New Large Resin Mixer, LCM-620IM

Kazuo YAMAGUCHI*1

*1 Industrial Machinery Engineering Department, Industrial Machinery Unit, Machinery Business

Abstract

The largest-ever LCM-620IM continuous mixer for polyethylene resins has been developed, and the first unit was shipped in 2024. This machine has a production capacity of over 100 tonnes per hour, improving production efficiency. By applying intermeshing rotor technology to a commercial mixer for the first time, this mixer achieves the same or better mixing performance with 12% less energy consumption compared with our company's conventional machines. In response to the increasing volume of polyolefin production, improving the mixing performance and production capacity will contribute to reducing CO_2 emissions and achieving a carbon-neutral society. A customer has also placed an order for the LCM-560IM and its intermeshing rotor technology is highly regarded in the industry.

Introduction

The annual global production of commodity polyolefins such as polypropylene and polyethylene has increased year over year. As such, in pursuit of improved production efficiency, production plants have increased the capacity per production line year on year. Kobe Steel manufactures the LCM™ series of large continuous mixing and pelletizing systems that are the nucleus of these production lines. We have developed and shipped the first unit of the LCM-620IM, the largest in the series with a nominal mixing shaft diameter of 620 mm, to meet the needs for larger production lines.

The LCM-620IM is not only the largest of its kind, but also the first commercial machine in the series with intermeshing rotor technology. This innovation reduces energy consumption in polyethylene production, furthering progress toward a carbon-neutral society. This paper introduces the LCM-620IM large continuous mixer.

1. Mixer size specifications

Equipment throughput has increased in recent years in support of more economical polyolefin pellet production. Annual per-plant throughput has increased from 400,000 metric tons/year in the 2010s to a range of 500,000 to 650,000 metric tons/year in the 2020s. Plans are underway to increase this figure to more than 800,000 metric tons/year in the future.

In the 1980s, Kobe Steel introduced the LCM™ series of large continuous mixers with combined gear pump in the size designation of 380 (LCM-380G), indicating a nominal mixing shaft diameter of 380 mm. Ever since, we have developed larger mixers roughly every 10 years to meet market needs: the 450 in the 1990s (LCM-450H), the 500 in the 2000s (LCM-500H), and the 560 in 2013 (LCM-560H). We released the 620 (LCM-620IM) in 2022 and shipped the first unit in 2024. **Fig. 1** shows the LCM™ pelletizer system. **Fig. 2** shows the change in production rate per unit of the LCM™ series over time. The launch of the LCM-380G spurred an accelerated pace of increases in capacity, owing to the pressure boosting technology of a gear pump downstream of the mixer. This development greatly increased the efficiency of polyolefin production worldwide.

Fig. 3 shows an external photograph of the LCM-620IM. Intermeshing biaxial mixing rotors turn in opposite directions in the chamber of the LCM™ to efficiently melt and mix polyethylene powder.

Over the past 30 years, each model in the LCM™ series has incorporated design improvements

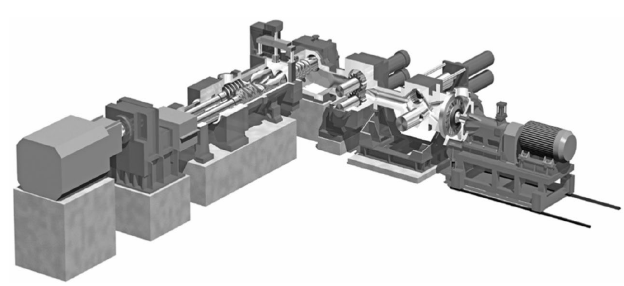

Fig. 1 LCM pelletizer unit overview

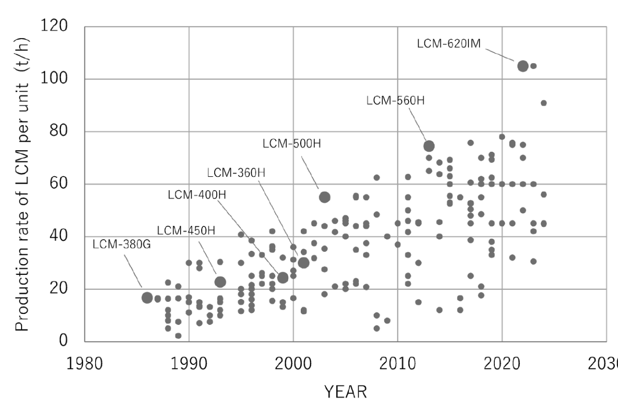

Fig. 2 Transitions of LCM production rate per unit

to accompany an increase in size. The LCM-G series had twin mixing rotors at a 45-degree angle, the LCM-H series featured horizontally aligned twin rotors alongside increased motor power and shaft torque, and the LCM-IM series introduced intermeshing rotors for increased power and improved mixing performance.

The LCM-620IM large continuous mixer is the largest ever of the series with its 620 size rotor shaft, which is about 10% larger than the 560 rotor that previously held this title. **Table 1** shows the specifications of each size class of LCM. The 10-meter mixing rotor makes the LCM-620 the world's largest continuous mixer. With a 13% increase in power over the LCM-560's rating of 23 MW, the 26 MW rating of the 620 results in an increased production capacity that can yield 100 metric tons or more of high-density polyethylene (HDPE) pellets per hour.

There was initial hesitation before the first customer agreed to purchase the largest continuous mixer ever. However, they were at ease after recognizing not only the machine's mixing performance, but also Kobe Steel's track record of reliable equipment and strong customer service as well as our machine production and operating record of around 300 units of 560 and smaller models.

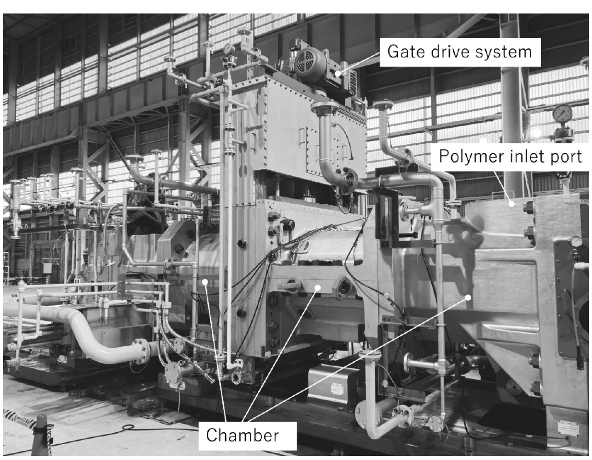

Fig. 3 LCM-620IM overview

Table 1 Main specifications of LCM

Model No.	Power (kW)	Rotor speed (rpm)	Rotor diameter (approx. mm)	Rotor length (approx. mm)	Typical production rate (ton/hour)
LCM-360	9,600	550	360	5,800	48
LCM-400	11,800	500	400	6,300	59
LCM-450	15,000	440	450	7,100	75
LCM-500	18,000	400	500	7,800	90
LCM-560	23,100	360	560	9,100	116
LCM-620	26,300	320	620	10,000	132

2. Mixer performance

One of the main components of the resin manufacturing process is the reactor, which produces resin powder. The large continuous mixer downstream of the reactor then begins the pelletizing process by melting and mixing resin powder, homogenizing the polymer with a specific molecular weight distribution. The equipment in this process is also sometimes responsible for uniformly mixing in additives.

Recent years have seen an increase in the development and production of bimodal HDPE resin, owing to its good formability alongside its superior durability and strength that yield a long service life. However, some grades of high-performance HDPE resin present greater challenges in homogenization and mixing compared with conventional materials. This is because the constituents of their raw powders do not easily compound into a homogeneous mixture. Such grades have peaks in the high and low ranges of the molecular weight distribution. As a result, clumps of high-molecular-weight PE are dispersed throughout a matrix of low-molecular-weight PE. The force of mechanical mixing does not readily transmit to the high-molecular-weight PE, inhibiting the dispersion of the high-molecular-weight components. More energy is then generally needed during mixing to achieve sufficient dispersion.

To produce these mix-resistant materials with less energy, our newly developed mixer has the intermeshing rotor technology with optimized geometry as detailed in an earlier issue of the Kobe Steel Engineering Report.[1)] **Fig. 4** shows the rotor configurations described next. In contrast to the conventional LCM-H series, the LCM-IM series features a larger rotor diameter in the downstream second mixing zone (D_2). This yields the relationships ($D_1 < D_2$) and (rotor diameter > shaft center distance) and thus a dimensional

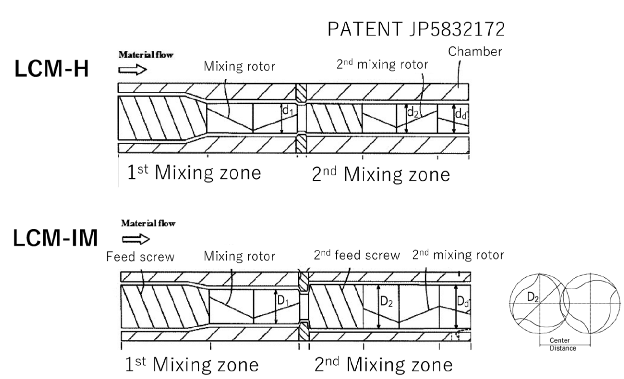

Fig. 4 Rotor configurations of LCM-H and LCM-IM

relationship in which the rotor lobes of the two abutting shafts intermesh with each other.

When we received the order for the first 620, we ran laboratory-scale testing of the new intermeshing rotor technology for the first time, with the customer present. The machine passed the mixing performance test and performed very well in terms of energy efficiency in particular.

One step in the process of melting and mixing HDPE resin powder is to disperse the non-dispersed polymer clumps (hereafter, "gel") to the required level. However, the specific energy input (SEI), or energy consumption, of the mixing process must be low. In developing the geometry of the intermeshing rotor, we used mixing performance evaluation technology based on Kobe Steel's proprietary flow dynamics simulation software.[2), 3)]

We conducted basic mixing tests to analyze the factors affecting gel dispersion and energy consumption of the LCM™ in detail. Furthermore, we ran simulations to find the rotor geometry that optimizes both gel dispersion and energy conservation.

Fig. 5 shows an example of a simulation used to evaluate mixing performance. The contour color (grayscale in this paper) indicates the stress level. We tuned the parameters of the rotor geometry to yield a stress distribution with larger areas of high stress, corresponding to high gel dispersion efficiency, and smaller areas of low stress, corresponding to low gel dispersion efficiency.

Fig. 6 shows the results of the mixing performance test using the simulated material in the lab-scale mixer. The simulated material was a blend of general-purpose polyethylene and ultra-high-molecular-weight polyethylene. The results confirm that the dispersion of ultra-high-molecular-weight polyethylene in general-purpose polyethylene during mixing correlates with the dispersion of the high-molecular-weight component in bimodal polyethylene. We evaluated the degree of dispersion based on the amount of white spots (hereafter, WSA: white spot area ratio), regarded as incomplete dispersion, when carbon was added and dispersed. A lower WSA (%) indicates higher quality. Fig. 6 shows the relationship between mixing quality and SEI for the conventional rotor and the intermeshing rotor, with SEI on the horizontal axis and WSA on the vertical axis. While the conventional LCM™ mixing rotor consumes 0.33 kWh/kg to achieve a WSA of 1%, the LCM-IM-series intermeshing rotor consumes only 0.29 kWh/kg for the same WSA, indicating a 12% reduction in SEI.

Lab-scale mixing performance testing using the customer's polyethylene also confirmed that

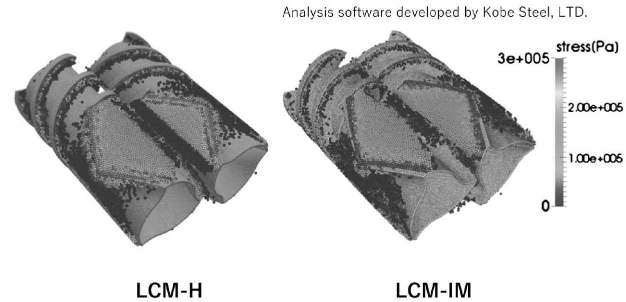

Fig. 5 Mixing stress contour by flow dynamics simulation

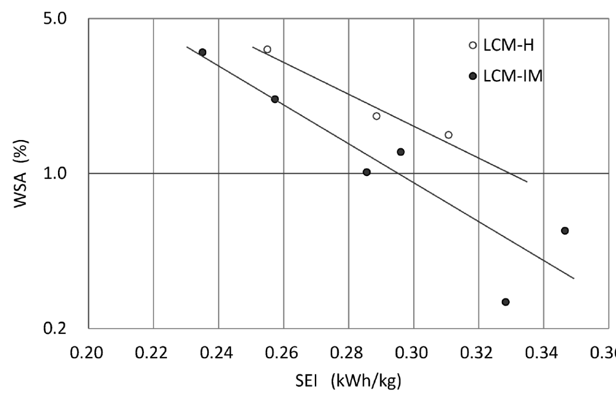

Fig. 6 WSA depending on SEI by LCM-H mixing and LCM-IM mixing

the intermeshing rotor technology required a significantly lower SEI for gel dispersion than did the conventional LCM™ mixing rotors. This was the deciding factor in securing the order.

The customer anticipates reduced SEI in the pellet production process after LCM-620IM installation. Assuming an annual resin production of 300,000 metric tons/year, an SEI reduction of 0.040 kWh/kg yields the calculation 300,000 metric tons/year × 0.040 kWh/kg = 12,000 MWh/year of energy savings. This amounts to a substantial reduction in energy, cost, and carbon emissions. The enhanced mixing performance and reduced SEI described are expected to be validated after operation begins in 2026.

3. Manufacture of the machine

The challenge in manufacturing the largest continuous mixer is the size itself. It is necessary to use technology for manufacturing large cast and forged parts with high quality. The largest machining and polishing equipment available must be used, and in inventive ways. Furthermore, the assembly and testing of such massive equipment require advanced manufacturing techniques and expertise. The success of producing the first of these large machines was built upon involving manufacturing engineering in the design phase and thoroughly reviewing each production step in advance.

4. Vibration analysis

Numerous technical aspects must be considered when designing the largest continuous mixer to ensure reliability, including component strength, the heating and cooling performance of the mixer, pressure loss in the flow channels for molten material, and each part's sealing performance. This section covers the particularly critical concern of mechanical vibration.

Large mixers experience extreme levels of vibration. When the mixing lobes of the rotor mix highly viscous polyethylene, the frequency of the reaction force is a multiple of the number of lobes, causing fluctuations in the mixing load. Since there was concern that the new larger machine would experience more vibration, we conducted vibration analysis during the machine design phase to ensure vibration would not exceed the permissible value.

We used laboratory equipment to measure the mixing load generated at the rotor. Specifically, we measured the load, the magnitude of fluctuations in load, and the frequency at which the fluctuations occurred. For the vibration analysis, we scaled up the mixing load of the lab-scale experiment to the mixing load of the production machine, accurately simulating the excitation frequency and the phase of the mixing load as generated by the two rotors. The analysis software used was Abaqus.

The simulation confirmed that the vibration level is permissible for the 620-size mixer. **Fig. 7** shows the mesh model used for vibration simulation via FEM analysis. **Fig. 8** shows an example of the program output from an analysis of equipment deformation caused by vibration due to the reaction force of mixing resin. We extracted the necessary information from depictions of deformation such as these for each vibration mode to increase component rigidity in areas with a high degree of deformation. As a result, we were able to suppress the overall vibration level.

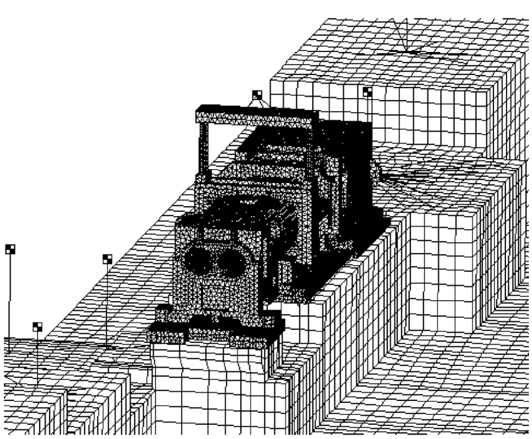

Fig. 7 LCM-IM chamber vibration analysis model

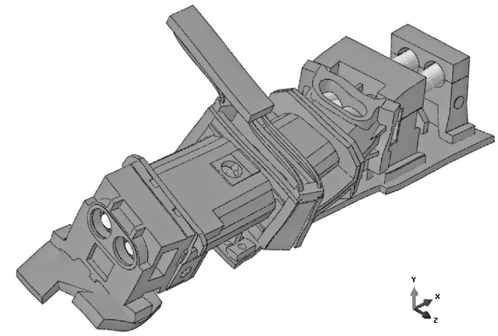

Fig. 8 LCM-IM chamber vibration analysis result

Conclusions

Kobe Steel launched and delivered the LCM-620IM, the company's largest-ever mixing and pelletizing system, in response to market needs for improved efficiency, energy conservation, and dispersion in polyethylene production. This machine has the new intermeshing rotor technology, which enables economical production of polyethylene pellets by consuming less energy than the conventional LCM™. Around the time of this development, another customer ordered an LCM-560IM with the same intermeshing rotor technology, validating the energy-saving capacity of Kobe Steel's intermeshing rotor technology. We anticipate the wide adoption of this technology.

We will continue the timely development and delivery of large continuous mixers with improved energy efficiency and dispersion performance for new high-performance materials developed by polyolefin producers. In this way, we will help reduce carbon emissions from the production and disposal of plastics, thereby fostering progress toward a carbon-neutral society.

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