
DEVICE AND METHOD FOR DETECTING BLENDING EFFECT OF ECCENTRIC ROTOR EXTRUDER ON LINE

TECHNICAL FIELD

[0001] The present invention relates to the field of online detection, and in particular to a
5 device and method for online detection of the blending effect of an eccentric rotor extruder.

BACKGROUND

[0002] Polymer blending is a method for blending two or more polymers in an appropriate
ratio to obtain properties that cannot be achieved by a single component. Single-screw or two-
screw extruders are generally used for polymer blending, and shear flow is the dominant flow
10 field form. A novel eccentric rotor extruder with a special spatial topological structure
plasticizes and transports polymer materials by volumetric stretching deformation. It can
overcome the negative effects of shear flow during plasticization and transportation in the
conventional extruders, generating better blending quality. Therefore, online detecting the
blending state of each section in the eccentric rotor extruder is promising to investigate its
15 blending mechanism, improving quality and efficiency during production as a result.

[0003] At present, in order to estimate the blend quality of materials during extruding, some
holes drilled on the extruder barrel are used to install an optical microscope for online detect,
or install a collecting device to collect samples for offline tests. However, these methods can
only characterize the blend quality in the region near the holes rather than the whole extruding
20 processing. For an eccentric rotor extruder, drilling on the barrel is difficult and unacceptable.
On the one hand, the inner surface of the stator meshes with the outer surface of the eccentric
rotor, and the pitch of some sections may be too small, so it is impossible to be drilled. On the
other hand, drilling too many holes may damage the stator cavity and its tightness.

[0004] Ultrasonic detecting has the advantages of high sensitivity, strong penetrating ability,

good directivity, and low cost. After transmitting in polymer melts, the ultrasonic echo can be used to characterize the melt properties, so detecting the blend quality during processing online is achieved. Conventional method of online detecting the blend quality by ultrasonics is required to drill on the extruder, and the probe needs to contact with the melt directly or indirectly through the hole. Although this method can reduce the ultrasonic attenuation and the negative effects of environmental noise, it is inappropriate for the eccentric rotor extruder because the inner surface of the stator is too complicated.

SUMMARY

Technical problem

10 **[0005]** The present invention uses a magnetic and contactless air-coupled ultrasonic device for on-line detection of the blending state of an eccentric rotor extruder to solve the problem that a traditional measuring device cannot be applied to the eccentric rotor extruder; and data processing is performed with machine learning to establish a prediction model for detecting a blending state of a polymer in each section of the eccentric rotor extruder conveniently and efficiently, which solves the problems of fewer evaluation devices for the processing effect of the eccentric rotor extruder and low detection accuracy.

Technical solution

20 **[0006]** In order to overcome the shortcomings and deficiencies of the prior art, the present invention provides a device and method for online detection of the blending effect of an eccentric rotor extruder.

[0007] The present invention uses a magnetic and contactless air-coupled ultrasonic device for on-line detection of the blending state of an eccentric rotor extruder to solve the problem that a traditional measuring device cannot be applied to the eccentric rotor extruder; and data processing is performed with machine learning to establish a prediction model for detecting the blending state of polymer materials in each section of the eccentric rotor extruder conveniently and efficiently, which solves the problems of fewer evaluation devices for the processing effect of the eccentric rotor extruder and low detection accuracy.

[0008] The present invention adopts the following technical solutions.

[0009] A device for online detection of the blending effect of an eccentric rotor extruder, including a computer, an ultrasonic detector, an air-coupled ultrasonic transmitting device and an air-coupled ultrasonic receiving device, wherein the computer is connected with the ultrasonic detector, the ultrasonic detector is connected with the air-coupled ultrasonic transmitting device and the air-coupled ultrasonic receiving device respectively, and the air-coupled ultrasonic transmitting device and the air-coupled ultrasonic receiving device are arranged on a stator of the eccentric rotor extruder.

[0010] The air-coupled ultrasonic transmitting device and the air-coupled ultrasonic receiving device both include a high-temperature resistant magnet, a cage, a spherical joint, and a cooling device, the high-temperature resistant magnet is provided at both ends of the cage for fixing with the stator of the eccentric rotor extruder, the spherical joint is arranged in the middle of the cage, the air-coupled ultrasonic transmitting device further includes an ultrasonic transducer transmitting probe arranged on the spherical joint, and the air-coupled ultrasonic receiving device further includes an ultrasonic transducer receiving probe arranged on the spherical joint.

[0011] The cooling device includes a cooling water channel for cooling the ultrasonic transducer transmitting probe or the ultrasonic transducer receiving probe and a sealing weldment, and a cooling water channel circuit is formed through the sealing weldment.

[0012] An eccentric rotor is disposed in the stator.

[0013] The cage is arc-shaped.

[0014] A method of the device for online detection of the blending effect of an eccentric rotor extruder includes the following steps:

[0015] S1, the air-coupled ultrasonic transmitting device and the air-coupled ultrasonic receiving device are disposed at a discharge end of the eccentric rotor extruder;

[0016] S2, the polymer blend samples with the same composition and the same weight ratio are prepared, and the ultrasonic echo signals of all the samples under the same temperature and different stator speed conditions are acquired to obtain the first echo signal reflected from the interface between the polymer melt and the stator;

[0017] S3, the polymer melt samples extruded at different speeds at an extrusion die of the eccentric rotor extruder are collected, and electron micrographs are obtained by scanning the

samples using scanning electron microscope, and a dispersion coefficient of a dispersed phase is calculated;

[0018] S4, the first echo signal reflected from the interface between the polymer melt and the stator is Fourier transformed, a logarithmic amplitude spectrum in a low frequency range is
5 chosen as the feature vector, and a support vector machine regression model between the feature vector and the dispersion coefficient is established;

[0019] S5, a sample with a known weight ratio at a fixed rotation speed is measured, the first melt echo signal of any section of the eccentric rotor extruder is obtained by using the air-coupled ultrasonic receiving device and transmitting device, the feature vector is obtained
10 according to the echo signal, and the dispersion coefficient of any section of the eccentric rotor extruder is obtained by substituting the feature vector into the model in S4.

[0020] The beneficial effects of the present invention are as follows.

[0021] (1) High-temperature-resistant magnets are magnetically attracted to the stator of the extruder, which can detect the blending state of any section of the extruder without
15 damaging the stator structure.

[0022] (2) The ultrasonic transducer transmitting and receiving devices are both equipped with a reflux cooling water channel to eliminate the influence of high temperature on the ultrasonic probe.

[0023] (3) The ultrasonic transducer transmitting and receiving devices are both equipped
20 with spherical joints such that the angles of the ultrasonic transmitting and receiving probes can be adapted to the complex curved surface of the eccentric rotor.

[0024] (4) The detection method according to the present invention is to prepare training samples required for modeling by adjusting the rotor speed of the eccentric rotor extruder, without additional preparation of numerous experimental samples; the present invention
25 establishes a prediction model of material dispersion coefficients through machine learning, greatly improves the accuracy of the model through a self-defined ultrasonic echo signal feature vector, and it also has a good generalization effect; and the device and method according to the present invention are versatile and not only limited to a certain specific material.

BRIEF DESCRIPTION OF THE DRAWINGS

- [0025] FIG. 1 is a schematic diagram of a structure;
- [0026] FIG. 2 is a schematic diagram of a structure of an air-coupled ultrasonic transmitting device;
- 5 [0027] FIG. 3 is a schematic diagram of a structure of an air-coupled ultrasonic receiving device;
- [0028] FIG. 4 is a schematic diagram of ultrasonic signal propagation;
- [0029] FIG. 5 is a scanning electron microscope image according to an embodiment of the present invention;
- 10 [0030] FIG. 6 is a working flow chart;
- [0031] FIG. 7 is a diagram of a first melt echo signal.

DETAILED DESCRIPTION

[0032] Hereinafter, the present invention will be further described in detail with reference to the embodiments and drawings, but the implementation of the present invention is not limited to this.

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Embodiments

[0033] As shown in FIG. 1 and 2, a device for online detection of the blending effect of an eccentric rotor extruder includes a computer, an ultrasonic detector (11), an air-coupled ultrasonic transmitting device (I), an air-coupled ultrasonic receiving device (II), an eccentric rotor (9), and a stator (10). The computer is connected with the ultrasonic detector (11). The ultrasonic detector (11) is respectively connected with the air-coupled ultrasonic transmitting device (I) and the air-coupled ultrasonic receiving device (II), all of which constitute an ultrasonic signal processing system. The air-coupled ultrasonic transmitting device (I) and the air-coupled ultrasonic receiving device (II) are arranged on the stator (10) of the eccentric rotor extruder.

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[0034] The air-coupled ultrasonic transmitting device is shown in FIG. 2 and is composed of two high-temperature resistant magnets (1), a cage (2), a spherical joint (3), an ultrasonic transducer transmitting probe (4) and a cooling device (5). The two high-temperature resistant

magnets are respectively installed on both ends of the cage (2). In this embodiment, the cage (2) is arc-shaped. The ultrasonic transmitting device can be fixed at any position of the stator through the high-temperature resistant magnets (1). The spherical joint (3) is located in the center of the cage (2). The ultrasonic transducer transmitting probe (4) is fixed on the spherical joint (5), and the spherical joint (5) can adjust an incident angle of the ultrasonic transducer transmitting probe (4). By adjusting the position of the ultrasonic transmitting device (I) and the incident angle of the transmitting probe (4), it is ensured that an incident direction of an ultrasonic signal is perpendicular to a cavity surface, such that an intensity of the incident ultrasonic signal is maximized. The spherical joint (5) is suitable for eccentric rotor extruders with complex cavities.

[0035] As shown in FIGS. (3) and (4), the structure of the air-coupled ultrasonic transmitting device (I) is basically the same as that of the air-coupled ultrasonic receiving device (II), in which the ultrasonic transducer transmitting probe (4) is changed to the ultrasonic transducer receiving probe (8), and the rest of the structure is the same as the air-coupled ultrasonic receiving device. The ultrasonic transducer receiving probe (4) is arranged on the spherical joint. The spherical joint can adjust a receiving angle of the ultrasonic transducer receiving probe (8) arbitrarily. By adjusting the position of the ultrasonic receiving device (II) and the receiving angle of the receiving probe (8), it is ensured that an intensity of a first melt ultrasonic echo signal received is maximized.

[0036] In this embodiment, the air-coupled ultrasonic receiving device and transmitting device are installed near the discharge end when modelled.

[0037] An eccentric rotor (9) is disposed in the stator of the eccentric rotor extruder.

[0038] The cooling device can make the ultrasonic transmitting and receiving probe suitable for high temperature environment. The cooling device (5) includes a cooling water channel (6) for cooling and a sealing weldment (7). The cooling device (5) forms the refluxing cooling water channel 6 through the sealing weldment (7).

[0039] First melt echo signals of a series of standard samples with known ratios at the same temperature and different rotation speeds, and then extruded samples are scanned to obtain electron microscope images, and then image processing is performed thereon to obtain a dispersion coefficient, and then a frequency domain analysis and support vector machine (SVR)

model establishes a prediction model between dispersion indices and the first melt echo signals, and finally this model can predict the blending states of a sample under test with a known ratio in different parts of the eccentric rotor extruder.

[0040] As shown in FIGS. 5, 6, and 7, the operation process of the present invention is as follows:

[0041] The device is placed as shown in FIG. 1. at the discharge end of the stator of the eccentric rotor extruder, the ultrasonic transducer transmitting probe (4) and the ultrasonic transducer receiving probe (8) are adjusted such that a transmitting intensity and a receiving intensity of an ultrasonic signal are maximized.

[0042] 10 groups of PP/PS blends with a 40/60 ratio are prepared. Under the same temperature and different speeds (the stator speed is 10/30/50/70/90/140/180/220/260/300rpm), a corresponding blended sample is obtained, and the sample is subjected to brittle fracture using liquid nitrogen. A dispersed phase (PS) in the PP/PS blend phase is etched by xylene, and the scanning electron microscope images taken after corresponding treatment is shown in FIG. 6.

[0043] The dispersion coefficient is obtained by counting the number of holes for each diameter range in the image after processed, as shown in the figure.

[0044] The first melt echo signals of PP/PS near the discharge port are measured by aforementioned air-coupled ultrasonic device. The melt echo signal is Fourier transformed, and the logarithmic amplitude spectrum in the low frequency range is chosen as the ultrasonic feature vector M0. The support vector machine regression (SVR) prediction model is established by the ultrasonic feature vector combined with the corresponding dispersion coefficient.

[0045] The first melt echo signal of PP/PS sample with weight ratio of 40/60 in any section of the eccentric rotor extruder is measured at a fixed rotation speed (any rotation speed within a specified range, such as 105 rpm). After the signal processing in the previous step, a corresponding ultrasonic feature vector M is obtained, and the dispersion coefficient of the sample under test at a certain speed in any section is obtained by substituting M into the established prediction model.

[0046] The air-coupled ultrasonic transmitting and receiving devices according to the present invention are suitable for the unique structure of an eccentric rotor extruder, and a

cooling water channel is included to ensure that the ultrasonic transducer operates at a proper temperature. The air-coupled ultrasonic device combined with the magnetic structure can detect the blending state of samples in any section or any position in the eccentric rotor extruder without damaging the stator of the eccentric rotor extruder.

- 5 **[0047]** The implementations described above are preferably for the present invention, but the implementation of the present invention is not limited by the embodiments. Any other changes, modifications, substitutions, combinations, and simplifications made without departing from the spirit and principle of the present invention should be regarded as equivalent replacement methods, and they are all included in the protection scope of the present invention.

CLAIMS

What is claimed is:

1. A device for online detection of the blending effect of an eccentric rotor extruder, comprises a computer, an ultrasonic detector, an air-coupled ultrasonic transmitting device and an air-coupled ultrasonic receiving device, wherein the computer is connected with the ultrasonic detector, the ultrasonic detector is connected with the air-coupled ultrasonic transmitting device and the air-coupled ultrasonic receiving device respectively, and the air-coupled ultrasonic transmitting device and the air-coupled ultrasonic receiving device are arranged on a stator of the eccentric rotor extruder;

and both of the air-coupled ultrasonic transmitting device and the air-coupled ultrasonic receiving device include a high-temperature-resistant magnet, a cage, a spherical joint, and a cooling device, the high-temperature-resistant magnet is provided at both ends of the cage for fixing with the stator of the eccentric rotor extruder, the spherical joint is arranged in the middle of the cage, the air-coupled ultrasonic transmitting device further includes an ultrasonic transducer transmitting probe arranged on the spherical joint, and the air-coupled ultrasonic receiving device further includes an ultrasonic transducer receiving probe arranged on the spherical joint.

2. A device for online detection of the blending effect of an eccentric rotor extruder according to claim 1, wherein the cooling device comprises a cooling water channel for cooling the ultrasonic transducer transmitting probe or the ultrasonic transducer receiving probe and a sealing weldment, and a cooling water channel circuit is formed through the sealing weldment.

3. A device for online detection of the blending effect of an eccentric rotor extruder according to claim 1, wherein an eccentric rotor is disposed in the stator.

4. The device for online detection of the blending effect of an eccentric rotor extruder according to claim 1, wherein the cage is arc-shaped.

5. A method of the device for online detection of the blending effect of an eccentric rotor extruder as defined in any one of claims 1 to 4, comprises the steps of:

S1, the air-coupled ultrasonic transmitting device and the air-coupled ultrasonic receiving

device are disposed at a discharge end of the eccentric rotor extruder;

S2, the polymer blend samples with the same composition and the same weight ratio are prepared, and the ultrasonic echo signals of all the samples under the same temperature and different stator speed conditions are acquired to obtain the first echo signal reflected from the interface between the polymer melt and the stator;

S3, the polymer melt samples extruded at different speeds at an extrusion die of the eccentric rotor extruder are collected, and electron micrographs are obtained by scanning the samples using scanning electron microscope, and a dispersion coefficient of a dispersed phase is calculated;

S4, the first echo signal reflected from the interface between the polymer melt and the stator is Fourier transformed, a logarithmic amplitude spectrum in a low frequency range is chosen as the feature vector, and a support vector machine regression model between the feature vector and the dispersion coefficient is established;

S5, a sample with a known weight ratio at a fixed rotation speed is measured, the first melt echo signal of any section of the eccentric rotor extruder is obtained by using the air-coupled ultrasonic receiving device and transmitting device, the feature vector is obtained according to the echo signal, and the dispersion coefficient of any section of the eccentric rotor extruder is obtained by substituting the feature vector into the model in S4.