

March 14, 1961

J. RŮŽIČKA
VIBRATING SYSTEM

2,974,798

Filed Oct. 28, 1955

2 Sheets-Sheet 1

Fig. 1

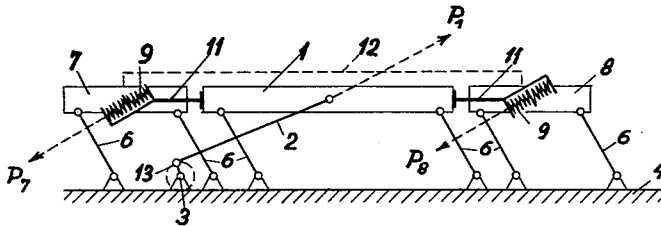
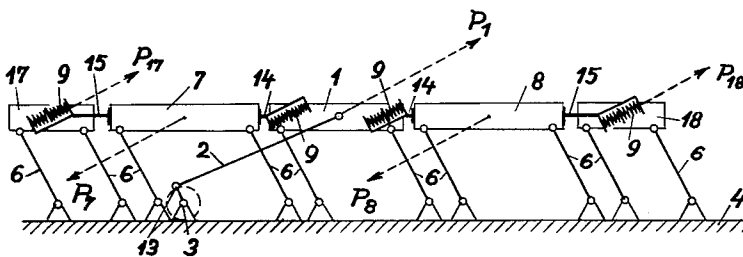


Fig. 2



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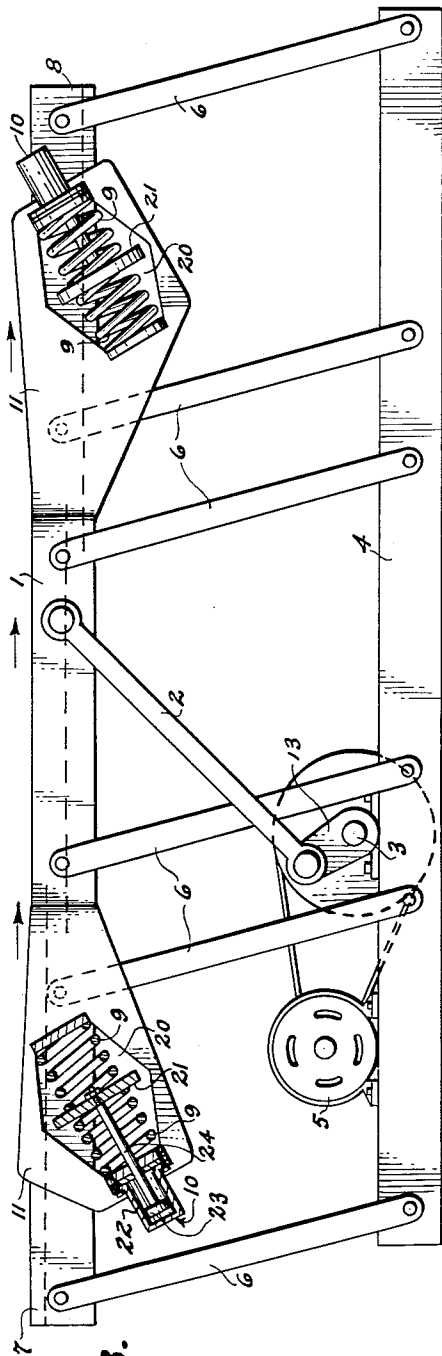


Fig. 3.

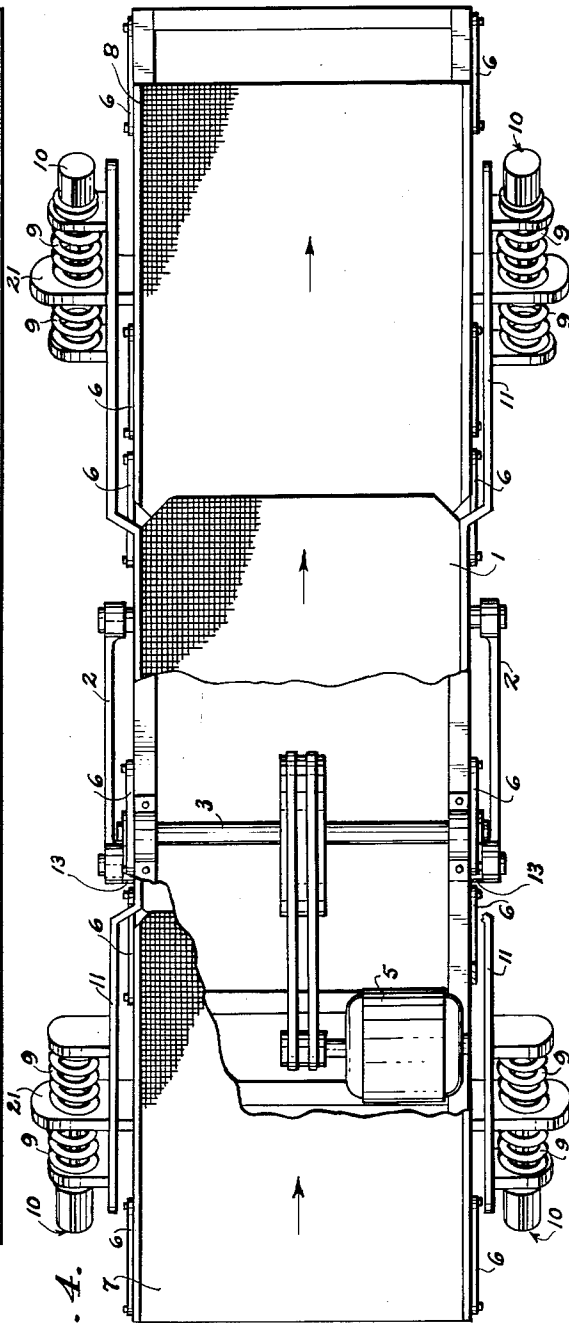


Fig. 4.

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2,974,798

VIBRATING SYSTEM

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4 Claims. (Cl. 209—365)

This invention relates to balanced vibrating systems consisting of at least three aligned masses. Such systems may be used for instance as reciprocating screens for grading such materials as sand, coal, broken stones, or different minerals, as vibrating conveyors or the like.

Vibrating systems of this kind generally use counterweights which are supposed to balance the movements of the oscillating masses, which counterweights are either agitated directly from the driving means or by resonance with the oscillating mass. In both cases it is rather difficult to balance the oscillating masses under different operating conditions, so that the reactions transmitted to the frame or foundation are generally considerable. But even if the masses are perfectly balanced, a forced drive of different masses transmits to the driving shaft rather considerable forces which may be in equilibrium with respect to the whole system, but which require the use of a drive means of large dimensions.

It is an object of the present invention to provide a vibrating system, which may be perfectly balanced for different operating conditions and which reduces all reactions of the oscillating masses to a minimum, so that the driving means can be reduced to a size capable of overcoming the passive resistances and where the reaction to the driving forces are minimized.

A further object of the invention is to provide for a smooth starting of the system and the increase of speed up to operating conditions without undue vibrations.

Further advantages and objects of this invention will be apparent from the following description with reference to the accompanying drawings, where Fig. 1 is a schematic layout of a reciprocating screen consisting of three separate screen frames, Fig. 2 is a similar view of a screen with five screen frames, and Figs. 3 and 4 are respectively an elevation and top view of a screen as shown in Fig. 1.

The screen according to Figs. 1, 3 and 4 consists of the central substantially horizontal screen frame 1 and two outer aligned screen frames 7 and 8. All frames are supported by substantially parallel bars 6, which are in turn supported by the solid frame or foundation 4. The screen 1 is agitated by a set of two parallel bars 2 pivotally connected at one end to cranks 13 of the shaft 3, which is supported either rigidly or elastically upon the frame 4 and which is driven for instance by an electric motor 5 (Figs. 3 and 4). The screens 7 and 8 are connected to the screen 1 only by means of elastic elements 9, arranged in the prolonged side bars 11 of the frame 1 and acting on the screens 7 and 8 in directions perpendicular to the support members or parallel bars 6 for such screens, as is apparent in the drawings.

The axis of each of the elastic elements 9 lies practically in a plane including the center of gravity of the mass driven thereby. As is apparent in Figs. 3 and 4, each side bar 11 has an opening 20 therein and the elastic elements 9 bear against the opposite end edges of the opening 20 and against a lug 21 which projects laterally

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from the adjacent screen 7 or 8 and enters centrally between the elastic elements 9.

The adjacent masses are supposed to vibrate in opposite phase relation, that is, at any moment, the adjacent masses move in opposite directions, and it is therefore necessary to choose the proper stiffness of the elastic elements 9 in order that the adjacent masses receive the proper phase relation.

If the screen 7 has the mass m_7 and if its amplitude of vibration is x , the amplitude of vibration of screen 1 is y and the stiffness of the elastic element 9 is c , the following differential equation must be fulfilled for the elastic element having one end leaning against the mass m_7 and its other end brought to oscillations $y = y_0 \cos \omega t$:

$$m_7 \ddot{x} + c(x - y_0 \cos \omega t) = 0$$

A partial solution of this equation will be

$$x = x_0 \cos \omega t$$

20 where

$$x_0 = y_0 \frac{c}{c - m_7 \omega^2}$$

If the magnitude of the amplitudes should be equal, but of opposite sign, there must be

$$-x_0 = y_0$$

then

$$y_0 \frac{c}{c - m_7 \omega^2} = -y_0$$

and

$$c = \frac{m_7 \omega^2}{2}$$

It follows therefore, that the stiffness of each of the elastic elements 9 does not depend upon the magnitude of the amplitudes of vibration, so that the system is balanced for any amplitudes, provided that they are proportionally changed.

If this system is oscillated, the forces P_1 , P_7 and P_8 are induced by the movements of the masses m_1 , m_7 and m_8 of the respective screens 1, 7 and 8. For an equilibrium the following condition must be fulfilled:

$$P_1 + P_7 + P_8 = 0$$

where

$$P_1 = m_1 r_1 \omega^2$$

$$P_7 = m_7 r_7 \omega^2$$

$$P_8 = m_8 r_8 \omega^2$$

where r_1 , r_7 , and r_8 are the amplitudes of the oscillations of the respective masses and ω the angular velocity of the oscillations.

If we substitute these terms in Equation 1 we receive

$$m_1 r_1 \omega^2 - m_7 r_7 \omega^2 - m_8 r_8 \omega^2 = 0$$

At the same time the sum of the moments of the oscillating masses must be zero, if a balanced state is to be achieved. If we suppose that the force P_7 acts at a distance a from the force P_1 and the force P_8 at a distance b from the force P_1 , the following condition will have to be fulfilled for an equilibrium of moments with respect to the center of gravity of mass 7

$$m_1 r_1 \omega^2 a - m_8 r_8 \omega^2 (a + b) = 0$$

From both Equations 2 and 3 we may abstract ω^2 , which we suppose the same for all masses so that we receive two equations with eight values, from which we may choose six at liberty.

In the case that the mass of each of the outer screens 7, 8 is half the mass of the central screen 1 and their

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centers of gravity are equally spaced from the center of gravity of the central screen, the system will be balanced, if the amplitudes r_7 and r_8 are equal and in the direction opposite to that of the amplitude r_1 .

It is however possible to attain a balanced state even for different masses m_7 and m_8 and for different amplitudes, and even for different distances a and b . We have thus the possibility to give for instance to the screen 7 a larger amplitude of vibration than to the screen 1 and at the same time to the screen 8 a smaller amplitude of vibration than to the screen 1, as is often advantageous when grading certain material, and achieve simultaneously, that the whole system is balanced as to its forces and the moments resulting from these forces. Similarly it is possible to choose within the limits of both fundamental equations the masses of the screens and the distances of their centers of gravity so that the whole system may be easily adjusted to the required conditions. If the stiffness of the elastic elements 9 is chosen so that the adjacent masses always move in opposite directions, with amplitudes of the required magnitude, then the parallel bars 2 are transmitting to the frame only reactions which correspond to the passive resistances of the whole system.

It should be mentioned that the system is working above the critical frequency with respect to the masses 7 and 8 and it is therefore normally necessary to damp the oscillations which are originated when increasing the frequency from zero to the normal working frequency, and this may be accomplished by suitable dampers, as indicated by reference number 10 on Fig. 3. As shown in Fig. 3 by way of example, each damper 10 arranged between the elastic elements 9 and a driven mass represented by the screen frame 7 or 8 may be a conventional device comprising a cylinder 22 secured to the related side bar 11 and containing a fluid, and a piston 23 reciprocable in the cylinder 22 and joined by a rod 24 to the lug 21 projecting from the adjacent screen frame 7 or 8 so that the fluid in cylinder 22 acts on the piston 23 to damp the movements of the screen frame 7 or 8 relative to the screen 1.

The fact that the system works above the critical frequency of the masses 7 and 8 has the advantage that minor changes in masses or other parameters do not produce undue forces or oscillations under operating conditions.

The system according to the invention may be however brought to full working frequency without dampers and without starting any undue oscillations by bringing the driving shaft 3 to full speed at zero or rather small eccentricity of the crank 13 with respect to the shaft 3 and by increasing thereafter the eccentricity until the required amplitudes are attained. The change in eccentricity during operation may be accomplished by any known means, for instance by changing the relative position of two eccentric discs. In a similar way the starting and stopping of the whole system may be accomplished if a drive other than a crankdrive is used.

The oscillating system according to the invention is not limited to three aligned individually oscillating masses, and it is theoretically possible to use a larger number of such masses, so long as the conditions given by the Equations 1 and 3 are fulfilled for such larger number of masses.

Fig. 2 shows schematically a system with five aligned oscillating masses 1, 7, 8, 17, 18. The elastic elements 9 are here connected to the prolonged side bars 14, 15 of the screen frames 7 and 8. The mass 1 is again directly driven. Otherwise all conditions described with reference to the system according to Fig. 1 also apply to the system of Fig. 2, with the same possibility of choosing the magnitude of the masses, amplitudes and distances of the centers of gravity. It is not necessary that the direct drive be of the mass 1, as the mass 7 or 8 may alternatively receive the direct drive.

Figs. 3 and 4 show in elevation and top view an em-

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bodiment of the invention employing a horizontal reciprocating screen. The reference numbers used in Fig. 1 are applied to the corresponding parts of Figs. 3 and 4. In addition there are shown the dampers 10 for damping oscillations when starting and stopping the drive. These dampers may have a linear or non-linear characteristic and may be arranged as shown between the elastic elements and driven mass, or, alternatively, between the driven mass and the frame or foundation of the system.

The system according to the invention may be used for different installations, as for vibrating screens, vibrating conveyors and the like. The individual elements may be adjusted according to local requirements. It is for instance possible to have the bars 6 rigidly fixed to the frame or foundation 4 by means of torsional links or to have the screen frames suspended from an overhead frame, or to use other arrangements suitable for a given purpose.

By practically eliminating all so called dead oscillating masses, that is, masses which do not perform any useful work, for example, masses which do not carry material, such as, masses acting solely as a counterbalance or oscillating supporting frames, a considerable reduction of the weight of the whole system is achieved, with a corresponding reduction of the driving and maintenance costs.

In addition to reducing the weight of the oscillating masses, a considerable reduction of the stress upon the driving mechanism is attained, and the latter need only be sufficiently powerful to overcome the passive resistances of the whole system. As a perfect balance of forces and moments may be achieved, practically no reactions need to be transmitted to the foundation so that undesirable vibration of the buildings or other adjacent machines is avoided.

The system may be used either in the horizontal, vertical, or inclined positions of the aligned elements. No special precautions are required in case of minor frequency changes in the electricity in the supply lines and of minor irregularities in the feeding or grading of the material, which do not involve any substantial undesirable reactions, as the system works above the resonant frequency of the masses 7 and 8, so that the state of balance need not be so rigidly maintained.

What I claim is:

1. A vibrating system comprising at least three aligned masses, a fixed base, substantially parallel elongated support members pivotally connected at their opposite ends to said base and each of said masses to support the latter for oscillation independently of each other about neutral positions wherein the related support members incline substantially from the vertical, drive means carried by said base and directly connected to only one of said masses to forcibly oscillate said one mass with an amplitude that is positively determined by said drive means, said support members and drive means constituting the sole connections between said masses and said fixed base, elastic elements transmitting oscillations from said one mass to the others of said masses and having stiffnesses causing the oscillation of adjacent masses in opposed phase relation so that the adjacent masses move in opposite directions, said elastic elements exerting forces, when deformed, which act along lines passing through the centers of gravity of the related masses oscillated thereby and extending substantially perpendicular to the support members for said related masses, the sum of the products of the values of said masses and of the amplitudes of oscillation thereof being zero and the sum of the moments of the oscillating masses with respect to any point also being zero so that the system is fully balanced at all amplitudes of oscillation.

2. A vibrating system as in claim 1; wherein each of said elastic elements is in the form of a helical spring, and the line along which the latter exerts said force is in the direction of the axis of the helical spring.

3. A vibrating system as in claim 1; wherein said drive means is adjustable to vary the amplitude of the oscilla-

tions imparted thereby to said one mass so that, in operating above the resonant frequency of the system, said drive means can be adjusted to impart zero amplitudes of oscillation during starting, and the amplitudes of oscillation are increased only when said drive means approaches its normal operating speed, while the amplitudes of oscillation can be decreased to zero before stopping said drive means, thereby to prevent undesirable vibrations in passing through said resonant frequency.

4. A vibrating system as in claim 1, further comprising vibration dampers connected to said other masses for damping the oscillations transmitted to the latter.

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