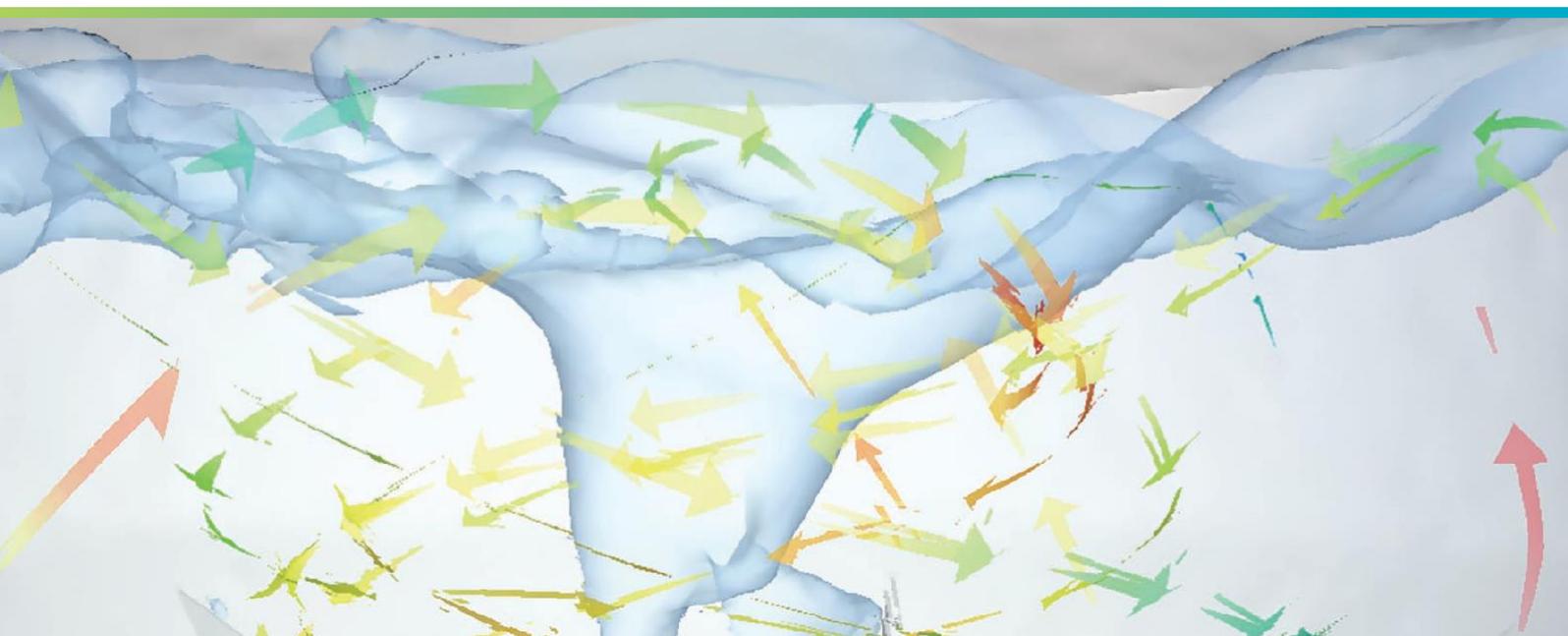


Ecological development of pulp preparation system with CFD DEM



Paper, which has been used for a variety of purposes since the birth of papyrus as a writing material in ancient Egypt, is undergoing a period of great change. Due to the trends of sustainability and digital transformation, contracts are being exchanged electronically and paper is no longer being used. What about newspapers and magazines? With the spread of smartphones and tablets, digitalised content is delivered to your gadgets, the number of print publications is decreasing, and it is not uncommon for the publications to be discontinued or closed.

On the other hand, facial tissues, paper towels, and toilet paper, which are consumed every day, are daily necessities and require a stable supply so the type of paper to recycle shifts. Some additional examples are that the straws provided at Starbucks, the coffee chain stores you may have often visited, are being phased out of plastic to paper as of January 2020¹. And you were probably less likely to go out during the widespread COVID-19 pandemic, so you've probably done your shopping on Amazon.com and received your order at home, wrapped in a recyclable cardboard box or plastic-free paper padded mailer². Possibly you might also have visited IKEA, with their Swedish named products, and found that all packing materials are made from paper and corrugated cardboard, as they aim to remove all plastic from consumer packing³.

These changes have been affecting not only the paper companies but also the paper equipment manufacturers that support them. While paper equipment manufacturers in Japan are going out of business or transferring their operations, there is a company that is taking on the challenges of the current era of change by streamlining its design and development. Founded in 1924 in Shizuoka Prefecture, Japan, AIKAWA Iron Works Co., Ltd is a long-established domestic pioneer that is celebrating its 98th anniversary this year. They also have subsidiaries in Finland and Canada, the major regions of the paper industry, and have now grown to 5 billion yen⁴ in sales (as of December 2019) and 255 employees (as of June 2021, in Japan only).

Before introducing their efforts in CFD (Computational Fluid Dynamics) analysis, I would like to briefly mention the paper manufacturing process. In the raw material conditioning process of papermaking, pulp fibres are obtained from wood chips and waste paper as raw materials are handled as slurry dissolved in water. Especially when recycled paper is used as the source material, it often contains, along with pulp fibres, garbage

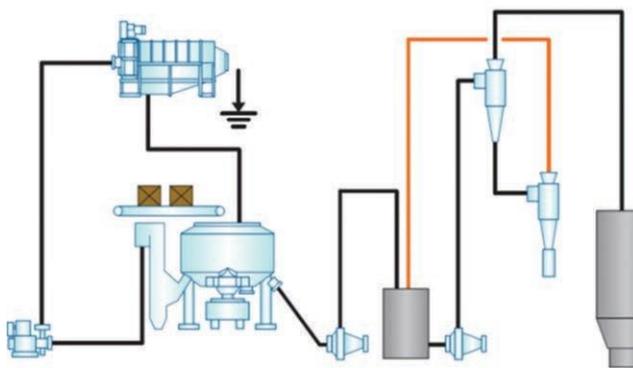


Figure 1: Okabe Plant, which is the primary manufacturing facility of AIKAWA Iron Works (completed in 2003)

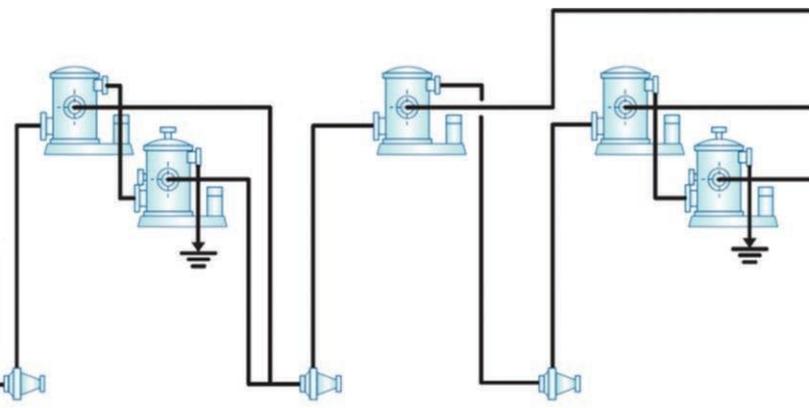
such as staple needles and plastic film, impurities such as ink, and adhesive materials such as stickers. Such raw materials are slurried by agitating them with water in a device called “Pulper system” in their entirety, and effective fibres and foreign matter are separated and sorted by a device called “Screen system” or “Cleaner system”. Before the papermaking process, one of the most important steps is the tapping process. This is an important process in which pulp fibres of various lengths and thicknesses are disintegrated in a device called “Refiner system” to make the final products, such as newspapers, magazines, corrugated cardboard, and tissue paper, suitable for their respective characteristics.

One of AIKAWA’s strengths is that they can provide onestop solutions for the pulp preparation equipment that

Low consistency Pulping System



Coarse Screen System



High consistency Cleaner

Figure 2: Overview of processing steps for recycled cardboard paper

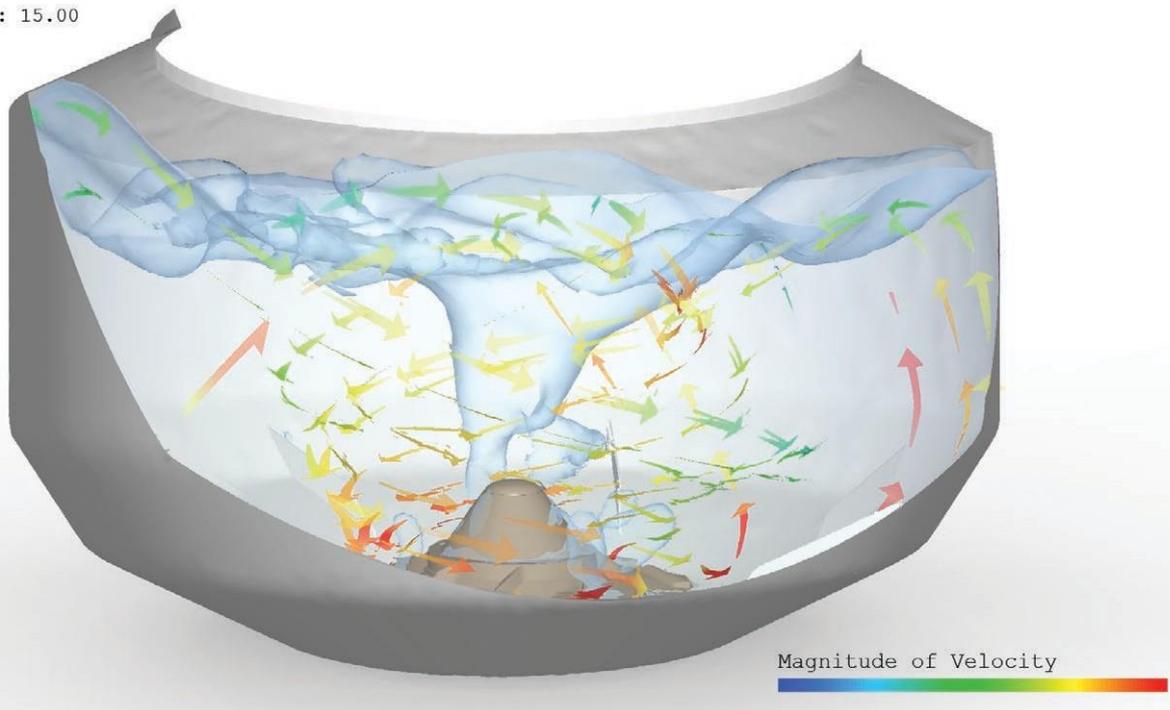


Figure 3: Analysis of pulper system

is indispensable for the paper manufacturing processes, and this time I would like to focus on the AIKAWA non-clogging pump (ANP) and the outward-type screen system (Figure 4).

They first implemented Cradle CFD back in July 2018. Originally, they had installed another CFD software, but that software did not have a free surface analysis function and could not reproduce the interface (vortex) of the raw material slurry caused by the rotation of the rotor in the pulper system (raw material tank). The problem was solved by using the free surface analysis function implemented in scTetra at that time, and that was the beginning of their success story that we will introduce to you now.

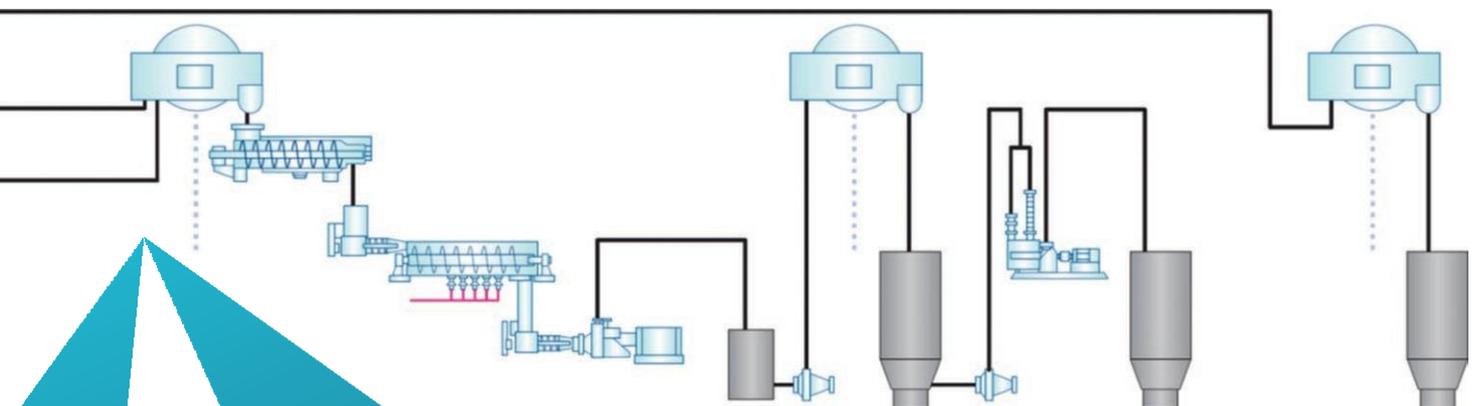
“ Using scFLOW, we have been able to narrow down the models to be prototyped from among the design candidates, and we have been able to shorten the development period from six months to one month for some models.

Mr. Hideo Horiike,
Product Development division,
AIKAWA Iron Works

High consistency Refiner System

Low consistency Refiner System

Finished stock (Back-Layer)



Finished stock (Under-Top)



Figure 4: AIKAWA non-clogging pump

They have now used the fabric model of DEM (Discrete Element Method) capabilities in scFLOW to simulate the inside of the pump more faithfully by reproducing various foreign particles as shown in Figure 5. The fabric model can be used to model string-like and cloth-like objects by connecting DEM particles with parameters such as spring stiffness.



Figure 5: Actual foreign objects

Mr. Fujita, Director & Senior Managing Executive Officer, said, “Continuous operation of the non-clogging pump is essential for efficient removal of foreign matter from the pulper. How to transport the raw material without clogging is important in the design. If it clogs, you need to stop the paper production line and clear the clog. If you shut down the line, in the worst case, you lose half of the production capacity.” For this reason, they use scFLOW’s DEM function to visualise the flow of waste (Figure 6) and the process of blockage, and to narrow down the design plan that is less likely to cause blockage. Mr. Horiike, who plays a central role in their CFD analysis, says, “Using scFLOW, we have been able to narrow down the models to be prototyped from among the design candidates, and we have been able to shorten the development period from six months to one month for some models. Reducing the number of prototypes also led to a one-tenth reduction in the cost of raw materials, water, and electricity for the evaluation tests, but most importantly, the development costs required to repeatedly modify prototypes have been greatly reduced.”

Next, I would like to introduce the screen system (Figure 7). Inside this device is a rotating body called “Screen rotor”, and between the rotor and the casing is the structure with fine gaps (basket bar) called “Screen cylinder (basket)”. In the case of the model introduced here, the flow field is generated toward the casing side, so that effective fibres can pass through the gap between the basket bars while the negative pressure generated from the rotation of the rotor prevents blockage due to foreign matter.

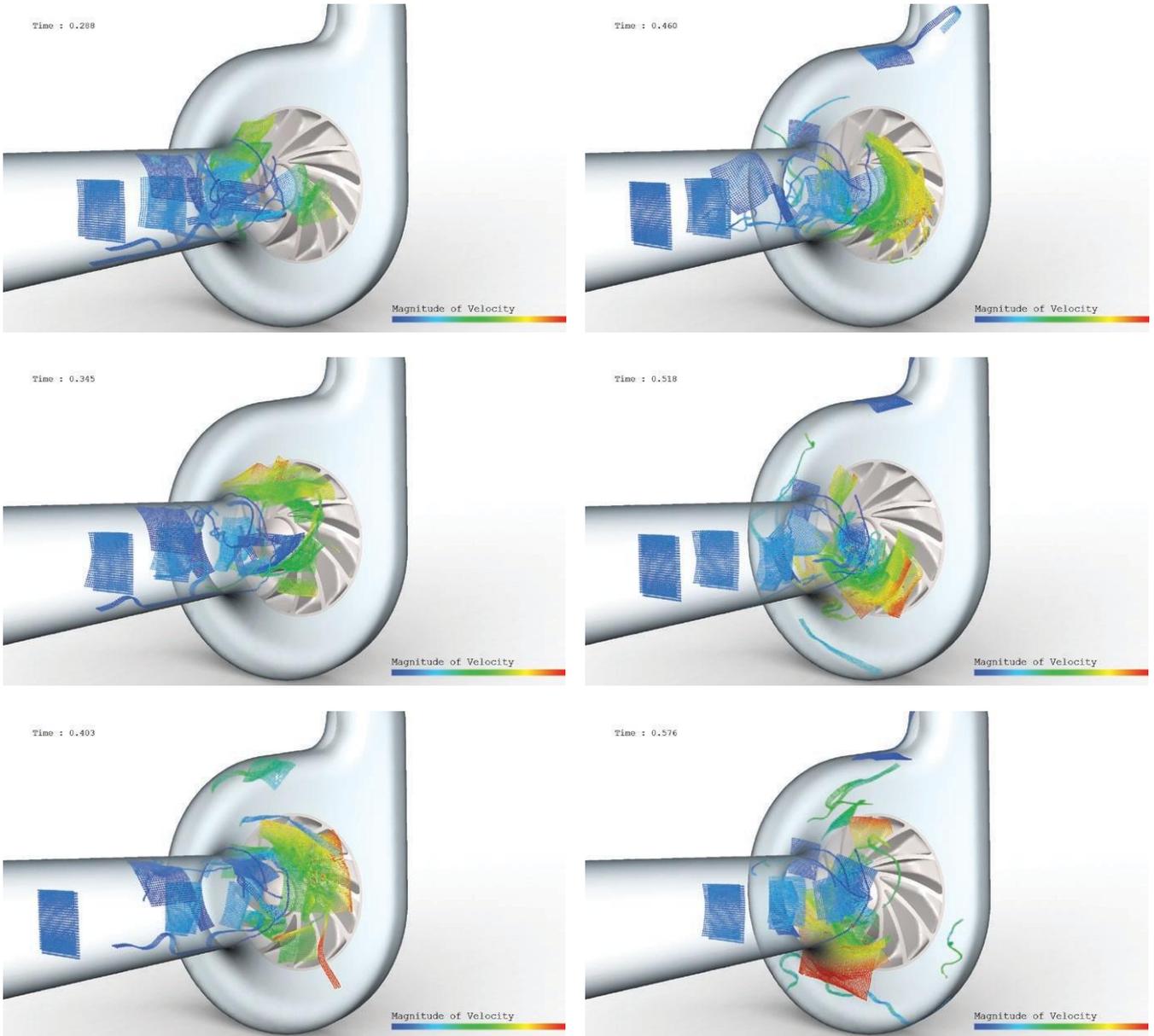


Figure 6: Foreign matter in the non-clogging pump before design improvement

Before analysing the entire system, they determined the pressure drop over the bar gaps and used it as a pressure drop model in the overall analysis. In this way, the computational load per analysis is reduced, and the entire analysis (about 1 million elements) can be completed in one to two days by simulating with 44 cores in parallel, even though it is a largescale transient analysis with a resolution time of more than 20 seconds. Figure 8 shows the results of the overall analysis. It shows that heavy particles tend to move to the lower part of the equipment and light particles tend to move to the upper part of the equipment, where they are called rejects. This trend is consistent with the experimental observations at the AIKAWA test facility. The effective fibres passing through the bar gaps were also analysed separately using the DEM function, as shown in Figure 9.



Figure 7: Appearance of outward-type screen system

Time : 10.0

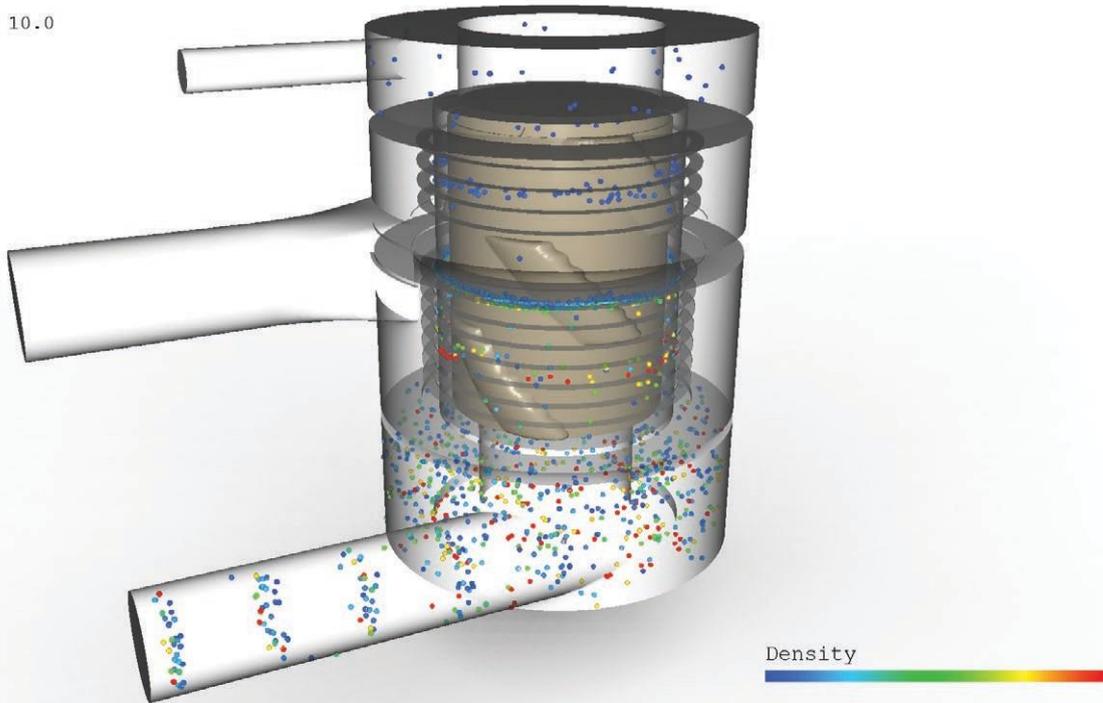


Figure 8: Analysis of the entire system using particle tracking before design improvement

With respect to the fact that scFLOW has already been widely applied to the development of other equipment such as refiner systems at AIKAWA Iron Works Co., Ltd, we asked them about the prospects of their analysis. Mr. Horiike said, "The apparent viscosity of the raw material varies with the final product and with the season. Therefore, we would like to visualise the flow inside the equipment of raw materials mixed with different pulps using the dispersed multiphase flow function." The mixing

of raw materials with different properties means different agitation and sorting by the rotor, and the power required to operate the rotor is also expected to change. The paper industry has long been environmentally conscious in terms of recycling and reusing raw materials, and AIKAWA Iron Works Co., Ltd is continuing to develop the technology to achieve even greater sustainability through energy conservation and higher efficiency in the paper manufacturing process.

Time : 0.0200

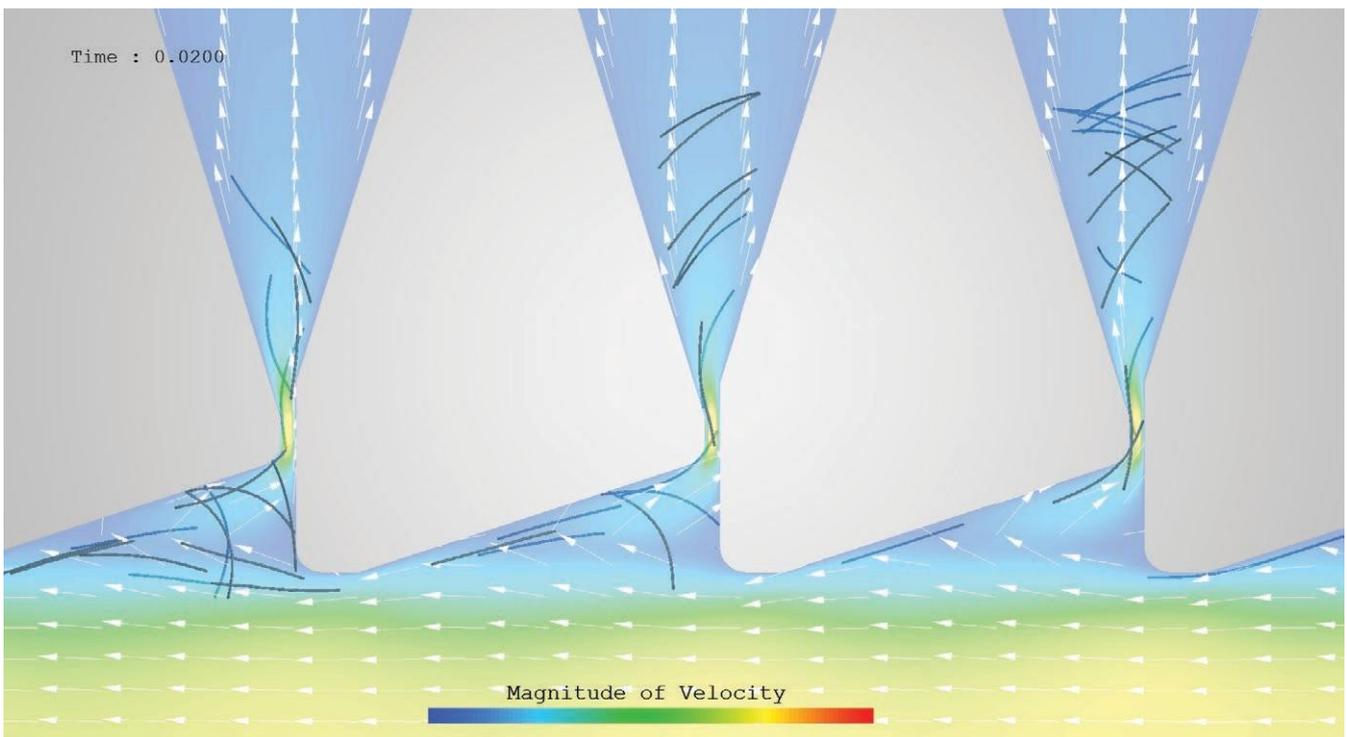


Figure 9: Effective fibres passing through the bar gaps

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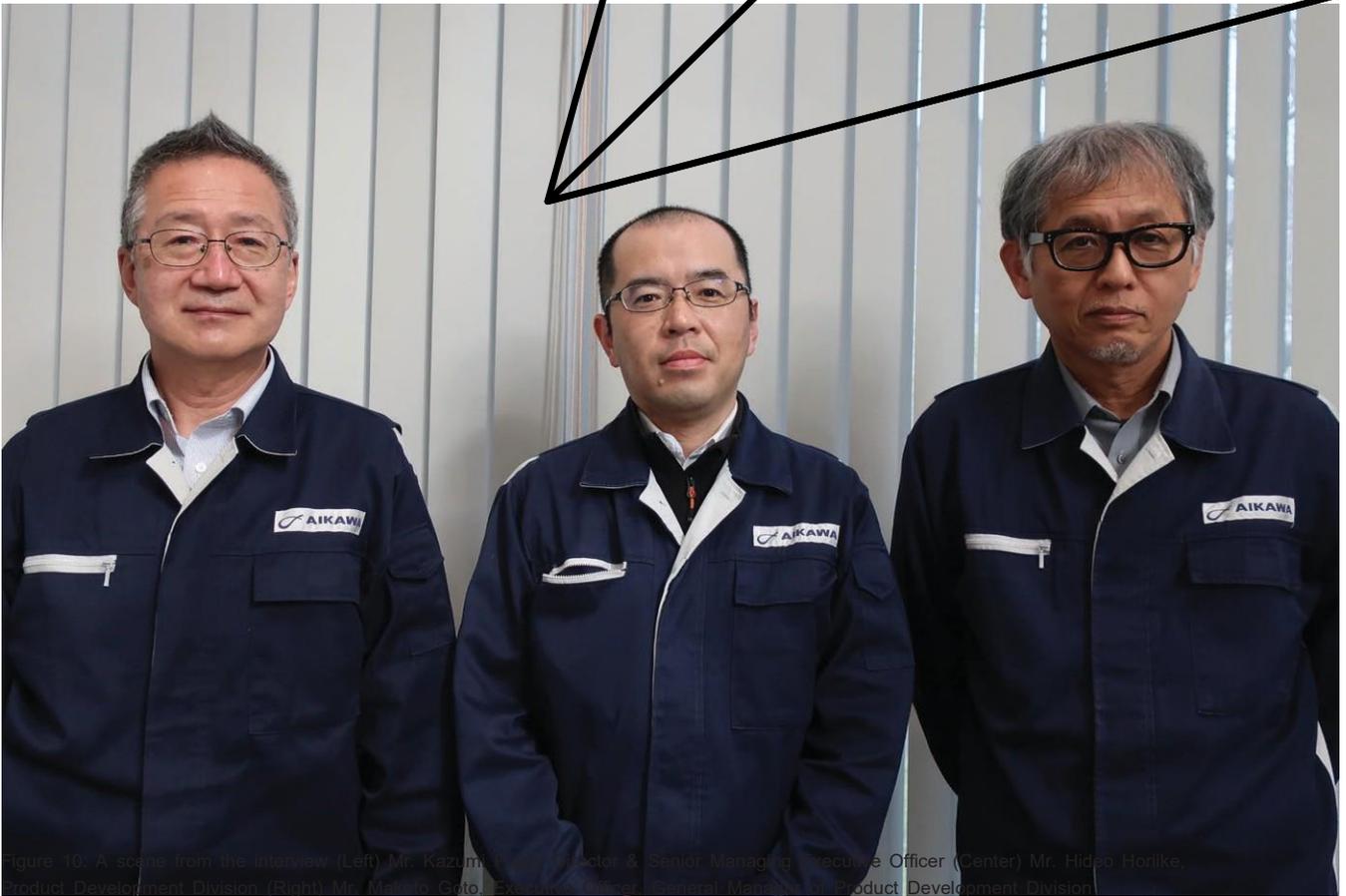


Figure 10: A scene from the interview (Left) Mr. Kazumi Kato, Director & Senior Managing Executive Officer (Center) Mr. Hideto Horike, Product Development Division (Right) Mr. Masao Orito, Environmental Management, Product Development Division

Reference:

- 1 Starbucks Source: <https://stories.starbucks.com/press/2019/starbucks-eliminatesplastic-straws-in-japan-beginning-january-2020/>
- 2 Amazon Source: <https://sustainability.aboutamazon.com/environment/circulareconomy/packaging>
- 3 IKEA Source: <https://about.ikea.com/en/newsroom/2021/11/17/ikea-to-phase-outplastic-from-consumer-packaging-by-2028>
- 4 Approximate 46 million USD or 41 million Euro with the exchange rates of April 2022.

