Latest technology innovation for counter rotating continuous mixer

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Abstract

The new generation continuous mixer has been developed in response to Bi-modal HDPE property progressions, this by means of a new mixing concept, which has been studied and realized through empirical experiments. By using the developed continuous mixer, the gel number and gel size of film samples have exhibited improved film appearance. The White Spot Area (WSA), a method used for evaluation of pipe grades with black pigment, has also been improved.

Introduction

Although the basic concept of the continuous mixer for the polyolefin post-reactor extruder/pelletizer has not been changed significantly from the original mixer configuration, mixing and homogeneity performance, especially for Bi-modal HDPE extrusion, has been largely improved by 1) longer L/D, 2) applying a gate valve, and 3) rotor geometry optimization [1].

In the latest conferences, homogeneity performance advantages of the counter rotating Long Continuous Mixer (LCM) compared with co-rotating Twin Screw Extruder (TSE) were presented [2], and an investigation of the mixing mechanism difference between LCM and TSE has been attempted by a numerical analysis [3].

In recent years Bi-modal HDPE has been polymerized with broader molecular weight distribution and 1-Hexene (C6) instead of 1-Butene (C4) has been applied as a co-monomer component in order to improve the post-extrusion processability and the strength of the final product.

However both modifications have brought about difficulties from the point of view of homogenization.

The new generation continuous mixer has been developed to respond to the above Bi-modal HDPE progress by means of a new mixing concept, which has been studied and obtained through basic experiments using a two-dimensional test mixer. And these obtained operation and mixing performance data from two-dimensional mixer have been applied to the development of a new generation continuous mixer.

This paper introduces improvements in the mixing performance of bi-modal HDPE extrusion by a new generation continuous mixer.

1. 1 Two-dimensional test mixer experiment

The schematic view of the two-dimensional test mixer is shown in Fig. 1 [1], that is composed of i) mixer barrel, ii) twin rotor counter rotating elements, the various dimensions of which may be changed by varying the element sets, and iii) main motor, which is connected through gear reducer to the twin rotor mixing elements. Motor speed can be controlled variably and the torque and the power could be measured during the experimental operation.

Bi-modal HDPE powder, 2.25 wt% of Carbon black and an appropriate amount of anti-oxidant were mixed by the two-dimensional test mixer.

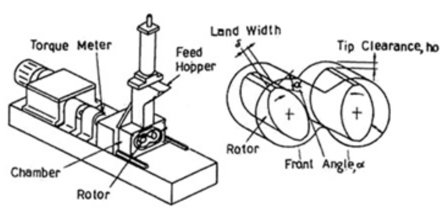

Fig.1 Two-dimensional test mixer

1. 2 Two-dimensional mixer experiment results

The positive effects of rotor dimensions for Bi-modal HDPE mixing homogeneity performance were investigated. Rotor element dimensions, which were a) Tip clearance, b) Rotor front angle, and c) Tip land width, were varied. Additionally the new concept rotor shape was introduced to the experiments. The rotor element dimension matrix is shown in Table 1.

Mixing performances of each of the different mixing elements and mixing conditions were evaluated by WSA (White Spot Area; [%]) measurement, which were observed and calculated from a total white spot area, versus well mixed black background in the microscope views. Ten (10) small samples, which were sliced from respective tested mixtures, of 20 micron thickness by the Microtome, were measured.

Table 1 Various rotor element dimensions matrix

		Front angle			Land width	New concept shape
		Small	STD	Large	Large	
Tip clearance	Narrow	Rotor # 15A	Rotor # 15B	Rotor # 15C	Rotor # 15L	Rotor # 15P
	STD	Rotor # 15E	Rotor # 15F [STD]	Rotor # 15G	Rotor # 15M	Rotor # 15Q
	Wide	Rotor # 15H	Rotor # 15J	Rotor # 15K	Rotor # 15N	Rotor # 15R

Among rotor element code numbers from '15A' to '15N', the best mixing performance, that showed smallest WSA value with shortest mixing time, was by the rotor code '15F' element. In fact, the '15F' 2D shape has already been applied for the MIXTRON™ LCM series of KOBE STEEL, LTD.

New mixing concept element profiles were also tested using 2-D mixer and interesting WSA evaluation results were obtained. Fig. 3 shows the relation between mixing time and WSA [%] evaluation by the standard 2D profile of '15F' element and the new concept 2D profile of '15Q' element.

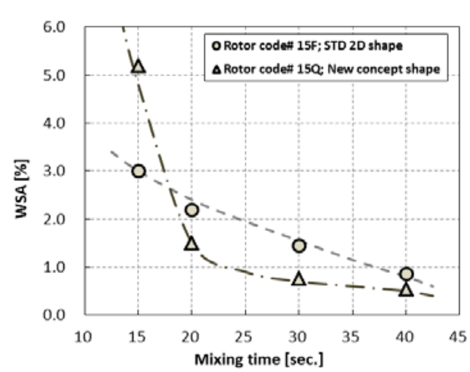

Fig.3 WSA reduction by mixing time

Until 15 seconds of mixing time, the 15F rotor profile provided better homogeneity performance than the 15Q rotor profile. After 20 seconds of mixing time, the 15Q rotor profile brought about better mixing performance than 15F rotor profile. The mixing performance features of respective rotor profiles are summarized in Table 2, below.

Table 2 Respective rotor features

	Melting performance	Mixing performance
15F profile	+ +	+
15Q profile	+	+ +

+ + superior performance

+ standard performance

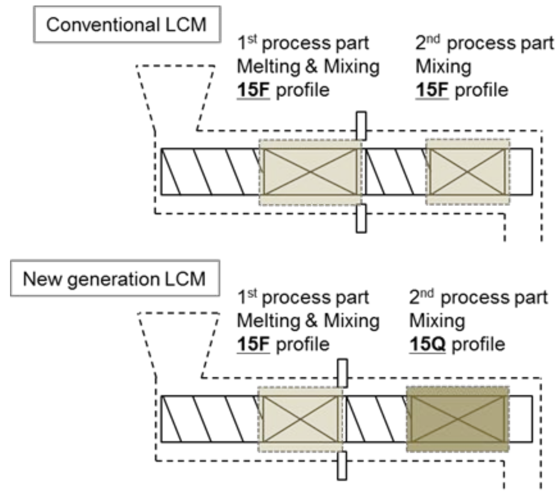

Fig. 4 Comparison between conventional LCM and new generation LCM

2.1 Continuous mixer development

The results from the two-dimensional test mixer suggested how to apply and arrange both rotor profiles to the continuous mixer.

The MIXTRON™ LCM is a two stage continuous mixer, in which the respective process parts have independent and different functions. Major role of the 1st process part is melting and mixing, while the role of 2nd process part is mainly mixing. The '15F' profile rotor has been applied to both the 1st and the 2nd process parts for the conventional LCM mixer.

The new generation LCM applies the '15Q' profile in the 2nd process part. The 1st process part should keep the 15F profile, because the 15F profile provides superior melting performance. Now, Fig. 4 is a schematic view, which compares the conventional LCM and the new generation LCM.

2.2 Mixing performance of new generation LCM

Mixing tests were performed on the newly designed continuous mixer MIXTRON™ LCM-IM (Intensive Mixing) to confirm improvement of the homogeneity performance. Bi-modal HDPE pipe grade without black pigment was used. Homogeneity performance was evaluated by film appearance, which was investigated by on-line gel analyzer (made by OCS GmbH, Germany) on cast film appearances.

Fig. 5 shows the relationship between total gel area [ppm] and SEI [kwh/kg] depending on the types of LCM. A significant improvement of LCM-IM was not observed below 0.230 kWh/kg of SEI, however for SEI above 0.230 kWh/kg regions, the LCM-IM the reduction in the gel number was dramatic. The mixing performance comparison result from both continuous mixers agreed well with the result from two-dimensional test behaviors.

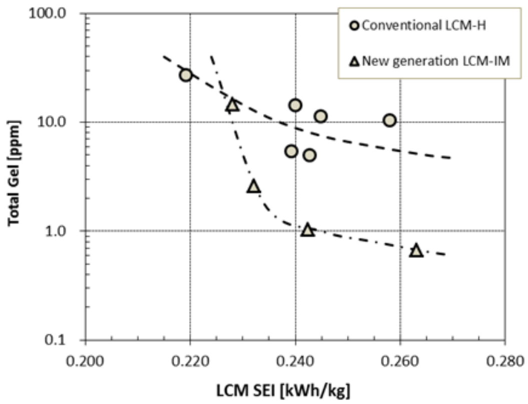

Fig.5 Gel reduction in casting film by mixer SEI

3. Summaries

Improvement of homogeneity performance has been confirmed through lab trials.

The significant development concepts of LCM-IM are not only superior mixing performance but also “easy retro fitting” to existing LCM-H lines. L/D of both the LCM-H and the LCM-IM is 8.0. Moreover adjusted raw material feed point / mixer support foot-print and the same rotor center-distance mean that rotor replacement may be implemented easily. Users of the LCM-H are able to re-use their existing ‘main motor, melt pump system, screen changer and under water pelletizer system’. Such easy retro fitting policy promises minimized replacement down time of the production line.

4. Reference

[1] Inoue, K. et al., Kobe Steel Engineering Report 44, 53 (1994).

[2] Yamaguchi, K. et al., SPE International Polyolefins Conference, Houston, TX, USA (2015).

[3] Sekiyama, K. et al., SPE International Polyolefins Conference, Houston, TX, USA (2016).