Industrial Tests with a New Mechanical – physical RMSW Processing Plant in Búslakpuszta, Hungary

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Abstract
In 2016, a Hungarian planning and manufacturing company, the 3B Hungária LtD. started a project with the Institute of Raw Materials and Environmental Processing, University of Miskolc to reduce municipal wastes landfilling in the western Hungarian region. A new, almost completely Hungarian developed and produced waste processing plant has been built in Zalaegerszeg (Búslakpuszta) to treat residual municipal solid wastes of the region (60 000 tons/year). The inauguration of the new plant was at 13th July, 2018. The designed and built mechanical-physical technology contains a bag opener machine, a drum sieve to separate the so called "bio" fraction, a hammer crusher for pre-comminution of the >200 mm fraction, the newly developed KLME (combined air flow, magnetic and eddy-current separator, KLME is the Hungarian abbreviation), two NIR sorters, the final shredder and all the necessary auxiliary equipment. Main products of the technology are the bio and inert fractions (landfilled at this stage), material streams for recycling, Fe, Al, PET and PVC and the secondary fuel material for energetic utilisation. Paper reports about the commissioning and process engineering tests of the new plant with three different designs of the KLME separator.

Keywords: *KLME separator, residual municipal solid wastes (RMSW), separation efficiency, hammer mill, rotary shear.*

Introduction, aim and literature survey
Modern lifestyles result in significant municipal waste generation and if we would like to maintain or even improve the achieved living standards, sustainable waste management is necessary. Even developed countries have to take the long-term generation of residual municipal solid wastes (RMSW) into account, because with the application of a sophisticated selective collection system there are still large amounts of residual materials that have to be non-selectively collected and handled (Aich and Ghosh 2016). There are many different country specific solutions for processing technologies for RMSW. There are 27 mechanical – physical processing plants right now in Hungary. Except of the recently commissioned one it is typical that the key comminution, separation and sorting machines were imported from abroad. Main products of these plants are the so called bio-fraction, some small material streams for waste-to-material recycling, such as Fe, Al and PET and the refuse derived fuel (RDF). Right now the bio-fraction is mainly landfilled in Hungary. In a small extent the bio-fraction is stabilised by aerobic decomposition before landfilling. There are ongoing intensive research about better handling and utilisation for the bio-fraction. The rate of separation of valuable materials for recycling is rather low recently because the aftermarket and processing industry capacities for recycling are still not so developed in the country.

The municipality of Zalaegerszeg decided on the improvement of the MSW management of the region according to the European Commission's Roadmap to a Resource Efficient Europe (EC, 2011) and the EU's Waste Framework Directive (EU, 2008). In the near past 100 % of the RMSW was landfilled in the up-to date landfill of the community. A consortium formed from a machine and technology producer (3B Hungary Ltd.), a scientific partner (the Institute of Raw Materials Preparation and Environmental Processing, University of Miskolc), and a public waste managing service company (Zala-Müllex Ltd.) has started the development and construction of an RMSW processing technology targeting no-landfilling for this waste stream (Faitli et al., 2018). The development and construction of the mechanical-physical processing plant as the first stage is supported by an EU-funded grant. A new, almost completely Hungarian developed and produced waste processing plant had been built in Zalaegerszeg (Búslakpuszta) to treat residual municipal solid wastes of the region (60 000 tons/year). The inauguration of the new plant was at 13th July, 2018. The aim of this paper is to report about the commissioning and process engineering tests of the new plant with three different designs of the KLME separator.

Materials and methods

Before the design of the processing technology a sampling campaign was carried out in the area (Faitli et al., 2018). The technology shown in Figure 1 had been designed on the basis of the results of samplings. The first unit of mechanical – physical RMSW plants is either a pre-crusher or a bag opener before the classification (drum sieve or cascade sieve) unit. Before the classification the waste bags must be opened. Generally a rotary pre-shredder is applied for this task; however it has a serious disadvantage, namely this machine makes the Fe and plastic particles to be intergrown and that is a huge problem for the downstream separation. The energy need of a rotary pre-shredder is also significant. Therefore, a bag opener machine (Figure 2) was developed and made in Zalaegerszeg. The big rotor with teeth of the bag opener rotates opposite compared to the moving floor conveyor; therefore the bags are lifted and teared into the hydraulically supported standing teeth.

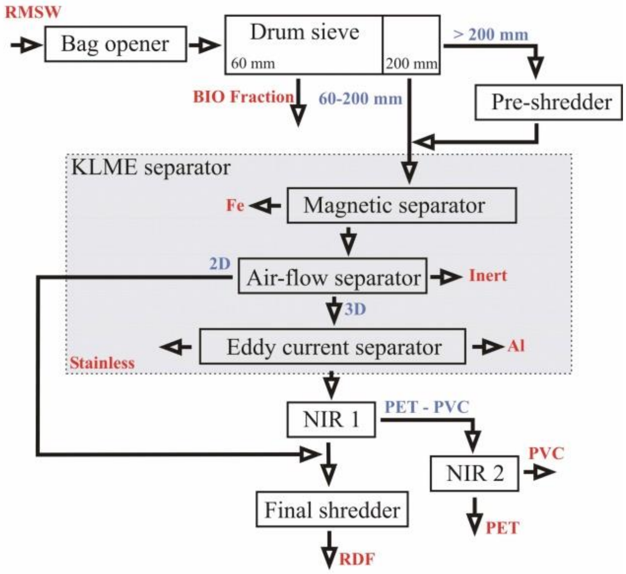


Figure 1. The designed mechanical – physical RMSW processing technology

The industry standard drum sieve (Figure 3) has two drum shaped screens, one with 60 mm and the other with 200 mm circular openings. The separated bio-fraction (< 60 mm) will be still landfilled after this first stage of development. The coarse fraction (> 200 mm) goes into a newly developed hammer mill (Figure 5) and its braked product is refeed into the 60-200 mm intermediate fraction before the KLME separator (Figure 3 and 4).

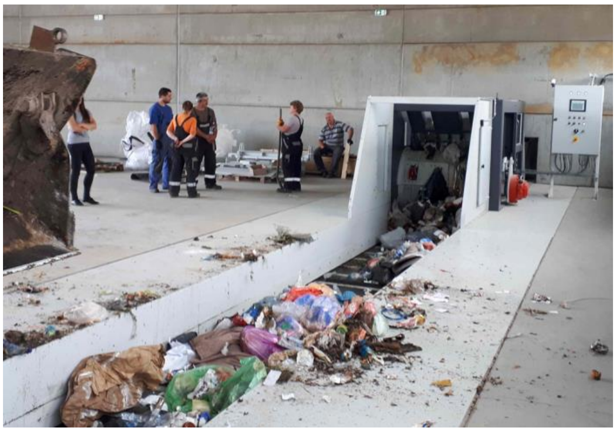
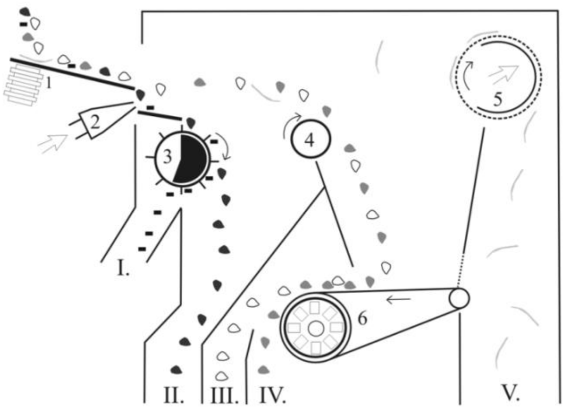


Figure 2. The moving floor conveyor and the bag opener

Figure 3. The drum sieve (back) and the KLME separator (front)

Figure 4 shows the schematics of the KLME separator with exhaust cage.



Main technological units:
1. Vibrated feeder
2. Air nozzle
3. Magnetic drum
4. Rotated auxiliary cylinder
5. Exhaust cage
6. Eddy current separator

Numbers and short names of products:

I.	Magnetic
II.	Inert
III.	Al
IV.	3D
V.	2D

Figure 4. The KLME separator with exhaust cage schematics

The 60-200 mm intermediate size fraction is fed into the KLME separator by a vibrated feeder. There are three different KLME separator designs described in the paper. The first one was the so called KLME separator with exhaust cage design (Figure 4). The air nozzle is located into the bottom of the first part of the vibrated plateau. Heavy particles fall through the air beam onto the magnetic drum. Magnetic particles are dragged into the Fe product, heavy inert particles, such as rocks, bricks and so on, as well as wet, therefore heavy books; shoes, etc. fall into the inert product. Light particles are blown and transported by the air beam. When a particle falls into the air beam, the initial acceleration part of particle settling is dominant, but afterwards when the particle is transported by the air beam, the particle settles in it and it has sufficient time to settle, therefore the terminal settling velocity is dominant. Another point is that the so called particle (body) density determines both the initial and terminal particle settling and not the material density. The material density of the aluminium cans and the PET bottles are significantly different, however their particle densities might be similar depending on how they had been compressed previously. Therefore the 2D (foils) and 3D (aluminium, plastics) shaped light particles are also blown by the air beam. The 3D plastics and aluminium particles settle out from the beam and then an eddy-current separator separates them into two products. The 2D like foils are sucked into the surface of the exhaust cage, because there is a strong suction from the middle of this cage. The rotating cage transports the 2D particles into the 2D output.

Figure 5. New hammer mill as pre-shredder

Figure 6. NIR sorters

Before the end of the technology there are two NIR sorters (near infrared). The first one is set to remove the PET and PVC particles and the second one cleans the PET product from this stream by removing the PVC. By this way the technology separates the Al, PET and Fe materials for waste-to-material recycling and the PVC is also removed from the produced RDF, because that is necessary for the thermal utilisation. The last machine of the technological flowsheet is a one rotor shredder produced by Metso. This is the only non-Hungarian made machine in the built RMSW processing plant.

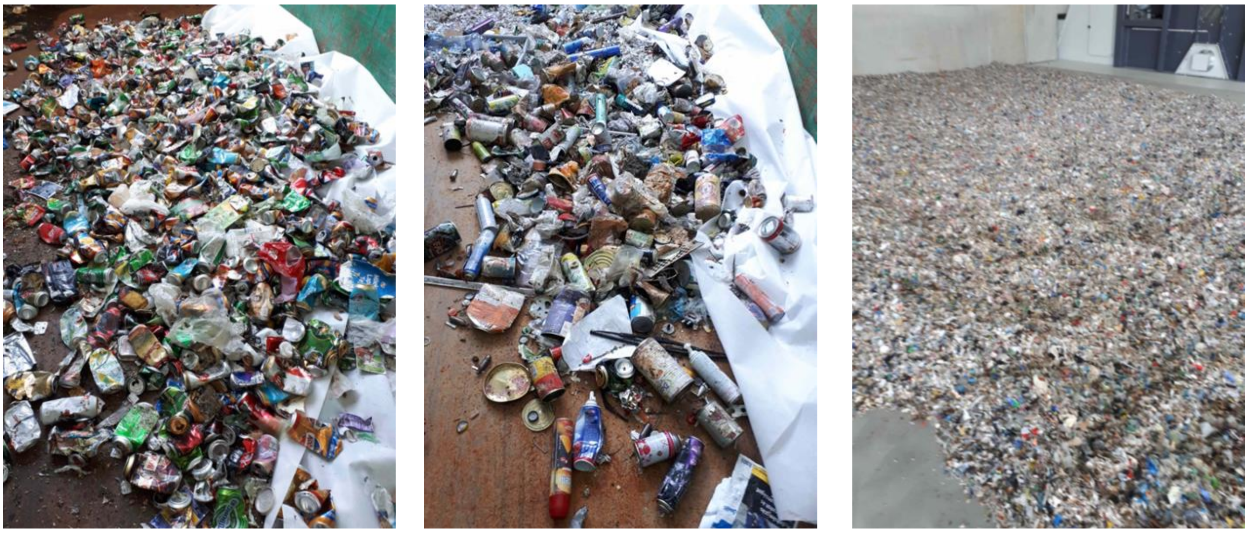
Results and discussion

The first industrial test with the complete processing plant was carried out on 23 May, 2018. At that time continuous operation was maintained for about an hour and materials were produced in all the outputs of the technology, but minor operational clogging and mechanical engineering problems were arose. After some experimental development a more successful industrial test was performed on 24 July, 2018. Main technical parameters are shown in Table 2.

Table 1. Main technical parameters of the 24 July, 2018 industrial test

Parameter	**Value**
Moving floor conveyor speed	0.05 m/s
Revolution number of the bag opener rotor	4.8 1/min
Tangential speed of the drum sieve perimeter	1.13 m/s
KLME air nozzle air flow rate (blow in)	4800 m3/h
air flow rate, sucked out from the KLME	7400 m3/h
Revolution number of the eddy-current separator pole motor	2800 1/min
NIR1 and NIR2 feed belt conveyor speed	3 m/s
Belt conveyor speed before the Metso rotary-shredder	1 m/s

Figure 7 shows photos about some products of the 24 July, 2018 industrial test.

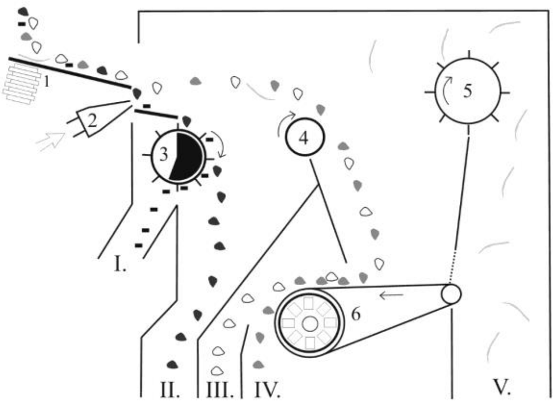


Al product Fe product RDF

Figure 7. Photos about some products of the 24 July, 2018 industrial test

Figure 7 shows, that these products are fairly clean. The eddy-current separator worked fine, because it is clearly visible to the naked eye that there are only a few extraneous particles in this product. The photo of the Fe product proves the success of the design concept of selecting the bag opener machine instead of the rotary pre-shredder, because plastic is not captured inside of the Fe particles. The produced RDF is good quality, Figure 7 simply shows it.

Afterwards of the so far described initial tests the technology was run for longer time periods. Unfortunately, clogging was happened on the surface of the exhaust cage when the hammer pre-crusher was operated for the comminution of the +200 mm particle size materials. When the crushed small particles reached the KLME separator, these small particles clogged the 10 x 10 mm square openings of the exhaust cage. Therefore, the KLME separator and especially its 2D separator were redesigned and a new industrial prototype was made. This 2nd design is called as KLME separator with nailed roller. The fans of the exhaust cage were removed and a new construction of the 2D channel was created. The schematic drawing of the KLME separator with nailed roller is shown in Figure 8.

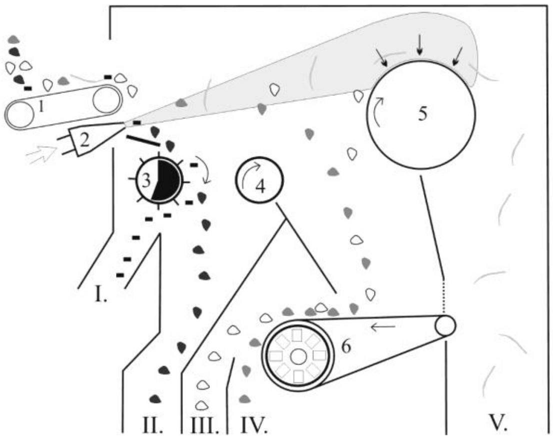


Main technological units:
1. Vibrated feeder
2. Air nozzle
3. Magnetic drum
4. Rotated auxiliary cylinder
5. Nailed roller
6. Eddy current separator

Numbers and short names of products:
I. Magnetic
II. Inert
III. Al
IV. 3D
V. 2D

Figure 8. The KLME separator with nailed roller schematics

Different parameters industrial process engineering tests have been carried out in the plant with the KLME separator with nailed roller. These tests showed that this construction is applicable but there are still operational issues, such as clogging of the nails on the roller and separation issues of the foils (2D) from the 2D air channel. On the basis of the gained information the KLME separator had been redesigned for the third time and a new industrial prototype was made. Some mock-up units made from wood sheets were made to study two phenomena. The Coanda effect is well known in the literature. In 1910, Coanda (Crivio and Doroftei, 2016) observed that flows near surfaces would bend because of the fluid dynamics influence of the surfaces. This was later referred to as the Coanda effect, after the Romanian engineer, who described this phenomenon first. The second phenomenon (issue) was experienced with the earlier designs of the KLME separator; this is the air beam dragging (distraction) by a neighbouring wall. On the basis of the preliminary tests with mock-up devices a new industrial KLME separator was built. Its schematic is shown on Figure 9.



Main technological units:
1. Belt conveyor feeder
2. Air nozzle
3. Magnetic drum
4. Rotated auxiliary cylinder
5. Coanda roller
6. Eddy current separator

Numbers and short names of products:
I. Magnetic
II. Inert
III. Al
IV. 3D
V. 2D

Figure 9. The KLME separator with Coanda roller schematics

The air beam released by the nozzle and induced by the centrifugal impeller fan should reach the upper ¾ part of the Coanda roller. If the operation is sufficient the air coming out from the nozzle with the retrained air together will flow above the Coanda roller into output V. If this flow pattern is fulfilled the evolved Coanda effect helps for the effective 2D separation, because 2D shaped particles (foils) are “sucked” onto the drum surface by the Coanda effect and the rotating drum transports them to output V. However, experimental difficulties were experienced during mock-up units at targeting the air beam into the Coanda roller. The angle of the air nozzle was changed systematically, however the design of the KLME house and its inner structure strongly influence the propagation direction of the air beam. During a bad preliminary design the air beam propagated into the upward direction, way above of the Coanda drum or into the downward direction, into the eddy-current separator. The direction of the blown-in air beam was not determined by the angle of the nozzle with this wrong construction. In the case of the upward beam distraction, air was retrained from above the beam, and an eddy was formed between the air beam and the upper wall and its result was the upper beam distraction. After redesigning the separator these problems were eliminated and now the direction of the air beam propagation can be set precisely by setting the angle of the air nozzle. Another significant modification was the change of the vibrated feeder into a short feeder belt conveyor. The particles before the air nozzle must be evenly distributed. If evenly distributed particles fall into the air beam a good separation is the consequence. The feed with the vibrated feeder was not sufficiently even, particles bulks were formed and that caused bad separation.

On 6-7 November 2018 systematic operational process engineering tests were carried out to find out optimal parameter set-up for the plant with the KLME separator with Coanda roller. The flow rate of the blown-in air beam, the angle of the air nozzle, the speed of the feeder belt conveyor, the position of the (4) rotated auxiliary cylinder and the Coanda roller were systematically changed. Products of the plant were checked by samplings and necessary modification on the system parameters was done accordingly. Good and stable operational conditions were achieved.

Conclusions

The municipality of Zalaegerszeg has decided to improve their MSW managing in the future, namely they would like to decrease landfilling near to 0 %. The first stage of this conceptual plan is almost fulfilled because a new, almost completely Hungarian made mechanical-physical RMSW processing plant was inaugurated on 13 July, 2018 at Búslakpuszta, Hungary. Since then, after the redesign of the KLME separator the plant is in normal operation. The KLME separator was equipped with a Coanda roller. The house of the KLME separator was also modified because of the experienced air beam distraction by nearby walls. If the blown-in air beam hits the upper part of the Coanda roller the evolving Coanda effect helps for the 2D particles separation.

Acknowledgements

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