissioned her to conduct further research. She
doesn’t know yet what will come out of it, since the
research results have only just been submitted.

**Sieve frequency**
Beunder also investigated another way of separating
particles according to shape or rather length using
sieves. In experiments with model particles she managed
to determine the optimum sieve frequency and amplitude
for particles of a certain length.
Beunder: ‘If you start with a mixture containing particles
of varying lengths, you should be able to predict changes
in the composition of the mixture depending on the way
in which the sieve is moved up and down.’
To her surprise, at a certain sieve frequency, some
particle shapes dropped through the sieve stack very
quickly. Even so, she was unable to correlate the
experimental results with the results of a simulation
model describing the jumping of particles in relation to a
sieve passing criterion. It would appear that the motion
of the particles on the sieve depends on too many chance
occurrences. Someone else can rack his or her brains
over that question.
Beunder: ‘I have demonstrated that a separation process
based on particle shape is a feasible proposition. The
behaviour of rolling particles in particular offers a good
basis. Whether anyone else will pick up the thread where
I left off is a bit hard to say. The recycling industry is a
strange world. Government policy can make it or break
it. If the authorities decide that the price of dumping a
tonne of waste is a few hundred guilders, there is room
for ideas. But cut the cost to ten guilders and all the
waste goes into a landfill. It’s as simple as that.’

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