

PATENT SPECIFICATION

(11)

1 396 242

1 396 242

- (21) Application No. 3816/73 (22) Filed 25 Jan. 1973
(31) Convention Application No. 3 828/72 (32) Filed 15 March 1972 in
(33) Switzerland (CH)
(44) Complete Specification published 4 June 1975
(51) INT. CL.³ G01B 17/02
(52) Index at acceptance
H4D G2 G3B G3R G6 G7D
(72) Inventor ERNST FELIX



(54) METHOD AND APPARATUS FOR DETERMINING THE CROSS SECTION OF FILAMENTARY OR WIRE-FORM MATERIAL

- (71) We, ZELLWEGER LIMITED, USTER FACTORIES for APPARATUS and MACHINES, CH-8610 Uster, Switzerland, a body corporate organised under the laws of Switzerland, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—
- This invention relates to a method of and an apparatus for at least approximately determining the cross section of filamentary or wire-form material, more especially of products of the textile industry and wire-manufacturing industry.
- There are numerous methods and apparatus for determining the cross section of such products. For example, mechanical, photoelectric and capacitive measuring systems have been extensively used for this purpose, the specific advantages of each system being offset by certain disadvantages and shortcomings.
- Acoustic measuring systems, especially those which function in the ultrasonic range, have also recently been studied in some detail. In their case, the extent to which the time taken by sound waves to reach a sound pickup from a sound generator is influenced by introducing the material whose cross section is to be determined is measured. This acoustic measuring principle has proved to be basically effective and has been found to have certain advantages over other conventional measuring techniques.
- Nevertheless, known acoustic measuring systems are still attended by the disadvantage that they do not have the necessary long-term stability. Accordingly, reference systems have had to be provided in order to maintain this stability. An object of the present invention is to obviate this disadvantage.

According to the invention there is provided a method of at least approximately determining the cross section of filamentary or wire-form material, wherein standing waves of at least two different frequencies are produced between at least one pressure wave generator and at least one pressure wave detector, the material to be tested is guided at least approximately through the pressure maximum of a first one of the standing waves and at least approximately through the pressure minimum of a second one of the standing waves, the alteration produced thereby in the apparent respective wave detector to give the said cross-section, and the alteration produced thereby in the apparent wavelength of the other or another of the waves being detected by the or a respective wave detector to give a zero adjustment valve.

The invention also provides an apparatus for at least approximately determining the cross section of filamentary or wire-form material comprising means for generating a pressure wave field having standing waves of at least two different frequencies, means for guiding the said material through a pressure maximum of one frequency and also a pressure minimum of the other or another frequency, and means for detecting the alteration produced thereby in the apparent wavelengths of the said waves.

The waves of these two frequencies produced by the pressure wave generators can be continuously or intermittently transmitted.

The invention is described in detail in the following with reference to the accompanying drawings, wherein:

Figure 1 shows a first basic measuring arrangement.

Figure 2 shows another basic measuring arrangement.

Figure 3 shows in principle an acoustic feedback oscillator.

90

Figure 4 shows another acoustic feed back oscillator for various frequencies.

Figure 5 shows a further development of the measuring arrangement shown in Figures 1 and 2.

Figure 6 shows an arrangement for filtering out different frequencies at the transmitting end.

Figure 7 shows an arrangement for filtering out different frequencies at the receiving end.

Figure 8 shows the basic measuring arrangement of Figure 1 with modified working conditions.

Figure 9 shows a preferred embodiment for the sound generator and sound pickup.

A material 1, for example a textile yarn, whose cross section is to be determined, is shown in cross section in Figure 1 and extends perpendicularly to a sound field which consists of standing waves between surfaces 2 and 3. These standing waves are produced by a generator 14 through loudspeakers or similar electro-acoustic transducers 10, and their intensity is measured by microphones or other electro-acoustic transducers 11. The interval 20 between the surfaces 2, 3 is selected in such a way that, at a predetermined frequency f_1 , a standing fundamental wave 4 occurs with a velocity minimum (pressure maximum) at the surfaces 2, 3 and a velocity maximum (pressure minimum) at half the distance 20. Accordingly, the pressure maxima have to meet at the surfaces 2, 3 and the pressure minimum in their middle plane. By introducing an object into the range of the pressure maxima or minima, the transit time is increased, i.e. the time for sound to travel the distance 20 is increased, the apparent wavelength is thereby increased, and the voltage measurable at the microphone 11 or its phase position undergoes a change.

If a standing wave is produced with a frequency f_2 equal to at least twice the frequency f_1 , a wave 5 is formed with a pressure maximum midway between the surface 2, 3. An object 1 introduced into this pressure maximum then shortens the transit time. By suitably combining the sound pressures picked up by the microphone 11 in a discriminator 15, an indicating and/or recording instrument 16 is able directly to indicate and/or record the quantity of test material 1 in the sound field.

At a frequency f_1 , therefore, the test material 1 increases the transit time whereas, at a higher frequency f_2 , for example, the transit time is shortened. This can be demonstrated theoretically as well as being found in practice. With each one of these frequencies it is possible to obtain a signal corresponding to the cross section

of the test material and to determine the cross section from this signal. Through the combination of these signals whether continuous or intermittent, it is possible to eliminate interference effects. If for example the temperature changes, the transit times of both frequencies f_1 and f_2 change in the same way. Similarly, if the distance 20 between the sound generator 10 and the pickup 11 is reduced, the transit times are also changed in the same way. The same also occurs when the atmosphere surrounding the sound generator 10 or the pickup 11 is changed through the deposition of foreign bodies, i.e. by soiling. This is an important advantage, especially for testing products of the textile industry, where the extent to which the measuring elements of all the known systems is impaired by deposits is particularly pronounced.

The material 1 does not necessarily have to pass exactly midway between the surfaces 2 and 3. By suitably selecting the stationary wave and its oscillation nodes i.e. through using relatively high frequencies in relation to the fundamental wave 4, it is possible to use other material positions. Figure 2 shows a measuring system in which the second harmonic 6 and the fourth harmonic 7 are present between the surfaces 2 and 3, whilst the test material 1 is positioned at one quarter of the distance 20 from the surface 2. In this example, similar conditions would also obtain if the test material 1 were to be positioned at three quarters of the distance 20.

It is of particular advantage to combine the sound generator 10 and the sound pickup 11 into an oscillator excited in known manner by acoustic feedback, in which case the oscillator frequency is determined by the transit times between the sound generator 10 and the sound pickup 11. Figure 3 shows a basic circuit arrangement suitable for this purpose. A signal U obtained in the sound pickup 11 passes back to the sound generator 10 through an amplifier 30. The oscillator frequency will be that frequency for which the phase relationship required for maintaining the oscillations is given in the sound pickup 11. If no phase shift (or a phase shift through 360°) occurs in the amplifier 30, a stationary wave whose wave length corresponds to twice the distance 20 between the surfaces 2, 3, is formed in the sound field 20. If by contrast the amplifier 30 is designed in such a way that a phase shift of the signal U through 180° takes place in it, the wave length formed will exactly correspond to the distance 20.

However, two frequencies f_1 and f_2 can also be simultaneously generated. The corresponding apparatus is particularly simple because the feedback from the sound

pickup 11 to the sound generator 10 can be carried out simply by sign change of both frequencies.

Figure 4 shows a combination of a sound generator 10 and a sound pickup 11 with two parallel amplifiers 30 and 31, of which the amplifier 30 produces no phase shift whilst the amplifier 31 works with a phase shift of 180° . One or other of the amplifiers can be placed in the feedback path, for example intermittently, by a switch 32.

In an arrangement of the kind shown in Figure 4, however, difficulties can arise as a result of so-called pulling effects, i.e. through the well-known phenomenon that the two oscillation systems 2, 3, 30 and 2, 3, 31 do not oscillate at their true resonance frequencies f_1 and f_2 or their harmonics, but instead they influence ("pull") one another in such a way that an integral frequency ratio is formed. Pulling occurs in the present case during the changeover from one property to the other as a result of transients. Although it is possible in principle satisfactorily to separate both frequencies, it can be of advantage in some cases to use at least two sound pickups. Figure 5 shows such an arrangement with two sound pickups 11 and 13, two sound generators 10 and 12 also being provided for reasons of symmetry.

Different combinations are of course possible. For example, it is possible to use two sound pickups and only one sound generator or two sound generators and only one pickup. In each case, the critical factor is the correct phase position of the sound waves. If for example two generators are arranged on either side of the sound field, each individual generator can be tuned to a certain frequency f_1 or f_2 . It is also possible however, to superimpose the two frequencies in the generators.

In this case, the frequency f_2 can be directly delivered to the generators as an even-numbered multiple of the fundamental frequency, whilst the frequency f_1 can be delivered as an odd-numbered multiple of the fundamental frequency to the one generator in phase and to the other generator in anti-phase. This arrangement is shown by way of example in Figure 6.

In an arrangement of the kind shown in Figure 7, in which one receiver is provided on either side of the sound field, it is of particular advantage to form both the sum and the difference of the signals received. Difference formation only produces signals of odd-numbered harmonics the fundamental frequency of the resonator, because the signals of the even-numbered harmonics cancel one another out approximately in view of the identical phase position on both sides. By contrast sum formation only pro-

duces a signal for the even-numbered harmonies because the odd-numbered harmonies are eliminated. Accordingly, the difference signal corresponds to the frequency f_1 and the sum signal to the frequency f_2 . An electrical separation of the two frequencies thus takes place without a filter. These two signals can then be returned to one or two sound generators in known manner. The only critical factor in this respect is the correct phase position.

In cases where the two frequencies f_1 and f_2 change intermittently, the apparatus shown in Figures 5 and 6 are of course unnecessary. It is possible, for example in an apparatus of the kind shown in Figure 1, to generate the frequency f_1 which is sufficient for measuring the cross section, for a prolonged period and only to generate the frequency f_2 which detects the magnitude of extraneous effects and substantially compensates them in known manner, for relatively short time intervals.

There is no need for the frequency ratio between f_1 and f_2 to amount to approximately two, as in the examples given above. Instead, solutions in which, for example, the ratio between the frequencies is far higher, are also possible. Ratios of even to odd numbers are of particular advantage. One example is illustrated in Figure 8. In this case, the frequency f_2 (curve 8) is four times the frequency f_1 .

The principal function in the arrangements described in the preceding examples is to determine the cross section of the test material 1 as exactly as possible. For certain applications, however, exact measurement of the cross section is unnecessary, and a so-called yes-no answer is sufficient, in other words it is only desired to know whether test material is or is not present. This is necessary for example in monitoring a production cycle when it is merely desired to detect whether or not test material is present. The apparatus according to the invention is ideally suitable for purposes such as these, because it has the necessary long-term stability.

The sound generator 10 and sound pickup 11 are advantageously built into flat, parallel surfaces 2, 3. However, they do not necessarily have to be active over the entire surface (Figure 8). Neither are parallel surfaces absolutely essential. Other forms are also sufficient, providing it is possible to obtain standing waves with at least two different wave-lengths. Figure 9 shows an embodiment in which the arrangement is such that, at least one harmonic, it represents a resonator in the form of an open pipe.

WHAT WE CLAIM IS:—

1. A method of at least approximately

duces a signal for the even-numbered harmonics because the odd-numbered harmonics are eliminated. Accordingly, the difference signal corresponds to the frequency f_1 and the sum signal to the frequency f_2 . An electrical separation of the two frequencies thus takes place without a filter. These two signals can then be returned to one or two sound generators in known manner. The only critical factor in this respect is the correct phase position.

In cases where the two frequencies f_1 and f_2 change intermittently, the apparatus shown in Figures 5 and 6 are of course unnecessary. It is possible, for example in an apparatus of the kind shown in Figure 1, to generate the frequency f_1 which is sufficient for measuring the cross section, for a prolonged period and only to generate the frequency f_2 which detects the magnitude of extraneous effects and substantially compensates them in known manner, for relatively short time intervals.

There is no need for the frequency ratio between f_1 and f_2 to amount to approximately two, as in the examples given above. Instead, solutions in which, for example, the ratio between the frequencies is far higher, are also possible. Ratios of even to odd numbers are of particular advantage. One example is illustrated in Figure 8. In this case, the frequency f_2 (curve 8) is four times the frequency f_1 .

The principal function in the arrangements described in the preceding examples is to determine the cross section of the test material 1 as exactly as possible. For certain applications, however, exact measurement of the cross section is unnecessary, and a so-called yes-no answer is sufficient, in other words it is only desired to know whether test material is or is not present. This is necessary for example in monitoring a production cycle when it is merely desired to detect whether or not test material is present. The apparatus according to the invention is ideally suitable for purposes such as these, because it has the necessary long-term stability.

The sound generator 10 and sound pick-up 11 are advantageously built into flat, parallel surfaces 2, 3. However, they do not necessarily have to be active over the entire surface (Figure 8). Neither are parallel surfaces absolutely essential. Other forms are also sufficient, providing it is possible to obtain standing waves with at least two different wave-lengths. Figure 9 shows an embodiment in which the arrangement is such that, at least one harmonic, it represents a resonator in the form of an open pipe.

In an arrangement of the kind shown in Figure 7, in which one receiver is provided on either side of the sound field, it is of particular advantage to form both the sum and the difference of the signals received. Difference formation only produces signals of odd-numbered harmonies the fundamental frequency of the resonator, because the signals of the even-numbered harmonies cancel one another out approximately in view of the identical phase position on both sides. By contrast sum formation only pro-

1. A method of at least approximately 130



(9)



4

1 396 242

4

- determining the cross-section of filamentary or wire-form material, wherein standing waves of at least two different frequencies are produced between at least one pressure wave generator and at least one pressure wave detector, the material to be tested is guided at least approximately through the pressure minimum of a first one of the standing waves and at least approximately through the pressure minimum of a second one of the standing waves, the alteration produced thereby in the apparent wavelength of one of the waves is detected by the or a respective wave detector to give the said cross-section, and the alteration produced thereby in the apparent wave-length of the other or another of the waves being detected by the or a respective wave detector to give a zero adjustment valve.
2. A method as claimed in claim 1, wherein the standing waves are continuously and simultaneously generated.
3. A method as claimed in claim 1, wherein the standing waves of different frequencies are produced intermittently in succession.
4. A method as claimed in any preceding claim wherein the standing waves are produced by feedback from a detector to a generator.
5. A method as claimed in claim 4 wherein an amplifier which does not produce any phase shift between an input signal and an output signal is used in the feed back path.
6. A method as claimed in claim 4 wherein an amplifier which produces a 180° phase shift between an input signal and an output signal is used in the feed-back path.
7. A method as claimed in claim 4 wherein an amplifier without phase shift and an amplifier with 180° phase shift are used in parallel in the feedback path.
8. A method as claimed in claim 5, 6 or 7 wherein the or each amplifier used in the feedback path is switched on and off by a switch.
9. A method as claimed in any preceding claim wherein the ratio between the frequencies is at least approximately integral.
10. A method as claimed in claim 9 wherein the ratio of the frequencies is substantially that of an even to an odd integer.
11. A method as claimed in any preceding claim wherein the standing wave of at least the higher frequency is formed in resonators constituted by pipes each open at one end.
12. A method as claimed in claim 1, wherein the frequencies are superimposed in two wave generators one frequency being approximately whilst the other frequency is an odd-numbered multiple of this fundamental frequency, the said other frequency being delivered to one generator directly and to the other generator in anti-phase.
13. A method as claimed in claim 1, wherein one generator and one detector are disposed on one side of the material being tested and a second generator and a second detector are disposed on the opposite side of the said material, the said one generator produces waves which are of a frequency which is approximately an even-numbered multiple of a fundamental frequency, the said second generator produces waves which are of a frequency which is approximately an odd-numbered multiple of the said fundamental frequency, the difference between the outputs of the detectors is fed back to the second generator, and the sum of the outputs of the detectors is fed back to the said one generator.
14. An apparatus for at least approximately determining the cross section of filamentary or wire-form material comprising means for generating a pressure wave field having standing waves of at least two different frequencies, means for guiding the said material through a pressure maximum of one frequency and also a pressure minimum of the other or another frequency and means for detecting the alteration produced thereby in the apparent wavelengths of the said waves.
15. An apparatus as claimed in claim 14 wherein the generator means and the detecting means are parts of an oscillating-resonance system and are connected by at least one feedback path.
16. An apparatus as claimed in claim 15, wherein there is at least one amplifier in the feedback path.
17. An apparatus as claimed in claim 16 wherein an amplifier which does not produce any phase shift is arranged in one feedback path, whilst an amplifier which does produce phase shift is arranged in a second feedback path.
18. An apparatus as claimed in claim 16 or 17 comprising a switch which switches the or each amplifier on and off.
19. An apparatus as claimed in any one of claims 14 to 18 wherein a single wave generator for generating waves of two frequencies and a single wave detector for detecting waves of the said frequencies are provided.
20. An apparatus as claimed in any one of claims 14 to 18 wherein a wave generator and a wave detector are provided for respectively generating and detecting waves of one frequency and another wave generator and another wave detector are provided for respectively generating and

20

detecting waves of another frequency.

21. An apparatus as claimed in claim 20 wherein one generator and one detector are arranged on one side of the wave field and the other generator and the other detector are arranged on the opposite side of the wave field.

22. An apparatus as claimed in claim 21 wherein one wave generator and the corresponding wave detector are arranged offset in relation to the other wave generator and wave detector.

23. An apparatus as claimed in any one of claims 14 to 22 wherein the or each wave generator and/or the or each wave detector is in the form of a pipe open at one end.

24. An apparatus as claimed in claim 14 wherein the frequencies are derived from a fundamental frequency, one of the derived frequencies being an odd-numbered multiple and the other frequency an even-numbered multiple of this fundamental frequency, one of the frequencies being applied to one wave generator directly and to another wave generator in anti-phase.

25. An apparatus as claimed in claims 21 or 22 wherein one of the generators produces a frequency which is an even-num-

bered multiple of a fundamental frequency and the other of the generators produces a frequency which is an odd-numbered multiple of the said fundamental frequency, and wherein means are provided for forming the sum and difference of the signals obtained from the two detectors, the sum and difference thus formed being fed back to the said one generator and the said other generator respectively.

26. A method of at least approximately determining the cross-section of filamentary or wire form material substantially as herein described with reference to any one of the Figures of the accompanying drawings.

27. An apparatus for at least approximately determining the cross-section of filamentary or wire-form material, substantially as herein described with reference to any one of the Figures of the accompanying drawings.

ELKINGTON AND FIFE
Chartered Patent Agents,
High Holborn House,
52/54 High Holborn,
London W.C.2.
Agents for the Applicants.



* C L H S *