A mixing machine for rapid mixing of dental materials and other substances, having a high speed rotor head on a vertical axis and an offset mixing vessel on an inclined axis with a common epicyclic drive from a single motor, such that the mixing vessel rotates at a controlled speed while the main rotor rotates at high speed. This produces an enhanced centrifugal force and internal shearing, resulting in rapid mixing without air being entrained.
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MIXING PROCESS AND APPARATUS

This invention relates to methods and apparatus for mixing materials where a very high degree of intimate mixing or homogeneity is required in the final mixture, and is particularly though not exclusively applicable in cases where the mixing must be rapid and where it is important that voids or air bubbles should be excluded.

Thus the invention may be applied particularly to the mixing of alginate dental moulding materials, or filling or stopping materials, or in general to any mixture of solid powders, liquids, pastes, semi-solids or the like, alone or in combination with others.

The invention may be of particular utility when a rapid mixing is required as in the case of chemical hardening mixtures such as thermo-setting synthetic plastics, e.g., epoxy resins and hardeners.

Broadly stated from one aspect the invention consists in apparatus for mixing materials comprising a main rotary head mounted on a vertical axis, a secondary rotor mounted in bearings on the main head with the secondary rotor axis inclined inwardly and upwardly toward the main rotary axis, an upwardly open holder for a mixing vessel, mounted on said secondary rotor, with its centre positioned on the secondary axis but radially offset from the main axis, and motor means for driving the main rotary head in one direction at a speed sufficient to produce a centrifugal field of at least 20 g at the centre of the holder, and for simultaneously rotating the secondary rotor at a controlled speed about the secondary axis.

Preferably the secondary rotor axis intersects the main rotor axis at an angle of between 15° and 75°, and in a preferred embodiment the angle of inclination of the secondary axis from the horizontal is approximately 50°. The inclination and the relative speeds of rotation, and dimensions, are preferably such that the materials being mixed cover a major part of the base of the mixing vessel and the outer part of the side wall of the vessel, while mixing takes place.

According to a preferred feature of the invention both the main and secondary rotors are driven from a common motor through transmission mechanism arranged to rotate the main rotary head and the secondary rotor in opposite directions, the speed ratio between the main and secondary rotors being between 3:1 and 10:1.

In conventional mixing apparatus the mixing vessel is usually provided with internal blades or paddles but by contrast in the present invention the cup holder and/or mixing vessel preferably has a substantially smooth internal surface, substantially in the form of a surface of revolution.

In a preferred construction the drive means to the secondary rotor is arranged to drive this rotor at its lower end, and the speed and directions of rotation of the main and secondary rotors are such that all parts of the secondary rotor and holder have a resultant angular velocity about the main rotary axis in the same direction as the main rotary head.

The main rotor head preferably carries an adjustable counterbalance to compensate for different weights of material in the mixing vessel. Also in a preferred arrangement the axis of the driving motor is offset laterally from the main rotor axis. This provides a particularly simple and effective gear transmission path, the motor spindle carrying two gears one of which drives the main rotor head while the other drives the holder through a secondary gear train.

From another aspect the invention consists in a process of mixing solid and/or liquid materials, in which the materials are placed in a substantially smooth surfaced mixing vessel, which is rotated about its centre line on a secondary axis inclined from the horizontal at an angle of between 10° and 75°, and simultaneously rotated about an offset main vertical axis, at a speed sufficient to create a centrifugal field of at least 20 g within the vessel, so as to mix the materials by internal shearing action.

Preferably the mixing period is prolonged sufficiently to remove substantially all included air or gas from the materials, but in view of the rapid mixing action the total mixing time can normally be kept to a relatively short interval of between 5 and 25 seconds.

In any case the rotation about the main vertical axis is preferably such as to create a centrifugal field of at least 50 g. Conveniently the rotation about the secondary axis is in the opposite direction from the rotation about the main axis, and at a slower speed, and preferably the rotational speeds and dimensions are such that all parts of the mixing vessel have a resultant velocity about the main rotary axis, in the same angular direction.

The invention is based on the concept that by creating an enhanced gravitational field and simultaneously causing the direction of the field to change with respect to the container and the mass of material in question, the material will be caused to move within its container vessel and a very effective shearing action will be created internally, without use of any mechanical beaters, paddles or the like. The absence of any beaters or internal vanes reduces the risk of air pockets being trapped and the high centrifugal force also acts very effectively in excluding air so that voids do not form in the mixture.

The invention may be performed in various ways and one specific embodiment with various possible modifications will now be described by way of example with reference to the accompanying drawings in which:

FIG. 1 is a sectional side elevation through a mixing machine according to the invention designed specifically for dental purposes, and
FIG. 2 is an end view partly in section on the line II—II of FIG. 1.

The machine illustrated comprises a main casing 10 with a removable snap-on top cover 11 having a large central opening 12 on its top wall. Within the casing 10 is a horizontal bulkhead 13 supporting the mechanism. The main mixing head 15 has a pair of limbs 16, 17 extending in opposite directions from the axis of a vertical spindle 18 carried in bearings 19, 20 mounted on the bulkhead. The limb 16 has a pair of brackets supporting a rod 22 on which is mounted an adjustable counterbalance 23. The other limb 17 carries a stub shaft 24 on which is mounted a cup holder 25 supported by a bearing 26. The cup holder has a substantially smooth cylindrical internal surface, and is designed to receive and grip a removable smooth surfaced mixing cup 14. The axis 27 of the spindle 24 is inclined inwards and intersects the axis of the vertical spindle 18, the inclination of this axis 27 from the horizontal being in this particular example approximately 55° (i.e., it intersects the main spindle axis at 35°). Secured to the main head 15 is a generally conical dish 60 with a circular aperture
through which the cup holder projects, the dish acting to prevent any of the materials being accidentally spilled over the operating mechanism.

The mixing head is driven by a small electric motor 30 supported from the bulkhead 13 and having a driving shaft 31 located by a bearing in the bulkhead. One gear 33 on this output shaft meshes with a gear 34 fixed to the lower end of the main spindle 18 so as to drive the mixing head 15. A second gear 36 attached to the motor spindle meshes with the lower gear 37 of a double pinion which freely surrounds the main spindle 18, the upper gear element 38 being arranged to mesh with a bevel gear 40 formed as part of the cup holder 25. With this particular arrangement, the motor speed and the rear ratios are such that the speed of the main spindle 18 is approximately 2,000 r.p.m. and the cup holder 40 is rotated in the opposite direction on its subsidiary axis 27 at a speed of about 500 r.p.m. The speed ratio is thus approximately 4:1. With these operating conditions, and with the particular dimensions selected, the centrifugal force acting at the extreme outer corner 42 of the cup 14 will be approximately 250 g. Also owing to the relative speed ratio between the main spindle and the cup holder, and the fact that they are rotating in opposite directions, it will be noted that all parts of the cup holder have a resultant angular velocity about the main spindle axis in the same direction as the main spindle rotation at all times.

The mixing period is controlled by a timing switch 45 with an adjustable knob 46, mounted in the main casing 10. In addition the apparatus will usually include a motor speed control (not illustrated) for setting the speed of the motor. The casing can be removably mounted on a flat surface such as a table by means of a suction cup 48 mounted in the lower part of the casing and actuated by a crank handle 49 which has a flattened or cranked central part 50 passing through a slot in a boss 51 on the cup to raise and lower the central part of the cup. In this way the cup can be deformed to exert suction so as to clamp the machine on a table when required.

In this particular example the total time taken to accelerate the mechanism up to full speed is about 3 seconds, the total mixing time for the dental alginate impression material is about 5 to 25 seconds or preferably between 5 to 10 seconds.

The angle of inclination of the secondary axis 27 is preferably in the range of between 10° and 75° from the horizontal. At the lower limit of the range the mixing efficiency becomes relatively low, since the centrifugal force exerted on the materials in the cup 14 tends to hold the materials in a mass against the base of the cup. The angle of inclination is preferably more than 20° and for best results between 30° and 60°. With an angle of inclination of this order, and with operating conditions selected to produce a radial centrifugal force equivalent to at least 200 g or 250 g at the outermost part of the cup holder, the materials in the cup adopt a sloping parabolic configuration as indicated diagrammatically at 21, and so make contact with both the base and the outer part of the side wall of the cup, which improves the mixing efficiency. If the angle of inclination is too great the materials will tend to be flung out of the cup, unless a cover is provided, and also mixing will be inefficient.

The radial displacement of the cup holder from the main spindle 18 is a factor in the centrifugal force generated, which is also a function of the rotational speed of the main spindle. Thus preferably \( w' r \) is at least 200 g or 250 g, where \( w \) is the main spindle speed in radians/sec. and \( r \) is the radius in inches from the spindle axis to the centre of the base of the cup holder. By varying the radius and the rotational speed the centrifugal field can be varied to suit requirements and for best results in the specific case of a dental alginate mix the field is preferably of the order of 100 g to 200 g, as obtained for example with a main spindle speed of about 2,300 r.p.m. and a mean radius to the centre of the bottom of the mixing cup of about 1.5 inches.

The relative speed ratio between the main spindle and the cup holder is preferably in the range between 4:1 and 10:1 but for different purposes different speed ratios may be required. Alternatively, though this is not preferred, the mixing cup may be driven by an independent drive such as a small motor mounted on the supporting arm, and this will allow independent control of the secondary spindle speed.

It has been found that the rotary acceleration is an important and critical feature in the mixing process, particularly for fast setting compounds such as alginate dental impression materials, and preferably the power and acceleration of the driving motor are such that the main and secondary rotors reach a velocity substantially equal to their peak velocity in less than one-half the total mixing period. It is preferred that this acceleration time should in fact be less than one-third the total mixing time. For example when mixing dental alginate moulding materials the total mixing time is preferably between 10 and 20 seconds and the acceleration time up to peak speed is not more than 6 seconds and preferably about 3 seconds.

The invention may also be applied to a process of mixing and simultaneously moulding materials in a container which acts both as a mixing vessel and a mould. The container in such cases has a suitably shaped internal mould profile rather than the smooth internal surface of the previous example. In other respects the apparatus and the procedure is identical but the process is continued for sufficient time to allow the materials to harden partly or fully, so that they can be removed as a moulded mass or block. This may be applied for example to synthetic plastics or cementious materials.

I claim:

1. Apparatus for mixing combinations of powdered and liquid materials, comprising a main rotor head mounted for rotation on a vertical axis, a secondary rotor mounted in bearings on said main head, the secondary rotor axis being inclined inwardly and upwardly towards the main rotary axis so as to intersect the main rotor head at an angle of between 15° and 70°, an upwardly open holder for a mixing vessel, mounted on said secondary rotor, with its centre positioned on the secondary axis but radially offset from the main axis, a motor connected through a positive transmission to drive said main rotor head in one direction at a speed sufficient to produce a centrifugal field of at least 20 g at the centre of said holder, and further positive transmission means connected between said motor means and said secondary rotor to drive said secondary rotor at a controlled speed about the secondary axis in the opposite direction, the speed ratio between said main and secondary rotors being between 3:1 and 10:1.
2. Apparatus according to claim 1, wherein said cup holder has a substantially smooth internal surface, substantially in the form of a surface of revolution.

3. Apparatus according to claim 1, wherein the speeds of rotation of said main and secondary rotors are such that all parts of the secondary rotor and holder have a resultant angular velocity about the main rotary axis in the same direction as the main rotary head.

4. Apparatus according to claim 1, wherein the axis of said motor is offset laterally from said main rotor axis.

5. A process of mixing a combination of powdered solid and liquid materials, in which the materials are placed in a mixing vessel having a smooth internal surface, which is rotated about its centre line on a secondary axis, and simultaneously rotated in the opposite direction about an offset main vertical axis, said secondary axis being inclined from the horizontal at an angle of between 20° and 75°, the rotation about the main axis being at a speed sufficient to create a centrifugal field of at least 20 g within the vessel, and the speed ratio between the rotations about the main and secondary axes being between 3:1 and 10:1, so as to mix the materials by internal shearing action.

6. A process according to claim 5, wherein the mixing period is prolonged sufficiently to remove substantially all included air or gas from the materials.

7. A process according to claim 5, wherein the total mixing time is at least 5 to 25 seconds.

8. A process according to claim 5, wherein the rotational speeds about said main and secondary axes are such that all parts of said mixing vessel have a resultant velocity about the main rotary axis, in the same angular direction as the rotation about said main axis.

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