June 7, 1960 E. W. SMITH 2,939,223

APPARATUS FOR VIBRATING SHEET MATERIAL

Filed Feb. 7, 1956 2 Sheets-Sheet 1

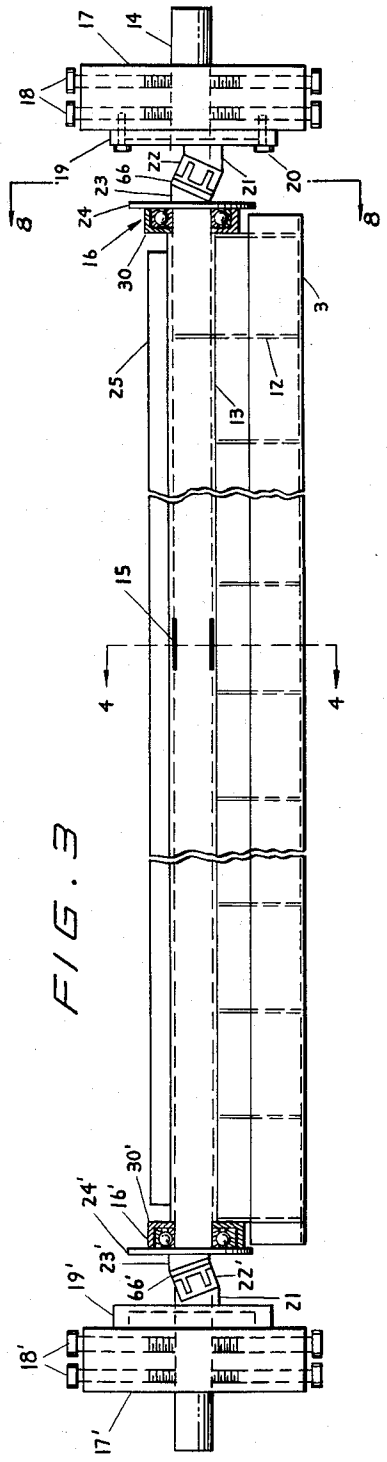


FIG. 3

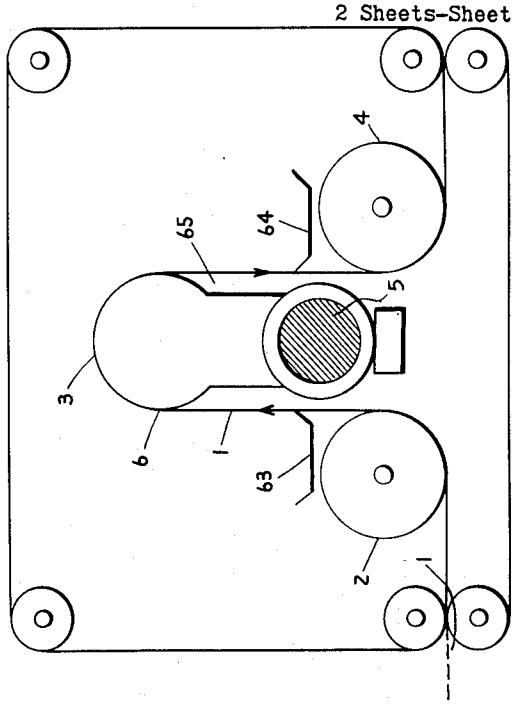


FIG. 1

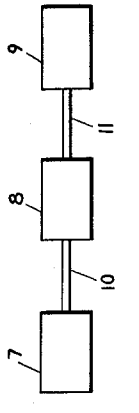


FIG. 2

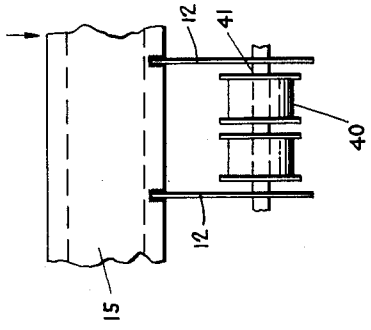


FIG. 5

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APPARATUS FOR VIBRATING SHEET MATERIAL

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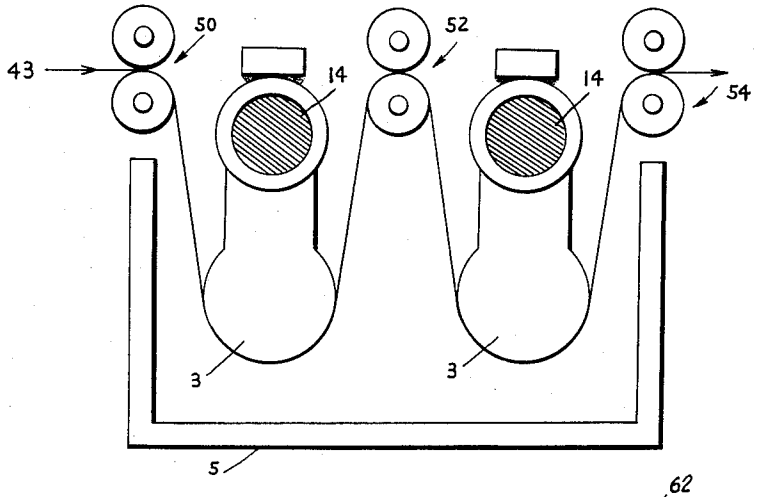


FIG. 6

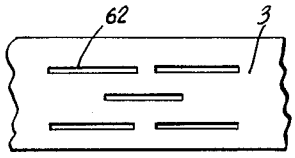


FIG. 7

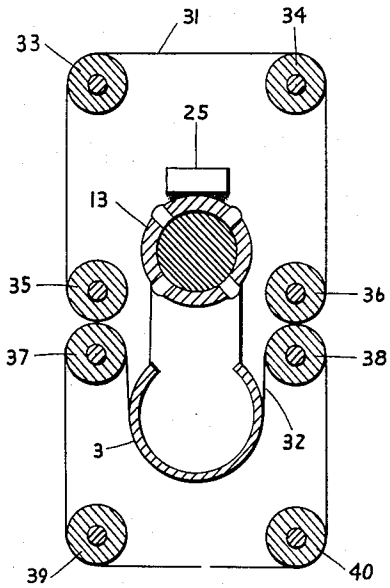


FIG. 4

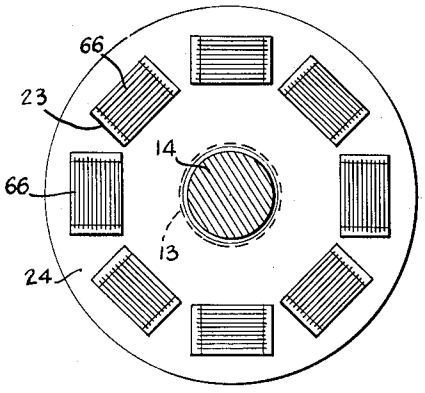


FIG. 8

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United States Patent Office 2,939,223 Patented June 7, 1960

2,939,223

APPARATUS FOR VIBRATING SHEET MATERIAL

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Filed Feb. 7, 1956, Ser. No. 564,025

11 Claims. (Cl. 34—58)

The present invention relates to a method and means for applying high and rapidly repeated accelerations to sheet and/or filamentous materials to accelerate their impregnation by liquid media or, conversely, to substantially remove such liquids from them as will appear in more detail below.

In the inventor's patent application, Serial No. 275,954, filed March 11, 1952, now Patent No. 2,741,111, issued April 10, 1956, a means and method is disclosed for accelerating the impregnation of sheet material or the like, by subjecting them to rapid to and fro oscillation in the liquid with which they are to be impregnated. This method and apparatus have proved satisfactory in use, but there are certain advantages to be gained in the size of equipment required if the frequency of oscillation could be materially increased.

In the present application a method and means will be disclosed for increasing this frequency of oscillation in the ratio of 10 or more to 1 as will presently appear, and by simple and effective means.

While reference has been made in the foregoing application primarily to a solution of the problem of speeding up the impregnation of sheet of filamentous materials, with a desired liquid by the use of high vibratory accelerative forces, it is likewise possible that such forces may be applied with equal efficacy to the removal of a liquid phase from such materials. Not only can the liquid phase be so removed but the process can be made a continuous one which is not the case with currently known methods for removing liquids from such materials by the use of high accelerative forces. This continuous operation makes this invention particularly adaptable for use in the commercial laundry field where a flow of sheets, towelling or the like may be dried in a continuous operation.

In the usual "batch process" clothes dryer now in use, it is common practice to remove liquids from cloth for instance, by the use of centrifugal forces. In such instances a perforated metal basket, perhaps four feet in diameter is loaded with the material from which water, or other liquids are to be removed, and the basket is then rotated at perhaps 750 r.p.m. which at the periphery of the basket develops an acceleration of 382 g., i.e. 382 times that of gravity. While such a method is reasonably satisfactory insofar as liquid removal is concerned and much superior to squeeze rolls for this purpose, it is still a "batch" process and considerable time and labor may be involved in loading and unloading the basket.

These objects and advantages of the present invention as well as others will be further described and understood when considered in connection with the accompanying drawings, in which:

Figure 1 is a schematic cross sectional plan view of a modification of the invention.

Figure 2 is a schematic diagram of the principal elements of the invention.

Figure 3 is a side fragmentary and partially cross sectioned elevation of the invention.

Figure 4 is a cross section taken along the lines 4—4 of Figure 3.

Figure 5 is a fragmentary elevation of a modification of a portion of the invention.

Figure 6 is a schematic plan of the invention as designed for and utilized in a welting or impregnating process.

Figure 7 is a plan fragmentary view of a modification of element 3 as shown in Figure 3.

Figure 8 is a cross sectional elevation taken along the line 8—8 of Figure 3.

The method and means whereby the present invention makes it possible to achieve accelerations comparable with those obtained with the rotating basket just mentioned, but on a continuous rather than a "batch" basis, can best be understood by referring first to Figure 1, where there is depicted in schematic form incoming goods 1 passing continuously around a rotatable roll 2, and then up and around the curved element 3 and then down and around rotatable roll 4. If now, element 3 is made to oscillate sinusoidally about an axis such as 5 by some suitable means, then the goods passing over element 3 will be subjected to accelerative forces which are directly proportional to the angular amplitude of the oscillation and to the square of frequency of such oscillation. Expressed mathematically, this means that the maximum acceleration applied to the goods will be

$$A=\frac{a\omega^2}{32.2}$$

where a is the amplitude of motion, expressed in feet, at the point under consideration, ω equals 2π times the frequency of vibration, and A is the numerical value of the acceleration expressed in g's, i.e. in multiples of the acceleration of gravity.

Now, let us suppose that point 6 in Figure 1, i.e. the point at which the fabric becomes tangent to a horizontal diameter of element 3, is vibrated through a stroke of ½ inch, that is through a distance of ¼ inch either side, of its position of rest and at a frequency of 120 cycles per second. It will be clear from substituting these values in the above equation that the maximum acceleration attained by element 3 at this point will be 368 g. Such an acceleration is comparable with the maximum acceleration produced by the rotating basket mentioned above and the liquid is literally thrown out of the fabric in passing around element 3.

Actually, in the present instance, the liquid is removed from the goods more effectively than with the rotating basket method, because all of the fabric being treated is subjected to the same maximum acceleration and, in addition, it is applied to only a single layer of the goods, whereas in the rotating basket, only goods close to the outer edge of the basket are subjected to the maximum acceleration of which the basket is capable. The acceleration applied to the rest of the fabric in the basket is subjected to an acceleration which decreases rapidly as the center of the basket is approached, and in addition, the liquid must pass through a thick layer of fabric in the basket before it can be thrown out at the periphery. Both of these factors tend to increase the difficulty of removing the liquid from goods placed in such a basket whereas neither of them are present in the case of the present invention.

The method and means whereby vibratory frequencies and amplitudes of the magnitude of those mentioned above can be obtained with the present invention, can best be understood by reference to Figure 2, where the essential elements of a torsionally resonant system are

shown schematically. Here it will be noted, three inertia elements, 7, 8 and 9 are connected by similar torsionally stiff members, such as steel shafts, 10 and 11, with shaft 10 being solidly secured at one end to inertia element 7 and at the other end, solidly secured to inertia element 8. Torsion member 11 is similarly solidly secured to element 8 at one end, and at the other end is solidly secured to inertia element 9.

In one of its possible modes of vibration, which is the only one with which we are concerned in the present invention, the system oscillates torsionally at its natural frequency for this mode. This frequency is dependent up the magnitudes of inertia elements 7, 8 and 9, and the stiffness of torsion shafts 10 and 11. Furthermore, inertia elements 7 and 9 oscillate simultaneously and in phase with each other, whereas inertia element 8 oscillates at the same frequency but in the opposite direction at any given instant to that of inertia elements 7 and 9.

With the above facts in mind we can now turn to Figures 3 and 4, where there is shown a piece of equipment designed to utilize the above principle in a practical manner and to ensure that the above mentioned mode of vibration and that only, is attained. Referring first to Figure 3, the curved element 3 with which the goods are brought in contact, is shown as being supported by a series of flat stiffening ribs 12, which in turn are solidly secured to a hollow torque tube 13, by welding or suitable means. Passing through the torsue tube is a torsion shaft 14 which is solidly secured to torque transmitting tube 13 at its center point 15 by welding or other suitable means, but does not touch it at any other point. This tube is torsionally stiff compared with the torsion shaft 14. Bearings 16 and 16' serve to ensure that the axis of torque tube 13 and torsion shaft 14 are maintained concentric and provide casings 30 and 30' secured at one end to the tube 13 and at the other to plates 24 and 24'. These plates rotate with and are secured to the casing and also maintain the ball bearing rings in position. At the extremities of torsion shaft 14, inertia elements 17 and 17' are solidly secured to the end of the torsion shaft by means of radial bolts 18 and 18' which also, of course, permit their removal from shaft 14 for servicing or the like. It will also be noted that plate elements 19 and 19', which may conveniently be circular and concentric with torsion shaft 14, are secured to inertia elements 17 and 17' by bolts 20.

Concentrically disposed on plate elements 19 and 19' is a group of angle blocks 21 and 21' which are solidly secured to plates 19 and 19', respectively, by any suitable means, such as machine screws and to these blocks are secured by welding, stacks of stator elements 22 and 22' made of E-shaped laminations. As will be noted these stacks of laminations are disposed opposite a similar group of I-shaped lamination stacks 66 and 66' and similarly secured on angle blocks 23 and 23'. Angle blocks 23 and 23' are similarly secured to support plates 24 and 24' which in turn are solidly secured to the opposite ends of torque tube 13 via the casings of bearings 16 and 16'. This structure is somewhat similar to that disclosed in my United States Letters Patent No. 2,604,503, issued July 29, 1952, insofar as the electrical elements are concerned. It will be noted in Figure 3 that for clarity only one angle block 21 (21') is shown at each end.

In order to dynamically balance the unit, a counterbalance 25 is solidly secured to the torque tube 13 and in a diametrically opposite position to that of the cloth contacting element 3 and its supporting ribs 12.

The shaft 14 may be suitably mounted on support bearings and if desired, may be placed in a tank to receive the drainage.

A pair of guiding continuous screen conveyors 31 and 32 of suitable screen mesh material are also provided as illustrated in Figure 4 (but not in Figure 3). These screen conveyors are supported by the rolls 33 to 40. All of these rolls 33 to 40, are suitably journalled at

either end in supporting structures such as for example, the side walls of the tank. Screen conveyor 31 extends about rolls 33, 34, 35, 36 and the curved member 3, and is continuously rotated thereby by suitable means such as a meshing gear arrangement which drives one or more of these rolls, carrying in turn with it, the screen conveyor 31. The screen conveyor 32 extends about rolls 37, 38, 39 and 40, and the curve section 3, being tangential, as is screen conveyor 31 to the sides of the curved section 3. The screen conveyor 32 is also suitably driven by a drive means applied to one or more of the rolls about which this conveyor extends. The conveyors 31 and 32 are in fact to face relation from substantially between the rolls 35, 37 to the rolls 36, 38, and thereby provide a conveyor system between which flat sheet material may be passed over the curve section 3. If desired an additional pair of feed rolls may be positioned parallel to and substantially level with the rolls 37, 38 with one on either side, to feed the continuous sheet material into the conveyor system between the rolls 35, 37 and to receive it from between the rolls 36 and 38.

A little study will make it apparent that in the equipment just described, we have, in essence, a counterpart of the schematic arrangement shown in Figure 2. In other words, inertia elements 17 and 17' correspond to the similar inertia element 7 and 9 in Figure 2, while the inertia elements of the assembly consisting of element 3, the stiffening ribs 12, torque 13, the housings of bearings 16 and 16', plates 24 and 24', with their associated angle blocks 23 and 23' and their I-shaped lamination stacks, together with counterbalance 25, correspond to inertia element 8 in Figure 2.

Similarly that portion of the torsion shaft 14 in Figure 3 which lies between the center connection point 15 and the point where inertia element 17 is secured to shaft 14, corresponds to the torsionally stiff element 10 in Figure 2, while the remaining portion of shaft 14 which lies between the center point 15 and the point of connection between inertia element 17' and shaft 14 corresponds to the torsionally stiff element 11 of Figure 2.

The angular arrangement of the E-shaped stator elements and the I-shaped armature elements has a special function as will now appear. When the coils (not shown) surrounding the center legs of stator elements 22 and 22' are energized, the magnetic flux produced causes a direct pull across the airgap between them. However, this pull, due to the angle at which the airgap is disposed, has a component which in effect tends to twist the ends of that portion of shaft 14 between the center point 15 and the point of connection with inertia element 17, in opposite directions. This force is transmitted to the point 15 through the tube 13. A similar situation occurs at the other end of the unit in that portion of shaft 14 between the center point 15 and the point of connection between shaft 14 and the inertia element 17' since the ends of this section are likewise twisted in opposite directions when the coils surrounding the middle leg of stator blocks 22' are energized.

Since these two groups of coils are simultaneously energized by the electric current supplied from any suitable source, the net effect is that at any instant, inertia elements 17 and 17' are both tending to rotate in the same direction whereas the torque tube 13 and its associated parts tend to rotate in the opposite direction. By properly choosing the frequency of the alternating current applied to the coils so that it matches the natural period of vibration of the system in this manner, larger amplitudes of vibration of the torque tube and its associated parts are made possible.

In designing such a unit, it is first necessary to establish the frequency and angular amplitude of oscillation desired and then to compute in the usual known ways the inertia of the torque tube and its associated parts such as the ribs 12, cloth contacting member 3, counterweight 25, etc. Once this has been done the maximum accel-

erating torque required to drive it at the given frequency and angular amplitude may be determined by the following equation, remembering that only one half of this value of inertia should be substituted in the following equation:

$$T=\frac{J_m}{144(32.2)}\alpha\omega^2 \quad (12)$$

where T is the torque required in inch pounds, J_m is the one-half value of the inertia of the torque tube assembly just mentioned in pound inches squared, α is the angular amplitude of vibration in radians, and ω is 2π times the desired frequency of vibration.

The shaft diameter can then be determined from the equation

$$T=\frac{S\pi d^3}{16}$$

where T is the torque value obtained above, S is the maximum desired fiber stress in the shaft which I prefer to make 10,000 pounds per square inch, and d is the shaft diameter in inches.

The length of the shaft **14**, i.e. its effective length can then be determined from the equation:

$$f=\frac{3400\ d^2}{\sqrt{J_m L}}$$

where f is the frequency in cycles per second desired, d is as before the shaft diameter in inches as obtained above, J_m is the inertia as before and L the length in inches from the center point connection **15** to the modal point of this section of the shaft. The factor "3400" is a conversion factor based on the assumption that the steel used for the shaft has a torsional modulus of elasticity of 11,000,000 pounds per square inch. Thus if the inertia of inertia element **17** plus its associated parts is made to have an inertia equal to one half that of the torque tube assembly inertia, then the total length of shaft **14** between point **15** and the point of connection with inertia element **17** will be twice the value of L as determined above. On the other hand if the inertia of inertia element **17** plus its associated parts is made some other value, the total length of the shaft from point **15** to the point of connection with inertia element **17** will be

$$L'=L+\frac{J_m}{J_{17}}(L)$$

where L' is the total length of the shaft from point **15** to the point of connection of it with inertia element **17** in inches, J_m is as before the inertia of ½ the torque tube assembly in inch² pounds, L is the length L as given above and J_{17} is the inertia in pound inches squared of the inertia element **17** and its associated parts.

The above, of course, applies with equal force to the other end of the system and the frequency of the alternating current required to drive the system will, as usual, be one half of the desired frequency of oscillation.

The design just discussed is particularly well suited to applications where element **3** must be 60 inches or more in width, i.e. where it will be used to handle goods of this width. For shorter lengths of element **3**, the design may be simplified by, in effect, cutting the unit shown in Figure 3 in half at point **15**, of course making an appropriate increase in the length of shaft **14** to provide support for the unit as a whole at this end of the system. For instance, a design made up for operation at a given frequency and stroke, or angular amplitude of oscillation, with say element **3** of such a length as to accommodate 72 inch wide material could be cut in half at point **15**, a shaft extension added at that point for physical support of the arrangement, and its operation at the same angular amplitude and frequency would be perfectly feasible. For the narrower widths of goods this would be an advantage and is made possible because of the symmetry of the system.

In cases where sliding the material over such a surface as element **3** might be detrimental to the product such as photographic film because of friction abrasion, or in the case of threads, tapes, etc., element **3** can well be replaced by pulleys **40** mounted on axles **41** and supported between stiffening ribs **12** as shown in Figure **5**.

Mention has been made earlier that the present invention could be equally well applied to the impregnation of sheet material with a liquid, or conversely, to remove liquids from such materials because the high accelerations obtained are equally applicable to effect both these purposes. In Figure 6 is shown a schematic arrangement of an application of the present invention to the impregnation of sheet materials by liquids. Incoming goods **43** are passed between a pair of driven rolls **50** and then down around element **3**, during which passage they pass under the liquid with which they are to be impregnated which is held in tank **51**, and vibrated energetically therein by element **3**. They then pass upward and between another pair of driven rolls **52** which serve to pull the material along, and then downward again around another vibrating element **3** may be provided with overlapping slots **62**, or other suitable apertures to facilitate passage of the liquid into the material being treated as shown in Figure **7**.

The pairs of rolls, **50**, **52** and **54**, as well as the shafts **14** are suitably secured in bearing and support structures at either side of the tank **51**. A suitable driving means for the driven rollers may be provided and if desired, may comprise a chain drive mechanism for a power source.

Reference is again made to Figure 1, which shows a schematic diagram of the essential elements of this invention, where it is noted the element **3** is positioned above the shaft or axis **5** rather than below it as illustrated in Figure 3. By providing such an arrangement in a structure for drying material, the continuous sheet of material, when it reaches point **6**, will have its liquid content thrown outward in both directions. That portion of the liquid falling on the outside of the continuous sheet of material will drain downwardly into the drain tray **63** on one side, and **64** on the other. The liquid falling from the continuous sheet of material on the inside between the sheet of material **1** and the supporting structure in the area indicated at **65**, will fall downwardly between the rollers **2** and **4**, where it may be suitably drained off. These draining trays may be of conventional design inclined slightly towards the ends and supported in a framework of suitable design. In the modification of such an arrangement, the parallel screen conveyors may be arranged in a manner similar to that described in connection with Figure 4.

It should be noted that where the material being processed is continuous in very long lengths, as for example several hundred yards, the screen conveyors may be dispensed with and the material fed directly through the system.

Having now described my invention, I claim:

1. A structure adapted to dry sheet material by a rapid oscillatory acceleration having a longitudinally extending torsion shaft, a plurality of inertia elements comprising a torque tube coaxial with and fixed at one location to said shaft, a counter balancing member and means providing a surface over which said sheet material may be drawn fixed to said tube diametrically opposite said counterbalancing member and means for applying oscillatory forces in opposing phases to adjacent inertia elements whereby said elements will oscillate at a resonant frequency.

2. A structure adapted to oscillate sheet material with a rapid oscillatory acceleration having a longitudinally extending torsion shaft, a plurality of inertia elements fixed to said shaft, one of said inertia elements having a torque tube coaxial with and fixed intermediate its ends to said shaft, bearing means positioned at the end of said tube and spacing it from said shaft for torsional oscillation of said

shaft, and means providing a surface over which said sheet material may be drawn fixed to said tube, and means comprising parallel plate members fixed one each to the end of said tube and other inertia elements, said plate members having fixed thereto stator and armature members adapted when electrically energized, to cause oscillations of opposing phases in said tube and other inertia element, whereby said adjacent inertia elements will oscillate at a resonant frequency.

3. A structure adapted to oscillate sheet material with a rapid oscillatory acceleration having a longitudinally extending torsion shaft, three inertia elements fixed at spaced distances on said shaft, the center element having a torque tube coaxial with said shaft terminating short of the other inertia elements, and having means providing a surface over which said sheet material may be drawn, and means fixed in part to said tube and in part to said outer inertia elements adapted to apply oscillatory forces in opposing phase to said center and outer inertia elements whereby said elements will oscillate at a resonant frequency.

4. A structure adapted to oscillate sheet material with a rapid oscillatory acceleration having a longitudinally extending torsion shaft, three inertia elements fixed at spaced distances on said shaft, the center inertia element having a torque tube coaxial with said shaft terminating short of the outer inertia elements and having means providing an elongated surface positioned in a fixed spaced parallel relation to said tube over which said sheet material may be drawn, and means fixed in part to said tube and in part to said outer inertia elements adapted to apply oscillatory forces in opposing phase to said center and outer inertia elements whereby said elements will oscillate at a resonant frequency.

5. A structure as set forth in claim 3, having a pair of continuous mesh conveyor belts in face to face contact over a portion of their length with said portion in contact with said surface.

6. A structure as set forth in claim 3, wherein said surface comprises a longitudinally extending arcuate surface parallelly interconnected by a plurality of rib members to said torque tube with a counterbalancing member secured to said tube.

7. A structure as set forth in claim 3, wherein said surface is positioned to oscillate above said torque tube.

8. A structure as set forth in claim 3, wherein said surface is positioned to oscillate below said torque tube.

9. A structure as set forth in claim 3, wherein said surface comprises a plurality of aligned rolls with means supporting said rolls for free rotation.

10. A structure adapted to process sheet material by a rapid oscillatory acceleration having a longitudinally extending torsion shaft, three inertia elements fixed at spaced distances on said shaft, the center element having a torque tube coaxial with said shaft terminating short of the other inertia elements and having means providing a longitudinally extending arcuate surface over which said sheet material may be drawn, said surface having a plurality of openings formed therein, and means fixed in part to said tube and in part to said outer inertia elements adapted to apply oscillatory forces in opposing phase to said center and outer inertia elements whereby said elements will oscillate at a resonant frequency.

11. In a structure for providing rapidly oscillatory acceleration a longitudinally extending torsion shaft, a center and two outer independent inertia elements fixed at spaced distances on said shaft, and means fixed in part to said shaft and in part to said outer inertia elements adapted to apply oscillatory forces in opposing phases to said center from both said outer inertia elements whereby said elements will oscillate at a resonant frequency.

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