VIC internal mixer · intermeshing rotors · filler dispersion · single stage process

A particular mixing technology for the production of sophisticated compounds is presented. The compounds are mixed in a VIC internal mixer, equipped with intermeshing rotors which can vary the distance between the rotors, allowing a better dispersion of the fillers and an outstanding quality level of the final compound in a single mixing stage. The cooling capacity of the mixer enhances the temperature control of the rubber and enables to process the compound in a single stage, using a nearly isothermic condition when loading and mixing the curing agent. A stock discharge temperature in a range of 100–110°C can easily be maintained.

Three different compounds, based on EPDM or SBR or NBR rubber, have been considered and the results in term of mixing quality and productivity is presented.

Intermeshing Rotor with Variable Clearance to Mix Compounds

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Mixing is the way to put together different raw materials to get a final compound that is substantially different from the initial single components, but absolutely homogeneous as far as its physical and chemical properties are concerned. To achieve a good mixing two main actions take place simultaneously.

- DISPERSIVE MIXING: reduction of the particle size and incorporation in the rubber matrix.
- DISTRIBUTIVE MIXING: uniform and complete distribution of the particles within the batch.

In a tangential mixer the shear action takes place between the rotor tip and the chamber wall and the shear rate value involved is quite high due to the relevant difference between the peripheral speed of the rotor and the static condition of the mixer wall (Fig. 1).

Tangential mixer

In 1934, a significant modification in internal mixer design was made by Rupert Cooke. He patented the first mixer with intermeshing rotors. Even today, intermeshing style mixers represent a unique alternative to the standard tangential style mixers in rubber compounding technology.

In the intermeshing mixers the shear values that ensure processing of the rubber is produced between the rotors, rather than between the chamber and the rotors, as it takes place in tangential-type machines, therefore the shear rate is much lower, since the difference between the peripheral speed of the tips of one rotor and that of the root of the other rotor is to be considered. From the above statement it becomes evident that the possibility of varying the clearance between the rotors in an intermeshing-type mixer gives the opportu-
nity to increase the value of the shear rate. Massif efforts have been made by our company to solve this problem and finally in 1988 the results was a new intermeshing mixer called VIC with one operating variable that no other internal mixer has; this is the ability to vary the clearance between the rotors.

The letters VIC in fact stand for:

V ARIABLE
I NTERMESHING
C LEARANCE

Intermeshing mixer with variable clearance between the rotors.

This means that the VIC has this additional operating variable that by reducing the clearance between the rotors surfaces improves the value of the shear rate (Fig. 2).

VIC: the latest improvement in the intermeshing rotors technology

The ability of the VIC mixer to adjust the clearance between the rotors leads to significant advantages such as:

- Faster loading
- Viscosity control
- Energy saving

Faster loading

Enlarged rotor clearance allows faster raw material intake, reducing mixing time.

The gap variation creates various dynamic volumes inside the mixing chamber, producing different filling factors. The mixer with intermeshing rotors is acting as a gear pump (mainly at the first stage of the mixing cycle). Its tendency is to move all the batch to the upper part of the mixing chamber. From that position the batch is forced through the rotors and larger is the gap, larger is the possibility to clear the upper part, allowing the ram to the lower final position. It has been noted that with the minimum gap the ram lowering is much slower. The trials done have shown the advantage to start the mixing cycle with large gap; the time saving in this part of the mixing cycle may reach 30 seconds or even more if the batch has a bulky volume. The experience so far obtained allows us to state that in general it is better to start the cycle with the maximum clearance, so as to decrease the incorporation time of the ingredients, and to reduce it during the final stage, when the temperature of the compound must be kept under control and the ingredients dispersion further improved.

Viscosity control

Mooney viscosity can be controlled during the mastication of the natural rubber simply varying the rotor clearance value. So doing you can skip one stage mixing with natural rubber compounds, such as the tire tread, obtaining the same final viscosity as the tangential rotors, but increasing productivity.

In fact we experienced that different values of the rotor clearance give different values of the final rubber viscosity, after mastication, being constant all the other mixing parameters.

On a VIC 275 (180 litres net capacity) a natural rubber SMR 10 has been masticated as follows:

<table>
<thead>
<tr>
<th>TIME</th>
<th>OPERATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 secs.</td>
<td>Rubber loading.</td>
</tr>
<tr>
<td>20 secs.</td>
<td>Ram ↓ bottom position.</td>
</tr>
<tr>
<td>165 secs.</td>
<td>Dump</td>
</tr>
</tbody>
</table>

The maximum clearance was able to transfer to the rubber a double amount of energy compared to the energy transfered with the minimum clearance. In fact the Mooney viscosity of the rubber has been reduced from 104 to 96 using the minimum rotor clearance and down to 86 using the maximum rotor clearance (Tab. 1).

Energy saving

One of the main goal of a mixer is to achieve a perfect mixing together with a good dispersion and a low energy input. Tangential rotors, due the reduced metallic surface area in contact with the batch are able to transmit lower energy input than intermeshing rotors (Fig. 3) and under this point of view they are energy saving rotors. Therefore to reduce the energy input using intermeshing rotors it is necessary to reduce the mixing time accordingly, maintaining the same compound quality level. This is possible again for the above mentioned reason. Thanks to the higher heat exchange surface the compound temperature is lower with intermeshing rotors than with the tangential, viscosity is consequently higher and a good dispersion of the fillers in the rubber is faster achieved. Therefore you can sooner dump the batch with a reduced energy input.

Anyhow a massive energy saving can be obtained only reducing the number of mixing stages. This can be done with a flexible machine, enabling to split the energy input action and the cooling action.
Today’s mixer flexibility is assured by a D.C. motor with variable rotor speed and by a variable ram pressure. However, increasing the rotor speed or the ram pressure will increase the energy input and the batch temperature as well. The only way possible to manage separately the two parameters is varying the rotor clearance and consequently the dynamic volume of the mixer chamber. By reducing the rotor clearance without changing the rpm you reduce the temperature rising of the batch, maintaining the good quality level of the compound. In fact, when the gap between the rotors is smaller the gap between the rotors and the sides opposite is larger, and this is the area where the shear is minimum and the heat exchange is maximum. The gap variation affects the dispersion of carbon black and/or other ingredients as follows:
- better dispersion with minimum gap if the batch is a low viscosity compound (< 60 Mooney);
- better dispersion with maximum gap if the batch is a high viscosity compound (> 80 Mooney).

Between the two extreme working conditions any other one can be selected. All these gap variations can be established, set in advance in the computer and automatically controlled during the cycle according the process in progress.

VIC mixers have been put in operation since more than ten years in all the rubber field, ranging from tires, cables and technical goods.

In this part of the paper some results are presented related to the industrial production of GFD Elastomere GmbH, a German company operating as a custom compounding.2)

Here are reported the considerations this customer made about the VIC technology.

**First approach**

When you have to start with a new technology you certainly have to pay for a lack of know-how and the consequent risk to get bad or even dramatic results. The solution to this problem was found by choosing a different rotor clearance, immediately after the polymer wetting by the C.B.

At this moment of the cycle, in order to increase the shear between the polymer and the filler, and consequently to reduce the incorporation and the dispersion time, the clearance was set to a lower value.

As a result, together with the experience on the clearance variation, it was possible to set a new cycle in which the clearance was varied during the first ram movement, in order to speed up the C.B. dispersion and the consequent reduction of the BIT (black incorporation time).

In Fig. 5 is shown the modified cycle that gave good results in term of productivity and quality.

**Mixing stages reduction**

Another very important characteristic of the VIC is the cooling efficiency and the ability to keep under control the temperature of the compound.

To show this feature a quite difficult SBR/NR compound was selected. This compound used to be mixed on a tangential mixer in three stages, because of its high Mooney viscosity and its ther-
mal behaviour, building up temperature very rapidly.

With the VIC, after a complete optimisation study, the same compound was mixed in a single stage, including the curving agents.

In Fig. 6 is shown the mixing cycle.

To control the batch temperature, avoiding scorching problem, a joint operation of the rpm reduction and the clearance reduction was made: more precisely the rpm and the clearance was reduced simultaneously during the first ram cleaning and only the rpm during the curatives loading.

The temperature curve shows a perfect profile: in the first part, thanks to the combination of enlarged clearance and high rpm, the compound temperature is rising very fast during the C.B. incorporation, then it reaches a level at which it is kept almost constant, to continue the dispersive mixing, without affecting the risk of a premature scorching.

As a result a good quality compound was obtained, with a considerable energy saving, due to the elimination of two mixing stages.

References


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