A Numerical Study for Air Flow from Ejector Nozzle of Sorting Machines Using Smoothed Particle Hydrodynamics

Tomoyuki Miyamoto [1], So Noguchi [1], Shinya Matsutomo [2]

[1] Graduate School of Information Science and Technology, Hokkaido University, Japan

[2] Department of Electronic Control Engineering, Niihama National College of Technology, Japan

1 Introduction

In this paper, we discuss the fundamental simulation data of a Sorting Machine for optimum planning, effective designing and cost-reduction. Accurate sorting of particulates is a fundamental problem in the Sorting Machine. Providing the accurate sorting is of high quality, sorted products command a considerably higher price than unsorted ones. In the sorting machine, a camera with high-detection capability and an ejector to exactly remove undesired particles are required. However, it should be avoided that the ejector removes a good particle in order to provide high sorting ratio. We would like to understand the behaviour of air flow ejected from an ejector nozzle in the Sorting Machine for effective designing. In this study, a numerical simulation was carried out with the three-dimensional Smoothed Particle Hydrodynamics (SPH) in order to highly accurately reproduce the behaviour of the air flow ejected from the ejector nozzle in the Sorting Machine.

2 Smoothed Particle Hydrodynamics Approach

2.1 Modelling Fluids Using Particles

The SPH is an interpolation method for fluid motion simulation [1]. The SPH deals with field quantities defined only at discrete particle locations and can evaluate them anywhere in space. In the SPH the field quantities are distributed in a local neighbourhood of the discrete locations with sphere symmetrical smoothing kernels.

A scalar value A is interpolated at location r with a weighted sum of contributions from the particles:

$$A(r)=\sum_j m_j \frac{A_j}{\rho_j} W\left(r-r_j,h\right)$$

where j represents the number of all particles in the scene, m_j is the mass of particle j, r_j the position, ρ_j the density, and A_j the field quantity at r_j, respectively. The function $W(r,h)$ is called smoothing kernel with core radius h. The kernel is normalized with

$$\int W(r)\,dr=1 \ .$$

Because $m_i = m$ (constant) in our case, we can evaluate the density at every step using a modified equation based on [2]:

$$\rho(r)=\sum_j m_j W\left(r-r_j,h\right) \ .$$

With the SPH approach the derivatives affect only the smoothing kernel. A problem of the method is that these equations are not guaranteed to satisfy some physical rules including symmetry of forces and conservation of momentum. The reference [2] also solves the problem related with the SPH.

Using particle-based simulation simplifies the solution of Navier-Stokes equations. The reason is that the number and the mass of particles are constant and the mass conservation is guaranteed. Therefore the mass conservation equation can be omitted.

Based on the simplified Navier-Stokes for the acceleration of particle i we can get:

$$a_i=\frac{d\vec{v}_i}{dt}=\frac{f_i}{\rho_i}$$

where $\vec{v}_i$ is the velocity of particle i, f_i and ρ_i are the force density field and the density field at the location of particle i, respectively.

2.2 Modelling Force Fields

Instead of an equation described by the SPH rule a modified solution is used for pressure force because it guarantees the symmetry of forces:

$$f_i^{pressure}=-\sum_j m_j\left(\frac{P_i}{\rho_i^2}+\frac{P_j}{\rho_j^2}\right)\nabla_i W\left(r_i-r_j,h\right) \ .$$

The pressure at particle location has to be computed first, it can be computed via the ideal gas equation:

$$p=k\rho$$

where k is the gas constant that depends on the temperature. Applying the SPH rule to the viscosity term also yields to asymmetric forces because the velocity field varies. The idea of symmetrizing the expression applies the velocity differences:

$$f_i^{viscosity}=\mu\sum_j m_j\left(\frac{v_j-v_i}{\rho_i\rho_j}\right)\left(\frac{r_j-r_i}{|r_j-r_i|^2}\right)\nabla_i W\left(r_i-r_j,h\right) \ .$$

3 Agenda Details

3.1 Sorting Machine

A rice processing equipment commonly has an Sorting Machine. The Sorting Machine is the machine that sorts discolored rice and foreign material like a stone and a glass by recognizing with a high-performance camera, and blows away the foreign particle with an ejector like an air-gun. Fig. 1 shows the schematic view of the Sorting Machine. There are three processes in the equipment. First, the material is supplied with a chute. Second, good particles or bad particles are recognized with the high-performance camera. Third, the unwanted particles are sorted with the ejector.

The evaluation points of Sorting Machine are the quality of products, the amount of throughput, and yield rate. High-quality products are sellable at high price. Increase in the amount of processing increases the production and reduces the running cost. The high yield rate reduces the product loss.

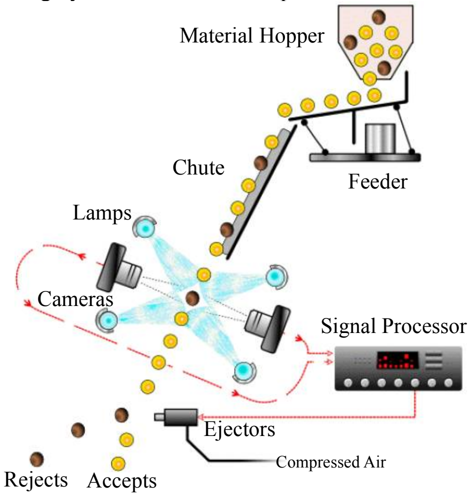

Fig. 1. Schematic View of Sorting Machine.

3.2 Subject Outline

In the Sorting Machine, a higher value can be added to existing impressive machines if there are ways to 1) increase the amount of throughput by raising particle packing density and speed, 2) reduce to wrongly reject good particles with the ejector. To achieve both 1) and 2), the air flow ejected from the ejector nozzle should be improved. It requires a straight flow, a sharp ON-OFF switching and an adequate pressure.

3.3 Simulation Model

As a simulation model for validation in order to reproduce the behaviour of the air flow from the ejector nozzle in Sorting Machine with the SPH, we have simulated a characteristic event (shown in Fig. 2). Fig. 2 shows the images captured with a schlieren photography and the waveform measured with a pressure sensor. It was clarified that one jet operation on the ejector produced twice the air flow from the ejector nozzle. Incidentally, we will be able to understand the mechanism of this behaviour. It will be a very valuable knowledge to develop a new Sorting Machine efficiently.

4 Conclusion

In this study, the numerical simulation was carried out with the three-dimensional Smoothed Particle Hydrodynamics based on the characteristic event for validation in order to highly accurately reproduce the behaviour of the air flow from the ejector nozzle in the Sorting Machine. We will figure out that the SPH is effective in the development of the Sorting Machine. Moreover, the details of the results will be represented in the full paper.

In future prospects, we will discuss an effective designing to improve the behaviour of the air flow from the ejector nozzle in the Sorting Machine.

Acknowledgements

We appreciate that SATAKE Corporation has suggested the subject of this research and provided the valuable information of the air flow from the ejector nozzle.

References

[1] R.A. Gingold, J.J. Monaghan, Kernel estimates as a basis for general particle methods in hydrodynamics, Journal of Computational Physics, Volume 46, pp.429-453, 1982

[2] M. Müller, D. Charypar, M. Gross, Particle-Based Fluid Simulation for Interactive Applications, SIGGRAPH/Eurographics Symposium on Computer Animation, pp.154-159, 2003

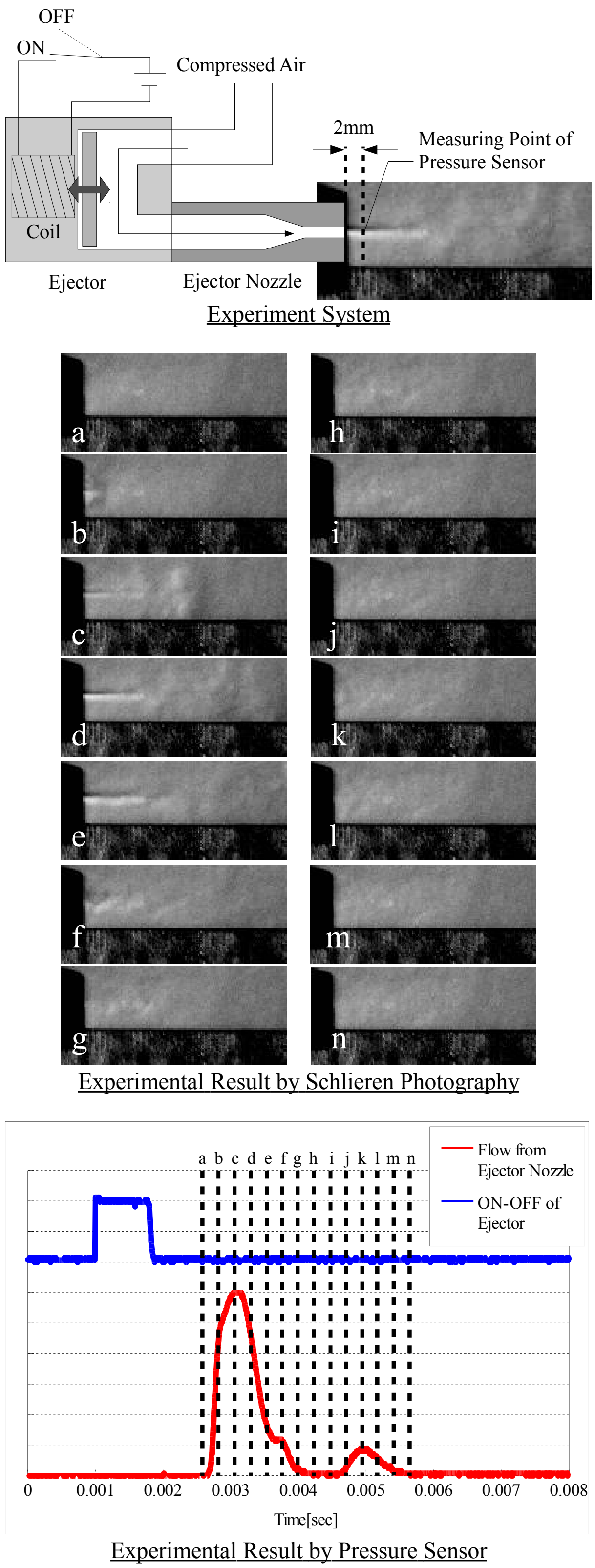

Fig. 2. Simulation Model.