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(54) Magnetic methods of separating electrically conductive materials.

(57) A method of separating predetermined non-magnetic electrically conductive items from a flow of non-magnetic electrically conductive materials containing such items comprises the steps of passing the flow of materials adjacent to electromagnetic field (3) generating apparatus ; subjecting the materials to the action of a fluid (6) whilst the flow of materials is adjacent to the electromagnetic field generating apparatus ; controlling the flux field generated by the apparatus such as to create electrical current within the predetermined electrically conductive items which react with the generated electromagnetic flux field causing the creation of a directional force upon the predetermined items, in association with the subjection thereof to the fluid (6), such as to move only the predetermined electrically conductive items out of and away from the flow of material in a predetermined direction for a predetermined distance (4).

In another aspect the method comprises passing the flow of materials adjacent to a linear induction motor (3) ; controlling the flux field generated by the linear induction motor and providing a pulse of such field by switching on and off the linear induction motor at a frequency lower than the supply frequency such as to create consequential pulsed electric currents within the predetermined electrically conductive items which react with the pulsed generated electromagnetic flux field causing the creation of an intermittent force upon the predetermined items such as to move only the predetermined electrically conductive items out of and away from the flow of materials.

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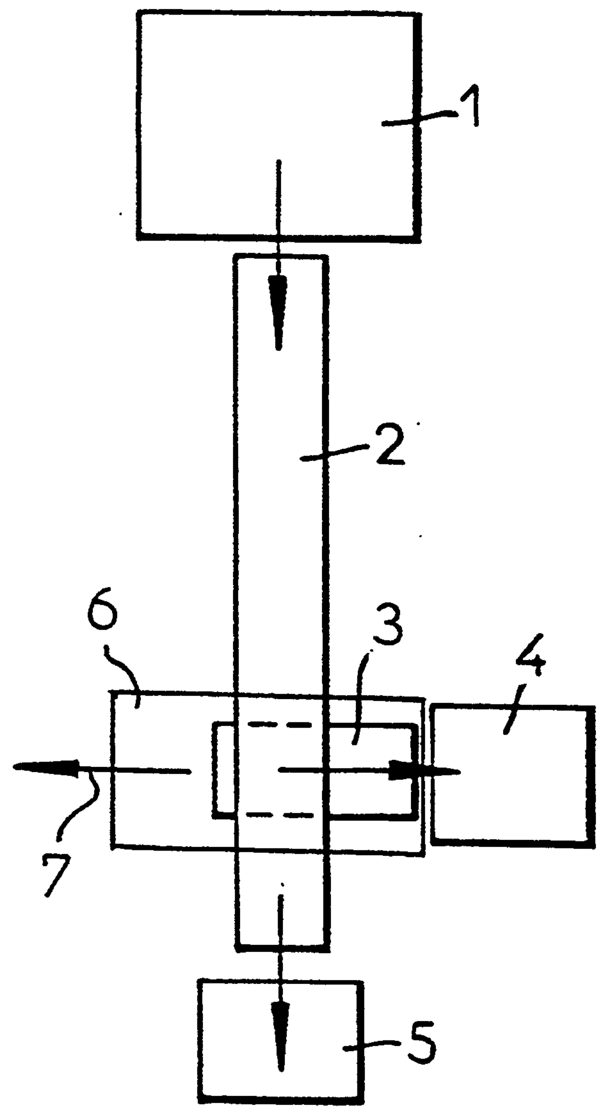
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This invention relates to the separation of materials.

A common industrial problem associated with the production of many items is that of the need for separation of the particular items produced from associated waste material involved in their production. Similarly a long standing problem is the general one of the separation and sorting between various scrap and rubbish materials. Whilst the separation out of magnetic portions of such materials by means of their magnetic properties has proved possible, the separation and sorting of non-magnetic materials still presents considerable problems.

This invention is particularly concerned with material separation methods for non-magnetic materials, and is especially concerned with the separation of a collection of items having significant electrical conductivity, either by virtue of conductive materials of which they are formed or by virtue of conductive coatings or inserts.

It is an object of the present invention to provide a method of material separation for electrically conductive items of simple effective and efficient operation which can overcome or at least subtantially reduce the above mentioned problems.

In accordance with one aspect of the present invention there is provided a method of separating predetermined non-magnetic electrically conductive items from a flow of non-magnetic electrically conductive materials containing such items comprising the steps of passing the flow of materials adjacent to electromagnetic field generating apparatus; subjecting the materials to the action of a fluid whilst the flow of materials is adjacent to the electromagnetic field generating apparatus; controlling the flux field generated by the apparatus such as to create electrical current within the predetermined electrically conductive items which react with the generated electromagnetic flux field causing the creation of a directional force upon the predetermined items, in association with the subjection thereof to the fluid, such as to move only the predetermined electrically conductive items out of and away from the flow of material in a predetermined direction for a predetermined distance.

The fluid may be air, and the subjection of the flow of materials to the fluid action may be by means of an air fan serving either to assist in the movement of the predetermined electrically conductive items, or to resist the movement of any other items from the flow of materials.

Preferrably however, the fluid is a liquid, and the flow of materials may be arranged to be immersed in a liquid at the point of separation, i.e. as the materials pass adjacent the electromagnetic field generating apparatus.

Advantages of this arrangements are as follows:-

(a) the friction experienced by the separated items is reduced as the liquid acts as a lubricator and the apparent weight of the items is reduced by virtue of the displaced liquid;

(b) the liquid can be a degreasing solution or solvent which helps in the separation of shapes and/or materials in that the tendency of the different items to stick together is greatly reduced (this is especially of use in the separation of specific shaped items from swarf of the same material after a machining operation);

(c) the liquid may have ultrasonic transducers introduced into it which not only helps if used in conjunction with (b) above, but also has the result of further reducing the static friction effect when trying to separate out very small items;

(d) the liquid can be made to flow in a direction roughly opposite to that of the selected items at the point of separation thereby reducing the tendency of unwanted items and/or materials to be dragged out of the mixture by the selected items as those unwanted items and/or materials are effectively swept back into the mixture by the flow of liquid.

The electromagnetic field generating apparatus may comprise an electromagnetic induction apparatus creating a fixed flux field such as, for example, a design modification of the structure of an induction heater. Alternatively, and in a preferred embodiment, the electromagnetic field generating apparatus is arranged to produce a travelling flux field transverse to the direction of travel of the materials adjacent thereto. Such a travelling flux field has been found to be of great effectiveness in the operation of the invention. Thus, most conveniently, a linear induction motor stator may be used as the electromagnetic field generating apparatus.

With a linear motor, it is to be noted that the speed of flux field movement (which I believe can be significant in some embodiments of my invention because induced current depends on the flux density and the speed of field travel) is directly related to the supply frequency and the pole pitch.

In the case of a linear motor it has been found that after making a suitable choice of pole pitch in the design of the motor, control of the flux field to provide the required movement of the predetermined items can be by determination of the necessary input power and/or the power supply frequency.

In accordance with another aspect of the present invention there is provided a method of separating predetermined non-magnetic electrically conductive items from a flow of non-magnetic electrically conducting materials containing such items comprising the steps of passing the flow of materials adjacent to a linear induction motor; controlling the flux field generated by the linear induction motor and providing a pulse of such field by switching on and off the linear induction motor at a frequency lower than the supply frequency such as to create consequential pulsed electric currents within the predetermined electrically conductive items which react with the pulsed generated electromagnetic flux field causing the creation of an intermittent force upon the predetermined items such as to move only the predetermined electrically conductive items out of and away from the flow of materials.

The switching of the linear induction motor may be by means of simple electronic control equipment.

On attempting to select either:-

(a) items which are very small, or which because of their topology or because of their material of composition have a low thrust:mass ratio when exposed to the flux field of the linear induction motor, or

(b) items which intrinsically have a relatively low ratio of conductivity:mass,

it is often the case that with a given configuration of linear induction motor with mechanical equipment comprising inter alia a conveyor (which may be vibrating) and a given electrical supply to that linear induction motor, the flux produced is insufficient to cause those desired items to move entirely satisfactorily from the mixed stream. A higher flux density can be achieved from a given configuration of equipment by pulsing the supply which causes a flux which is intermittently high, the rest of the time being zero. This method overcomes the problem of the overheating of the electrical winding of the linear induction motor whilst achieving flux densities higher than would otherwise be possible.

It has been found in practice that for the removal of relatively small predetermined items away from the flow of materials (for example items having dimensions varying from a score or so of cm's down to a mm or less) the method of the invention is particularly effective when used with a linear motor stator having a small pole pitch (for example less than 6 cm) and a high flux density (for example greater than 0.3 Teslar).

The method may be used with a control system for the linear induction motor incorporating variable terminal voltage as the single control variable, determining flux density. Such supply-frequency system may be either single phase and three phase.

The method may also be used where the motor is provided with a variable frequency control system whereby in the method both frequency and flux density can be controlled, and this may be by means of a three-phase invertor.

A variable frequency supply, although adding to the cost of capital equipment in use of the method, (which can be in the form of a three phase invertor) enables both frequency and flux density produced by the induction motor to be controlled. A single phase supply can be made to operate on a three phase system by means of the already known steinmetz connection, for example.

A typical problem to which the present invention is applicable is that of separating cast or moulded electrically conductive items, after release from the appropriate dies or moulds and from those solidified portions of material with which the items are formed, from the feed and/or overflow parts. Thus, purely by way of example, a problem arises in the die casting of conductive metal alloy components, which, after ejection from the die are broken from the metal solidified in the sprue, feeder and overflow portions, and are then fed away from the casting machine for separation of the component itself. In such circumstances separation tends to be a somewhat difficult and expensive task because the sharp angularity of the sprue formed material in particular, and the generally awkward dimensions of the various products render vibratory screen separation techniques difficult and expensive to utilise so that separation of the items from their associated scrap metal portions is of necessity commonly carried out by manual operation. This is itself an expensive and inefficient method of sorting, particularly since it necessitates a considerable cooling of the items and the scrap metal. This is particularly disadvantageous if it is intended, as frequently is the case, that scrap metal be immediately remelted for reuse, because of the consequent expense of additional reheating.

Another typical example of material separation in an area where the invention has good application is the separation of items produced on a lathe or machining centre, particularly small items, from their accompanying swarf. Yet again normal separation techniques in such a situation can be time consuming and costly.

Whilst a linear induction motor has particular advantages in that it can be arranged to move a conductive item in a particular direction over a considerable distance, a simple inductive device similar to that used for induction heating can, with the appropriate configuration and power arrangments, provide an adequate "throw" force with respect to the particular items concerned easily to remove specific items from a mixed collection of materials.

In one convenient form of the invention, the material from which items are to be separated can be moved by means of a travelling and/or vibrating conveyor across the upper face of a suitable induction apparatus. Vibration of the conveyor, in some instances, is particularly beneficial in assisting the removal of the predetermined items.

I have found it especially beneficial for the conveyor to be inclined on its upper face with its windings and power configuration arranged such that materials not experiencing the appropriate induced forces, slide across the inclined upper face of the device into an appropriate receptacle, whilst the specified items are "thrown" in a different direction, for example, up the inclination and into a second appropriate receptacle. Such an arrangement has been found to be particularly capable of ensuring that only the desired specified items are moved to their receptacle.

These forms of the invention have been found to be eminently suitable for separating small metallic items, such as brass or light metal alloy, from swarf or other appropriate flashing or scrap material associated with it. Again, by appropriate choice of power in a sequence of induction apparatus disposed under a continuing conveyor, conductive scrap can be sequentially separated into different sizes and/or shapes and/or materials.

The invention includes within its scope apparatus for carrying out the methods hereinabove defined.

In order that the invention may be more readily understood, one embodiment thereof will now be described by way of example with reference to the accompanying drawing which illustrates schematically and diagramatically the application of the invention to the separation of die cast items from associated scrap metal;

In the figure a die cast machine 1 produces fashion accessories such as buckles for belts from light alloy metal. The die casting operation is of a standard nature, and on opening the dies after casting, the solid metal comprising the components for use as the belt buckles, and scrap metal which comprises the metal solidified in the sprue and the feeders to the component, and the overflows therefrom, together with flashing from the joints between the die pieces are all joined. The belt components are automatically physically broken from the scrap metal, and all the material is ejected, still hot, onto a vibratory conveyor 2. This carries the combined metal components and scrap metal forward to a small linear induction motor 3, which can be in the order of 25 cm x 50 cm in plan view, although sizes can vary considerably in practice with dimensions between, for example, 15 cm and 60 cm. With appropriate configuration of windings producing an appropriate inductive effect, electric currents are set up within the components such as to provide an appropriate force upon the buckles to remove them from the linear motor to one side into an appropriate collecting receptacle 4, whilst not having the same effect, because of different dimensions and masses, on the scrap metal parts of the remaining material on the motor. The linear motor itself may be set with its upper face at an inclined angle to the horizontal so that the selected components have to rise up the incline thereby increasing the selectivity. Remnant scrap metal left behind on the conveyor after the belt components have been lifted off will slide into a container 5 at the end of the conveyor, or alternatively may be fed directly back to a melting furnace associated with the die cast machine. It is to be stressed that by testing an appropriate configuration and power setting for the motor it can be provided such as to move the components, but not to move the metal solidified from the sprue or feeders or overflows of the die cast, these in practise invariably being of different size and/or shape and dimension to the belt components.

It is to be observed that the linear induction motor 3, and the conveyor, and the flow of materials carried thereby at the place of separation are immersed in a tank 6 of liquid which may conveniently be a degreasing solution or solvent. The liquid is arranged to have a flow in the direction of arrow 7. By this means, the friction experienced by particles on the conveyor are reduced, the nature of the liquid helps separate individual items, and the flow of the liquid reduces the tendency of unwanted items to be dragged out of the mixture by the preselected items.

In addition the linear induction motor is arranged to operate on a pulse basis. Thus, the motor may be a nominally 20 amp motor, but may be arranged to operate on a pulse basis at 40 amps for half of the time in any given period, and be switched off for the other half of the time. With such an arrangement, provided the frequency of pulsing is less than the supply frequency to the motor, more flux is generated providing a stronger separating force upon the preselected items, but no extra heat is in aggregate generated, which is of key importance. In practice the switching frequency should, I believe, be no less than double the supply frequency. It is to be noted that in some arrangements the period during which the motor is on and the period during which it is off need not be equal. Thus, the motor can be on for one unit, and off for two units of time.

It is to be understood that the invention of the present application is not applicable to the separation of magnetic materials, since these would have a different reaction with respect to electromagnetic induction apparatus by virtue of normal magnetic effects. Various separation systems with respect to magnetic materials from non-magnetic materials have been developed over many years. Indeed the success in dealing with the separation of magnetic materials from non-magnetic materials serves to stress even more highly the problems of achieving satisfactory separation where no magnetic materials are involved, of the kind to which the present invention is so suitably applicable.

By means of the invention as described and illustrated, I have provided a most convenient and effective method for separating specific metal or other conductive items from a miscellaneous assortment of items of the same or other conductive materials.

It is to be understood that the foregoing is merely exemplary of separation methods in accordance with the invention and that modifications can readily be made thereto without departing from the true scope of the invention.

Claims

1. A method of separating predetermined non-magnetic electrically conductive items from a flow of non-magnetic electrically conductive materials containing such items comprising the steps of passing the flow of materials adjacent to electromagnetic field generating apparatus; subjecting the materials to the action of a fluid whilst the flow of materials is adjacent to the electromagnetic field generating apparatus; controlling the flux field generated by the apparatus such as to create electrical current within the predetermined electrically conductive items which react with the generated electromagnetic flux field causing the creation of a directional force upon the predetermined items, in association with the subjection thereof to the fluid, such as to move only the predetermined electrically conductive items out of and away from the flow of material in a predetermined direction for a predetermined distance.

2. A method as claimed in Claim 1 wherein the fluid is a liquid.

3. A method as claimed in Claim 2 wherein the flow of materials is arranged to be immersed in a liquid as the materials pass adjacent the electromagnetic field generating apparatus.

4. A method as claimed in any one of the preceding claims wherein the electromagnetic field generating apparatus is arranged to produce a travelling flux field transverse to the direction of travel of the materials adjacent thereto.

5. A method as claimed in Claim 4 wherein a linear induction motor stator is used as the electromagnetic field generating apparatus.

6. A method as claimed in Claim 5 wherein control of the flux field to provide the required movement of the predetermined items is achieved by appropriate selection of the necessary input power and/or the power supply frequency.

7. A method of separating predetermined non-magnetic electrically conductive items from a flow of non-magnetic electrically conducting materials containing such items comprising the steps of passing the flow of materials adjacent to a linear induction motor;
controlling the flux field generated by the linear induction motor and providing a pulse of such field by switching on and off the linear induction motor at a frequency lower than the supply frequency such as to create consequential pulsed electric currents within the predetermined electrically conductive items which react with the pulsed generated electromagnetic flux field causing the creation of an intermittent force upon the predetermined items such as to move only the predetermined electrically conductive items out of and away from the flow of materials.

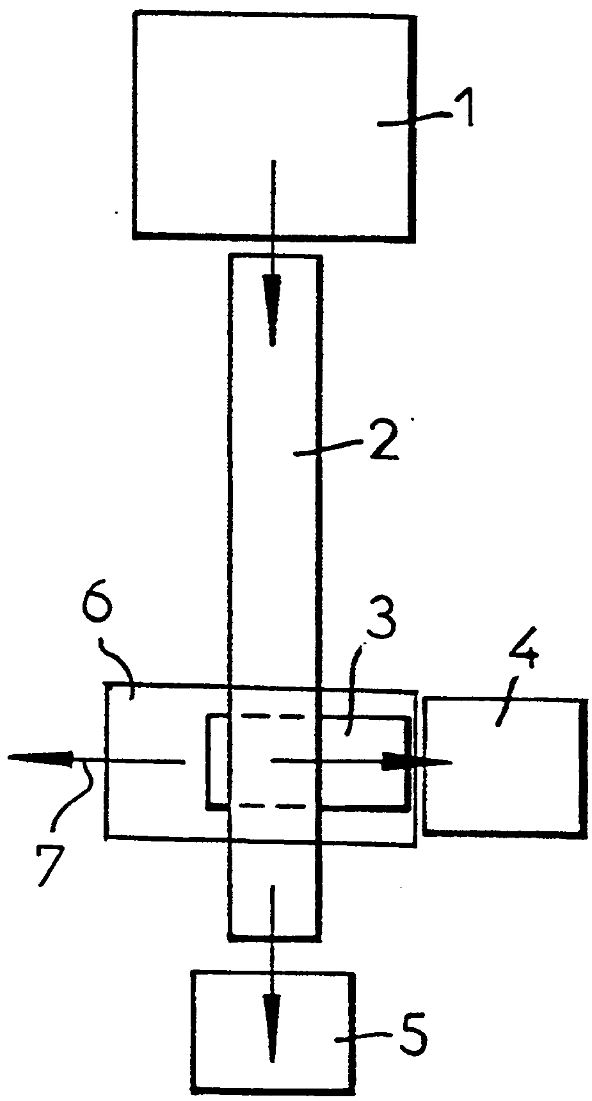
8. A method as claimed in Claim 7 wherein the switching of the linear induction motor is by means of simple electronic control equipment.

9. A method as claimed in any one of Claims 7 or 8 wherein the linear motor incorporates a stator having a small pole pitch and a high flux density.

10. A method as claimed in any one of Claims 7, 8 or 9 including a control system for the linear induction motor incorporating variable terminal voltage as the single control variable, determining flux density.

11. A method as claimed in any one of Claims 7, 8 or 9 wherein the linear inducation motor is provided with a variable frequency control system whereby both frequency and flux density can be controlled.

12. Apparatus for carrying out the methods claimed in any one of the preceding claims.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European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 91 30 2903

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	DE-C-307370 (G.W.MEYER) * claim 1; figure 1 * * page 1, line 24 - page 2, line 40 *	1-4, 12	B03C1/23 B03C1/24
A	DE-C-297585 (G.W.MEYER)		
Y	EP-A-0154207 (LINDEMANN MACHINENFABRIK GMBH) * claims 1, 2, 5, 7 * * page 11, line 30 - page 7, line 8 *	1, 4, 5, 12	
Y A	EP-A-0014564 (COTSWOLD RESEARCH LTD.) * claims 1, 2, 5 * * page 9, lines 20- - 25 * * page 10, lines 9 - 27 * * page 15, lines 15 - 19 *	1, 4, 5, 12 6, 7, 9-12	
A	US-A-4069145 (E.J.SOMMER ET AL.) * claims 1, 4; figure 5 * * column 11, lines 1 - 8 *	1, 4-8, 12	
A	PATENT ABSTRACTS OF JAPAN vol. 2, no. 43 (M-77)(4594) 23 March 1978, & JP-A-52 74167 (KOGYO GIJUTSUIN) 21 June 1977, * the whole document *	1-4, 12	TECHNICAL FIELDS SEARCHED (Int. Cl.5) B03C
A	DE-A-2644635 (DEMAG AG) * claim 1 * * page 3, paragraph 5 - page 4, paragraph 2 *	1-5, 7, 12 1-5, 7, 12	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	27 JUNE 1991	DECANNIERE L.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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