A design study of a centrifuge for separating water and plastic

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Introduction and motivations

This paper presents the preliminary simulation study of a typical centrifuge currently produced by Gamma Meccanica. The objective of this study is to evaluate the behaviour of the centrifuge using moving particle simulation and discrete element method (MPS-DEM) simulation techniques with Particleworks 7.2.1 to gain a better understanding of phenomena that are impossible to monitor experimentally.

Qualitative and quantitative results, such as the distribution of water and plastic particles within the centrifuge, will be compared to identify key factors for further analysis and improvement in future studies. Particular phenomena like blade erosion due to particle impact will be used for qualitative validation of the model.

The presented model and results formed part of a feasibility analysis of different rotor configurations. The varying distribution of the water and particles enabled observations about the performance of different rotor geometries in terms of energy efficiency and moisture in the final product. The results of the numerical comparison will be very useful for future improvements not presented in this article.

Centrifuge design

The centrifuge design presented in this study consists of a number of different geometries as listed here and visible in Fig. 1:

- Rotor 1: closed square section surrounded by four blades.
- Rotor 2: closed circular section surrounded by four blades.
- Rotor 3: open square section surrounded by four blades.

The importance of simulation

Using MPS-DEM simulation to analyse the centrifuges used in plastic recycling plants makes it possible to investigate phenomena that are impossible to monitor and understand experimentally.

Prior to the introduction of simulation, each machine was designed using the considerable experience of Gamma Meccanica's engineers and technicians and with valuable customer feedback that is always important for continuous improvement. Simulation will now enable the pluriannual experience to be represented

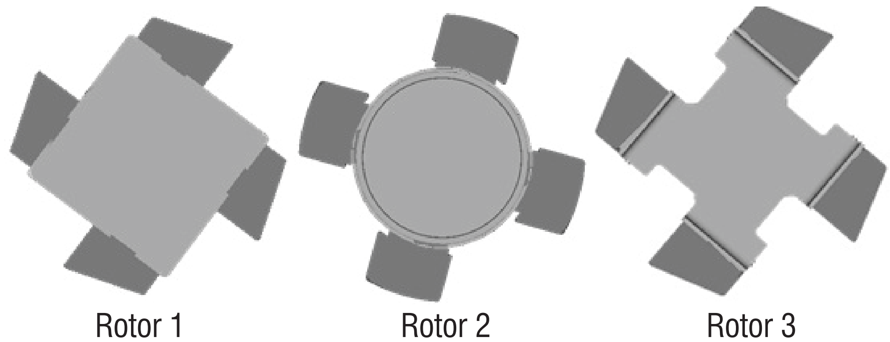

Fig.1. Comparison of different rotor sections: a) closed square section, b) closed circular section, open square section.

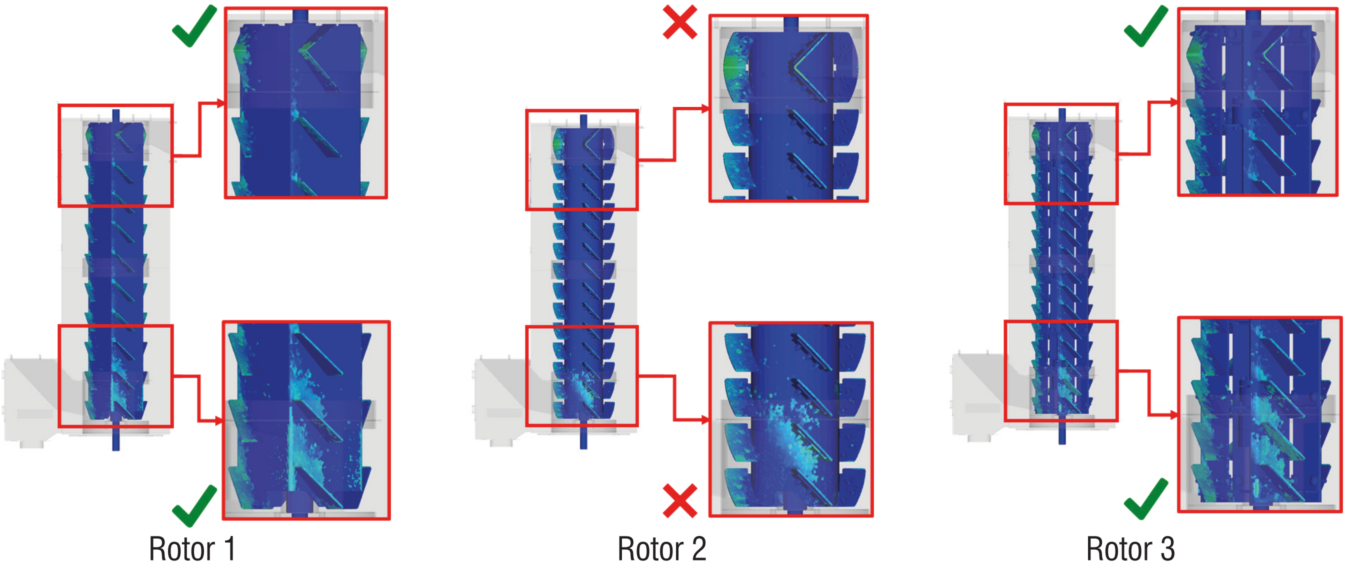

Fig. 2. Mapping the water distribution on the rotor surface: a) closed square section, b) closed circular section, c) open square section.

numerically and to improve current solutions with new and innovative configurations not previously studied due to the high experimental time costs.

Simulation results

The simulation study conducted by Gamma Meccanica provided valuable information on the centrifuge design's behaviour and performance. The results revealed the distribution of the water and plastic within the system and exposed areas for improvement. In the following paragraphs, we discuss the detailed engineering analysis and observations emerging from the simulation.
One of the main purposes of the simulation was to assess the distribution of water and plastic particles within the centrifuge. Mapping the flow patterns (Fig. 2) demonstrated the influence of different rotor sections on the distribution.

The simulation showed that the rotor with the rounded cross-section (Rotor 2) let a considerable amount of water flow upwards to the top of the system. In contrast, the square cross-section of the rotor restricted the flow of water, resulting in a more concentrated distribution of water towards the lower part of the system. This analysis provided a qualitative understanding of water distribution and its relationship to the rotor design. The observed differences in water behaviour between rotor sections formed the basis for further investigation into their impact on overall performance.

Another critical aspect of the simulation was to evaluate the impact of plastic particles on the centrifuge. The simulation provided detailed information on the behaviour of particles and their effect on the machine's long-term performance.

The results indicated that some sections of the rotor were impacted significantly by the particles, suggesting potential erosion in those areas over time (Fig. 3). These findings were supported by qualitative observations from customers, who experienced similar defects due to particle impact.

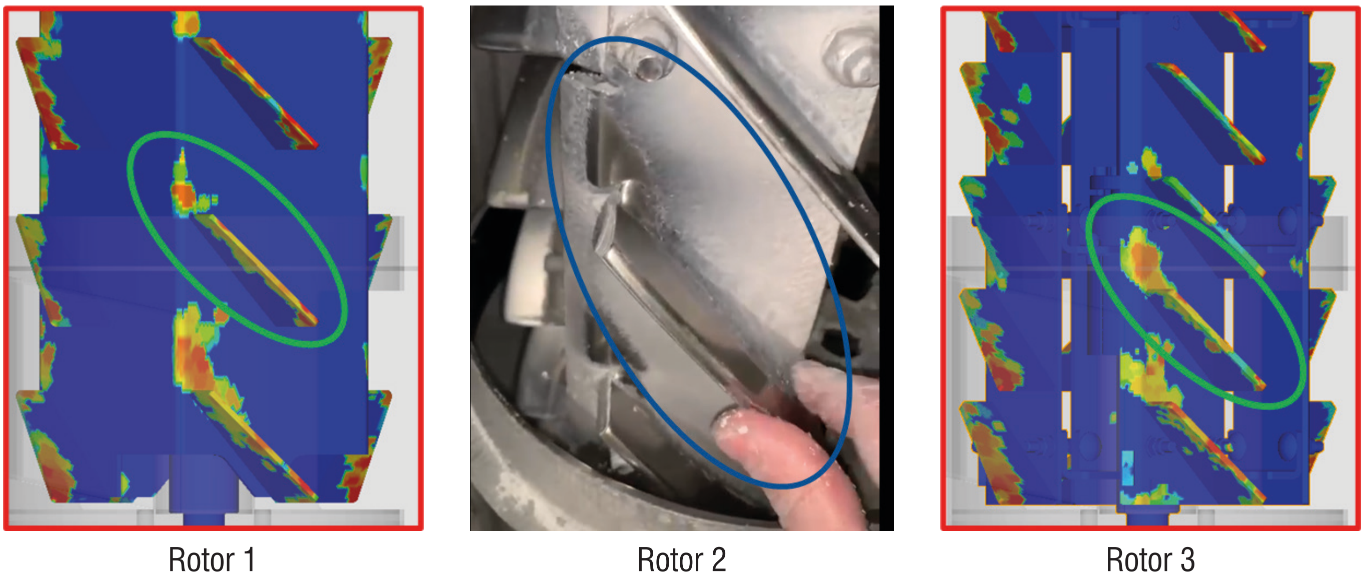

Fig. 3. Erosion phenomena – numerical-experimental comparison: a) numerical evidence on rotor with closed square section, b) experimental evidence on rotor with open square section, c) numerical evidence on rotor with open square section.

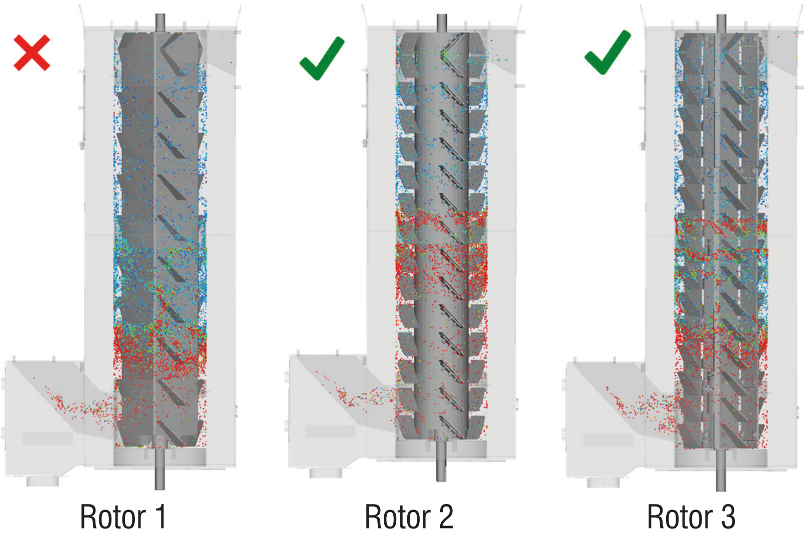

Fig. 4. Plastic particle distribution inside the rotors: a) closed square section, b) closed circular section, c) open square section.

The analysis of particle distribution (Fig. 4) using numerical density visualization showed that the first rotor was not efficient at expelling plastic particles from the system. This suggested that although the first rotor was efficient at expelling water, it struggled with plastic separation. Furthermore, the analysis of energy consumption (Fig. 5) revealed that the second rotor required more power than the other two rotors. Based on the results of the water distribution, a qualitative analysis of the amount of water expelled by the rotors at the plastic particle outlet allowed the humidity of the final product, which should be as low as possible, to be assessed. The results presented in the figure below show that Rotors 1 and 3 dramatically reduce the moisture content of the end product compared to Rotor 2.

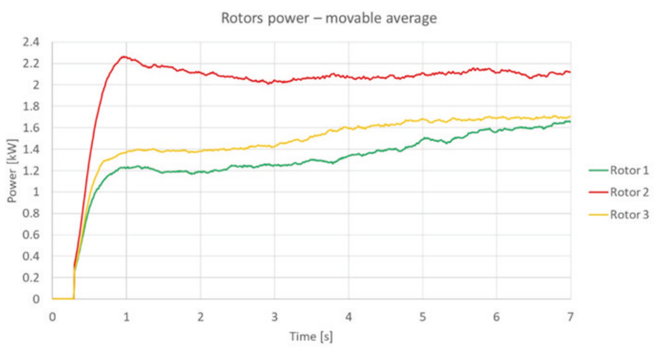

Fig. 5. Rotor energy consumption.

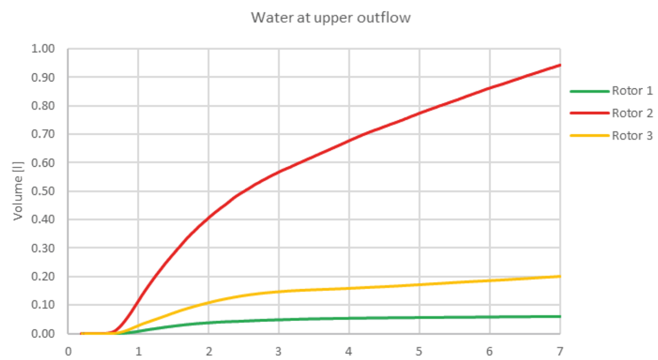

Fig.6. Water volume expelled by the rotors at the plastic outlet in 7s.

Conclusions and future developments

The proposed study allowed the behaviour and performance of different rotor models to be better understood in terms of water and plastic particle distribution, blade erosion, energy consumption, and moisture levels in the final product.

The results showed that Rotor 2 with the round cross-section performed worst for energy consumption and product humidity. Rotor 1 performed well in energy consumption and humidity but worst for plastic particle distribution along the rotor's axis. Rotor 3 demonstrated a good compromise between energy consumption, water and particle distribution, and final product humidity (quality).

All results are sufficiently in line with technical experience and customer feedback gathered over the years, so as a result this model will be used for future improvements. Rotor 3's configuration will also be used as the base configuration for new design proposals.

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About Gamma Meccanica

Gamma Meccanica is a world leader in mineral wool production lines, both single machines and complete lines for the production of mineral wool, i.e. stone wool and glass wool.
The company also manufactures special lines for the production of pipe sections and sewn mattresses, laminate production lines, ceramic fibre machinery and hydroponic lines for stone wool and glass wool. Gamma Meccanica's machinery offers a combination of high performance and advanced technology. It meets and exceeds customer demands by constantly improving quality and energy efficiency through technological advancement and high levels of technical support, while meeting the strictest environmental standards. Established in 1977, today the company has three divisions, each focused on a specific sector:

- the insulation division designs and produces lines for the production of mineral wool;
- the extruded polystyrene division creates systems for the production of XPS boards;
- the plastic division specializes in lines for recycling plastic material.

Its constant technological and applied research and highly qualified staff makes Gamma Meccanica one of the main players in its field globally. Gamma Meccanica designs and manufactures its systems at its plant in Bibbiano in Reggio Emilia in Italy which allows the company to directly control both development and the full production process.