A vibrating apparatus utilizing a plurality of vibrating sources, in which confronting massive bodies each including a rotary-type vibration-applying machine are distributed, through respective resonant resilient members such as springs, onto such a vibrating body to be vibrated as a conveyor, and said machines are operated in synchronous and in phased relation, whereby an extremely long vibrating-type conveyor which has not been possible has become practical, power output capacity of the apparatus is increased, and manufacture of a vibrating-type conveyor having a desired length can be made possible by connecting a plurality of unit conveyors.

3 Claims, 13 Drawing Figures
FIG. 7

I

II

III

IV

SYNCHRONOUS STATE

SAME PHASE

120-180°

DIFFERENT PHASE

VIBRATING DIRECTION

SAME PHASE

120-180°

DIFFERENT PHASE

FIG. 8

SAME PHASE

DIFFERENT PHASE

SAME PHASE

DIFFERENT PHASE

AMPLITUDE

VIBRATION

OPERATING POSITION
VIBRATING APPARATUS UTILIZING A PLURALITY OF VIBRATING SOURCES

BACKGROUND OF THE INVENTION

The present invention relates to a vibrating apparatus in utilizing a plurality of vibrating sources.

A long conveyor to be vibrated and to which a plurality of magnetic vibrators are attached has been conventionally well known. In the conveyor mentioned above, since the magnetic vibrators are usually excited by the same electric source, vibration-applying forces generated by the respective magnetic vibrators are necessarily in synchronism and in phase.

The above-mentioned conveyor, however, has a disadvantage in that the vibration-applying force is relatively low and its capacity is limited in comparison with proposed system in which a vibration-applying force may be generated by means of a machine consisting of an eccentric weight and an induction motor for rotating said weight, said machine being referred to as a rotary type vibration-applying machine hereinafter.

Vibrating apparatus comprising a plurality of the rotary type vibration-applying machines have not yet been manufactured. The reason therefor resides in the fact that induction motors have a certain amount of slip with respect to their synchronous speed so that it is impossible to maintain a predetermined vibration-imparting direction; that is, the rotary positions of the eccentric weights cannot be maintained in synchronism or in phase. Accordingly, for the purpose of embodying practically a system in which a conventional long conveyor is vibrated by means of rotary-type vibration-applying machines, it has been usual to adapt a system of the type, in which large capacity type vibration-applying machines of a pair are provided and these machines are combined with a plurality of resonant springs or one of said machines is made to have a greater rigidity than the other machine, and these machines are coupled with a plurality of resonant springs, whereby two mass-vibrating systems are formed. However, the vibrating apparatuses as mentioned above have various disadvantages. In example, their construction are very complex, they are not suitable for standardization because of the necessity of designing individually the apparatus in accordance with the length of the conveyor, and it is impossible to intentionally adjust the length of the apparatus so as to be matched with a modification of a process in a factory in which said vibrating apparatus is to be provided.

SUMMARY OF THE INVENTION

Therefore, it is an essential object of the invention to provide a vibrating apparatus adapted for a particularly long conveyor and having no disadvantages of the conventional vibrating apparatuses.

The above and other objects of the invention have been attained by vibrating apparatus comprising a vibrating body like a conveyor, a plurality of confronting mass bodies which are distributively attached to said vibrating body through respective resonant resilient members, vibration-protecting device for supporting the apparatus on a stationary member, and rotary-type vibration-applying machines each comprising an induction motor and an eccentric weight, said machines being respectively possessed by said confronting mass bodies.

The foregoing objects as well as the characteristic features and functions of the invention will become apparent and more readily understandable by the following description when read in conjunction with the accompanying drawings, in which the same or equivalent members are designated by the same numerals and characters.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1, 2 and 3 are schematic views showing vibrating apparatus according to the invention;
FIG. 4 is a side view of an example of the invention;
FIG. 5 is an enlarged view of a part of the example shown in FIG. 4;
FIG. 6 is a lateral view, in section along VI—VI in FIG. 5;
FIG. 7 (I), (II), (III) and (IV) are schematic views showing various resonant conditions of the vibrating apparatus according to the invention;
FIG. 8 is a characteristic curve of the vibrating apparatus according to the invention; and
FIGS. 9, 10, 11, 12 and 13 are schematic views for showing, respectively, other different examples of the invention.

DETAILED DESCRIPTION OF THE INVENTION

In general, when several rotary-type vibrating machines are directly attached to a vibrating body, stable states of various modes are produced in accordance with various conditions such as rigidity, weight and natural vibrating frequency of the vibrating body, property of supporting spring, vibrating force applied to the vibrating body, and the like. For the sake of convenience, FIGS. 1 to 3 will be described in respect of a case in which two vibration-applying machines A and B are provided.

1. When, as shown in FIG. 1, the weight of a vibrating body C is very large in comparison with the vibration-applying force applied to said body C and rigidity of said body C is very large, two vibration-applying machines A and B are asynchronous to each other irrespective of their rotating directions and each of said machines rotates without relation to the other machine.

2. When, as shown in FIG. 2 the vibrating body C is small in its vibrating weight and large in its rigidity and the vibrating frequency of the vibration-applying force is greater than the natural vibrating frequency of the whole system, a synchronizing power due to the vibration is imparted upward and downward in the case when rotating directions of the vibration-applying machines A and B are mutually opposite thereby to cause synchronous rotations of said machines, but rotary phases of the machines are same in only the vertical direction and different by 180° in the horizontal direction, that is, in the direction so as to cancel mutually the forces applied from the machines in said direction, whereby only vertical vibration of the body C is generated.

3. In the case described in the above item (2), if the vibrating frequency of the vibration-applying force is extremely smaller than the natural vibrating frequency of the whole system, the synchronizing force due to the vibration is imparted to right and left directions thereby to cause synchronous rotations of the machines A and B, but rotary phases of the machines A and B are same in only the horizontal directions as shown in FIG. 3 and different by 180° in the vertical direction, whereby only horizontal vibration of the body C is generated.

4. In the case described in the above item (2), if the vibration-applying machines A and B are rotated in the same direction, a pendulum vibration center of which corresponds to the center of gravity of each machine is generally established, so that the machines A and B are synchronously rotated with a difference of 180° in their phases.

5. In the case described in the above item (2), the vibration-applying machines A and B cannot be operated in synchronous and same-phased states. (According to the present invention, the vibration-applying machines A and B can be synchronously rotated with same phase as will be described hereinafter.)

Now, the reason for the possibility of operation as mentioned in the item (4) and the impossibility of operation as mentioned in item (5) will be considered in the following.

In the case of item (4), the vibration corresponds to a pendulum vibration and intensity thereof corresponds to 2R/F, where R represents a half of the distance between the machines A and B, F represents the vibration-applying force of the vibration-applying machine, and I represents the inertia moment of the vibration mass. On the contrary, in the case of the item (5), the vibration becomes a circular vibration and the intensity thereof corresponds to 2F/W, where F represents the same force as described above and W represents weight of the vibration mass. Accordingly, if it be assumed that in both
cases of the above items (4) and (5) the weight of the vibration mass and vibration-applying forces caused by the vibration-applying machines A and B are the same, the following relation is established 2RF/1 < 2F/W. Accordingly, in the case of the item (5) the vibration intensity is larger and a larger vibration energy is required than the case in item (4).

As will be understood from the cases of items (2) and (3), it is clear that the vibration state is stable where the vibration energy is minimum, so that vibration is not stable in the case of the item (5), but is stable in the case of the item (4).

In the present invention, the vibrating apparatus is constituted that the amount of pendulum vibration may be larger than the energy of circular vibration. That is, as shown in FIG. 3, the vibration-applying machines A and B are, respectively, mounted on the vibrating body C through respective resonant springs D and E. Now, let it be assumed that the vibration-applying machines A and B are rotated in the same direction at a speed corresponding to a rotation near the natural vibrating frequency of the vibration system consisting of the machines A, B, the vibrating body C, and the resonant springs D, E. In this case, the machine A and B are brought into synchronous and stable states when their rotational phases are different by 180° from each other, compression, tension and bending moment are exerted onto vibrating body C, so that the generated energy should be relatively large. However, when the machines A and B are made to be synchronous and stable and in the same rotational phase, the immoderate stresses as mentioned above cannot generate, so that the energy required for the vibration of the system becomes minimum. That is, according to the construction as shown in FIG. 3, continuation of the stable operation of the system will be secured only when the vibration machines A and B are synchronously operated in the same rotational phase.

Referring to FIGS. 4, 5 and 6, the vibration system comprises a vibrating body 1 such as, for example, a vibrating trough consisting of a plurality of unit troughs each having a predetermined length, said unit troughs being fixedly connected to one another, a plurality of confronting massive bodies 3 each of which is connected with a respective unit trough through a resonant rubber spring 4; vibration-applying machines 5 each of which is attached to a respective massive body 3; plate-shaped springs 6 for regulating the vibration direction of the vibrating body, said springs acting to regulate the system so that the trough 1 and massive bodies 3 vibrate in the direction that of the plate-shaped springs; and vibration-protecting springs 7 which support the parts of the apparatus on a stationary member such as the ground. The vibration-applying machine 5 consists of an induction motor and an eccentric weight attached to an end of the shaft of said motor, so that a circular vibration-applying force is generated by driving said motor by application of an electric source thereto.

The example as illustrated in FIGS. 4, 5 and 6 constitutes a vibration system having four freedoms, in which the trough 1 and the confronting bodies each including the vibration-applying machine 5 are connected by means of the resonant springs 4. Since the members constituting said system have, respectively, their natural vibration frequencies, the vibration system is restricted by said frequencies, whereby the vibration-applying machines are operated in their synchronous and in-phased states or in their synchronous and out-of-phased (about 180°) states. Now, let it be assumed that the spring constant of each resonant spring 4, weights of each unit trough and the confronting mass body 3, and vibration-applying force are constant. In this condition, if sequence and synchronous state of generation of the resonances are considered from that having the lowest vibration frequency, they become as shown in FIG. 7.

That is, in the state of FIG. 7 (I), the whole parts of the trough 1 are subjected to upward and downward vibration owing to actions of the vibration-protecting springs, and in the state of FIG. 7 (II), the trough 1 is shown in FIG. 7 (II) owing to the primary lateral natural frequency of the trough 1 itself. Further more, in the state of

FIG. 7 (III), owing to the natural vibration frequency of the each confronting mass body 3 (including the vibration-applying machine 5), said mass body 3 vibrates in the arrow direction a and the trough 1 takes an almost stationary state; and in the state of FIG. 7 (IV), the trough 1 and the confronting mass bodies 3 are subjected respectively to their vibrations having their natural vibration frequencies in respective arrow directions b and c having a certain angle (about 20°-30°) with respect to feeding direction of one material.

In FIG. 8, there are shown respective resonant states of the above-mentioned cases (I), (II), (III), and (IV). In embodying the examples according to the invention, it is preferable to separate the positions of the state (II) and (III) from that of the state (IV) as much as possible so as to avoid disturbance to be applied to operation of the apparatus. If the state (III) is near the state (IV), even when the electric source is switched on, the operation of the apparatus at the state (III) and a normal operation cannot be established. Furthermore, sometimes there is an operational need to vary the amplitude of the trough by varying rotational speed of the induction motor thereby to control feed quantity of the material; or also, if the operation stays at the state of (III), normal operation cannot be established, so that from the design point of view the positions of the cases (II), (III) should be selected toward the lower vibration frequency as much as possible.

The example shown in FIG. 9 relates to an apparatus, in which the unit troughs 2 are fixedly connected to one another and the confronting mass bodies 3 are fixedly connected to respective unit troughs, and mass bodies being attached to one another by means of respective resonant springs 4. Operation and effects of the example of FIG. 9 is the same as those of the example of FIG. 4 except that the confronting mass bodies 3 also are subjected to vibration together with the trough 1. The confronting mass body 3 may be constructed so as to be of trough-shape, whereby to form a two-step conveyor. In this case, the direction of the feeding material is the same at the upper and lower positions.

The example of FIG. 10 relates to the case, in which the trough 1 and the confronting mass bodies 3 are continuously unified so as to have no joint portions. Operation and effects of the example of FIG. 10 are the same as those of the example of FIG. 9, but the former example has an inconvenient disadvantage such that it is necessary to design anew massive body 3 and the trough 1, depending upon required lengths of each of the mass bodies 3 and the trough 1.

The example of FIG. 11 relates to the case, in which upper and lower troughs 1 and 11 are arranged so as to clamp the confronting mass bodies 3, said troughs and mass bodies are connected by means of resonant springs 4 and 14 respectively, the trough 1 and the confronting mass bodies 3 are connected by means of plate-shaped springs 6 slanted leftward at an angle, and the trough 11 and the mass bodies 3 are connected by mass of plate-shaped springs 16 slanted rightward at an angle. According to the example of FIG. 11, when the vibration-applying machines are driven, the troughs 1 and 11 are subjected to different and inclined vibration, respectively, (the confronting mass bodies 3 are quartered by the height direction), whereby the material is conveyed toward one side, for example, rightward by means of the trough 1 and the material can be conveyed toward the other side, for example, leftward by means of the trough 11. Accordingly, a simple and efficient both-directional feeding conveyor can be obtained.

The example of FIG. 12 relates to the case, in which the vibration applying machine 5 is divided to an induction motor 5 and an eccentric weight 15e and the members are coupled by means of a belt. This example is particularly advantageous from the view point of securing maintenance of the bearings in the case of using vibrations-applying machines each having large capacity. The example of FIG. 13 relates to the case, in which the induction motor 15 is provided at a stationary position such as the ground, whereas more advantageous maintenance of the motor can be secured.
In all examples, if each of the vibration-applying machines has a mass required for the necessary vibration, the confronting mass bodies may be omitted.

According to the present invention, since as described above in detail, confronting mass bodies each including the rotary-type vibration-applying machine are distributed, through respective resonant resilient members such as springs, onto such a vibrating body to be vibrated as a conveyor and said machine are made to be operated in synchronous and same-phased states, an extremely long vibrating-type conveyor is practically embodied. Furthermore, there is no limit in power capacity of the apparatus, and a vibrating-type conveyor having a desired length can be easily constructed by connecting a plurality of unit conveyers.

We claim:

1. A vibrating apparatus having a plurality of vibrating sources, comprising, in combination, an elongated body of indefinite length to be vibrated, a plurality of confronting massive bodies equidistantly spaced at a substantial distance apart one from the next adjacent one and attached to said body to be vibrated through respectively independent resonant springs and each comprising an induction motor and an eccentric weight driven by said induction motor, and a vibration protecting device for supporting the apparatus of a stationary member.

2. The vibrating apparatus according to claim 1, wherein a plurality of confronting massive bodies are firmly fixed to one another.

3. The vibrating apparatus according to claim 1, wherein a common confronting massive body is disposed on the center line of a pair of parallelly arranged vibrating bodies.

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