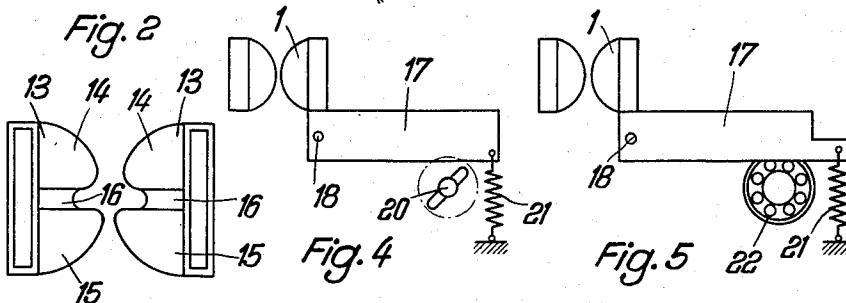
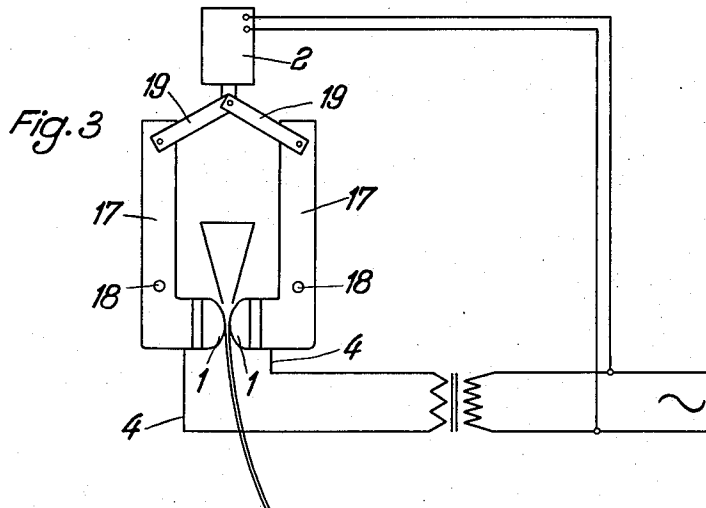
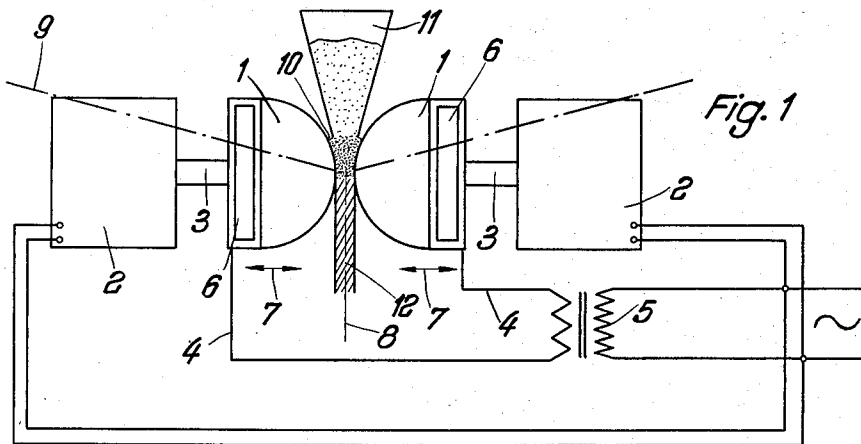


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METHOD OF PROCESSING PULVERULENT RAW MATERIALS  
AND AN APPARATUS FOR PERFORMING THE SAME  
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## METHOD OF PROCESSING PULVERULENT RAW MATERIALS AND AN APPARATUS FOR PERFORMING THE SAME

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The present invention relates to a method of processing pulverulent raw materials and an apparatus for performing the same.

The method of reacting pulverulent raw materials in the solid state is known as such. For example, finely ground metal oxides or oxidic ores may be commixed with carbon and passed through the nip of two rolls which are connected with a source of electric power. The powder mixture in the nip of the rolls is then subjected to the direct passage of the electric current which raises the temperature sufficiently to cause the desired reaction, in the present example the reduction of the oxide, to proceed in the desired direction. The result is the production of a metal powder. Conditions may be varied to produce carbides directly from the reduced metal oxides. An alternative possibility consists in directly sintering, in the nip of the rolls, the metal produced by the chemical reduction. Furthermore, metal powders may be passed between the rolls individually or in mixture for the direct production of a sintered product, the alloy being simultaneously formed in the case of mixtures of powdered metals.

This known method is therefore extremely flexible both in regard to the nature of the metallic raw materials and by this term I include metalloid materials and the products that can be obtained. However, a disadvantage inherent therein is that the heavy electric currents required must be fed to the revolving rolls which may consist of metal, graphite, or carbon through sliding contacts. To circumvent this necessity it has been already proposed to incorporate a transformer in the roll itself. However, this expedient complicates and increases the cost of the plant.

Another disadvantage is that not inconsiderable pressures must be produced in the nip of the rolls. The power required to drive the plant is therefore rather high and the surface of the rolls is subjected to a substantial amount of wear.

It is the object of the present invention to avoid these drawbacks which are attached to the method as hitherto known, by vibrating the pressure-producing electrodes in such a manner that the gap through which the powder must pass will continuously expand and contract. It has been discovered that by taking this step the pulverulent raw materials are already shaken together and compacted before they actually reach the gap and that this effect is equivalent to a compressional effort of 500 to 600 kg./sq. cm. It is therefore possible to reduce the pressure obtaining in the nip of any revolving cylindrical electrodes to very considerably below that which the conventional method requires.

However, an advantage of even more decisive importance secured by the provision of a vibrating gap is that the revolving roll-type of electrodes can be entirely dispensed with. These can be replaced by non-rotating electrodes which merely perform a reciprocating vibratory movement. The pulverulent raw material is fed into the electrode gap by means of a hopper or like means

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and the vibrations will then cause the mixture to pass through the gap. In the gap itself the current will flow through the mixture from one electrode to the other. The consequent generation of heat causes the wanted reactions to be induced and, if desired, the metallic materials produced by the reaction or introduced in powder form, to be sintered.

Since the electrodes do not revolve but merely vibrate there is no difficulty in supplying the current through flexible cables, water-cooled if this is required.

The processes that occur within the gap between the two electrodes can be readily controlled when using this method. The mean distance between the electrodes, i.e., the mean width of the gap, determines the thickness of the product that issues continuously from the gap if the conditions are suitably chosen for the production of a body rendered more or less compact by sintering. If in case of a certain raw material the width of the gap is increased beyond a definite point, a less compact or even a powdery product may be obtained in conformity with the degree of compaction within the gap that may be desired. The temperature may be controlled in a manner that is well understood by the variation of current and voltage. The temperature will then determine the degree of sintering that will ensue. The result may be influenced by varying the periodicity of the electrical pulses. Generally it will be convenient to use an alternating rather than direct current and to adapt the frequency of mechanical vibration to the frequency of the current. Mains frequency has been found to be satisfactory and may be used to induce the vibration of the electrodes. It is possible to work asynchronously in such a manner that the vibrating electrodes are furthest apart when the alternating current reaches its peaks. However, according to the physical properties of the raw material this may cause the creation of arcs which will lead to undesirable local heating effects. In many cases it will therefore be better to synchronise the vibrations and the current in such a way that the electrodes will be moving apart when the current passes through zero. If this is done the electrodes will separate when the current is practically nil and arcs will not then be formed. It is also possible to use a device of this kind for hot forging solid materials like wire. Wire is often rolled down into ribbon. Hence, local heating of the wire is an advantage.

For performing the method and in accordance with a further development of the invention a number of especially suitable embodiments will be described with reference to the diagrammatic illustrations shown in the drawings. However, the method could be performed and applied in actual practice with apparatus that differed from that hereinafter described.

To provide the electrodes, bodies of graphite, carbon, or metal with curved or oblique surfaces are employed. It is especially convenient to make use of hemispherical shapes. These hemispherical bodies are disposed on vibrators. They are placed face to face in pairs to form at least one gap for the passage therethrough of the material. This gap continuously contracts and expands as a result of the vibrations impressed upon the electrodes.

It is also possible to give the electrodes a special conformation by the provision of humps or the like which will create two gaps, the one above the other, the region of the upper humps being if desired electrically insulated from the region of the lower humps. If the electrodes are shaped and disposed in this way the upper gap may be used for reactions and to produce a sintered product. Such a sintered product will then be compelled to pass through the lower gap where it is hammered. According to whether the region of the lower humps is supplied with an electric current or not, the hammering process will be

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performed with or without the simultaneous passage of current through the material. Several such devices, for instance angularly displaced through 90° might be disposed one above the other for the purpose for instance of sintering a rectangular section in the first gap, which could then be transformed into a square or round section in the second gap.

The vibrations of the electrodes may be induced by electrical or by mechanical means.

Fig. 1 shows an apparatus in which hemispherical electrodes 1 are connected directly and in axial alignment with electro-dynamic vibrators 2. The electro-dynamic vibrators may be of conventional construction and they may consist of a coil through which an alternating current is passed and which is provided with a movable iron core with springs. A solid connection with the iron core, as indicated at 3, directly carries the electrodes 1. The latter are supplied with current through flexible cables from a suitable transformer 5. The supply cables may be cooled with water. It may be advisable to water cool principally the actual cable junctions at 6.

It will be readily understood that the electrodes will perform vibratory movements in the directions indicated by the arrows 7, i.e., perpendicularly to the median plane of the gap indicated by the dot-dash line 8. On the other hand, it is quite possible and may be an advantage in many cases, to incline the axes of vibration in relation to the median plane 8 of the gap, say for instance as indicated by the dot dash line 9. This will hasten the feed speed of the powder material 10 which may be introduced to the gap between the two electrodes for instance by means of a hopper 11. 12 is intended to show the manner in which a compact sintered product will emerge from the electrode gap.

Fig. 2 shows a pair of electrodes 13 provided with humps 14 and 15. The two upper humps form an upper gap in which reactions are performed or the material is sintered. The sintered material that issues from the gap is therefore compelled to enter the gap between the two lower humps 15 where it is hammered. It is advisable electrically to insulate the region of the upper humps 14 from the region of the lower ones 15, as indicated at 16, so that the lower humps may be operated without current or at least at a different voltage and amperage to that employed for the upper humps.

According to the invention the electrode may also be mounted on cranked levers as exemplified in Fig. 3. The short arms of two cranked levers 17 adapted to pivot on fulcrums at 18 carry the hemispherical electrode 1 which are supplied with current through flexible cables 4. The longer arms of the cranked levers are connected through a linkage 19 with an electro-dynamic vibrator 2. The effect of this arrangement will be clear without further explanation. The advantage inherent in this arrangement is that the vibrators may be constructed to work with larger amplitudes. In conformity with known measures adopted in the practice of vibratory equipment a transformation of amplitude can be obtained by providing a tuned vibrator of large amplitude for energising and exciting a heavier operational vibrator which works with a smaller amplitude.

Fig. 4 shows such a cranked lever 17 which is mechanically induced to vibrate by means of cams 20. The lever is spring-loaded by a spring 21. An analogous arrangement is illustrated in Fig. 5 in which the lever is induced to vibrate by the rollers 22 of a revolving ball ring. The spring load could be replaced by a weight.

Apparatus according to the invention may be used to produce, according to the nature of the raw materials and the conditions of operation, either a powdered or a sintered product. In the latter case strip, ribbon, round or other profiles, and even sheet may be directly produced from pulverulent materials and, if required, these products may be subjected to a further compacting hot or cold treatment by hammering. The desired reactions

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and/or the sintering operations may be performed in an inert atmosphere if this be required or desirable with regard to the circumstances. The inert gas may then be introduced into the gap from outside. Alternatively the gas might be evolved in the gap by admixing with the reaction components liquid or solid hydrocarbons which would be converted into gaseous form at the temperature within the gap, or which would evolve the desired protective gas by chemical action.

The described apparatus without electric heating is also suitable for replacing the conventional metal powder cold rolling mills. For if the apparatus is operated without being supplied with a current a cold-pressed metal strand or ribbon will form which can then be sintered by providing heat in any desired way. In such a case the cheeks will naturally have to consist of steel. They may be adapted to the nature of the working materials and disposed at any desired relative angle to form a tapering gap. When rolling metal powders the practically constant angle at which the material is drawn into the nip of the rolls and which depends upon the diameter of the rolls has an undesirable effect.

The frequency to be used in the process depends on the thickness of the sintered product that is produced by the process e.g. a sintered metal sheet, whereas the amplitudes have to be chosen according to the range of compacting necessary for the powder. In producing for example a metal sheet 0.5-1 mm. thick a suitable frequency of vibration of the electrodes is from 10 to 50 cycles per second; and a suitable range of amplitudes is from 0.5 mm. to 1 mm.

What I claim is:

1. The method of heating and chemically reacting pulverised solid material which comprises passing the material continuously through a rapidly expanding and contracting gap produced by electrodes by continuously vibrating said electrodes in such synchronism that they approach and separate from one another whilst they pass a current across the said gap through the material; and controlling the rate of flow of the material through said gap so that heat and chemical reaction are generated in the material; flowing through the gap whilst said material is subjected to rapidly-following pressure pulses by the electrodes.

2. The method of heating and chemically reacting pulverised solid material which comprises passing the material continuously between electrodes; passing a current from an alternating source through the material passing between the electrodes whilst vibrating the said electrodes and creating an expanding and contracting gap between them; controlling the rate of flow of the material through said gap so that heat and chemical reaction are generated in the material whilst the material is subjected to rapidly-following pressure pulses by the electrodes; and synchronising the frequency of the current with that of the vibrations so that the current is at zero substantially when the electrodes begin to separate.

3. The method of heating and chemically reacting pulverised solid material which comprises passing the material progressively between pressure-producing electrodes; passing a current from an alternating source through the material between the electrodes whilst vibrating the said electrodes at a frequency corresponding to that of the current and creating an expanding and contracting gap between said electrodes; thereby heating and chemically reacting the material.

4. The method according to claim 1 which consists in sintering the material as a result of the action of the said electrodes and allowing the sintered material to emerge progressively from the said gap.

5. Apparatus for performing chemical reactions at elevated temperatures on pulverulent materials, comprising opposed pressure-producing electrodes forming feed converging surfaces terminating in an elongated gap hav-

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ing opposed convex faces; means for feeding the material continuously into said converging surfaces and into said gap between the said faces; and means for continuously impressing vibrations upon the said electrodes and in such synchronism that the electrodes will approach and separate in rapid succession creating an expanding and contracted gap between said faces; said feeding means being adapted in relation to the said gap to permit the gap to control the rate of flow of the material and means for supplying the electrodes with current so that the material flowing through the gap will be subjected to heat generated by the current and to rapidly-following pressure pulses by the electrodes.

6. Apparatus for performing chemical reactions at elevated temperatures on pulverulent materials, comprising opposed pressure-producing electrodes having opposed convex faces forming a feed convergency to an elongated gap; means for feeding the material progressively continuously into said convergency to said gap between the said faces; and means for supplying alternating current to said electrodes and means for continuously impressing vibrations upon the said electrodes at a frequency corresponding to that of the said current; thereby to creating a gap between said faces which expands and contracts corresponding to the said frequency, said feeding means being adapted in relation to the gap to permit the gap to control the rate of flow of the material so that the material flowing through the gap will be subjected to heat generated by the current and to rapidly-following pressure pulses by the electrodes.

7. Apparatus according to claim 6 in which said current-supplying and vibration-impressing means are operative so that the frequency of the current will be synchronised with that of the vibrations to cause the current to be at zero substantially when the electrodes begin to separate.

8. Apparatus according to claim 5 in which each said face comprises hump-like convexities, those on one face being opposed to those on the other to provide a plurality of expanding and contracting gaps one above the other.

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9. Apparatus according to claim 5 in which each said face comprises hump-like convexities, those on one face being opposed to those on the other face to provide a plurality of expanding and contracting gaps one above the other; the upper co-operating humps being electrically insulated from the lower co-operating humps.

10. Apparatus according to claim 5; said means for impressing the vibrations upon the electrodes comprising electrodynamic vibrators, mounted on and in axial alignment with said electrodes.

11. Apparatus according to claim 5; said means for impressing the vibrations upon the electrodes comprising electrodynamic vibrators, the axes of vibration of which are arranged at an angle with the medial plane of the gap.

12. Apparatus according to claim 5; said means for impressing the vibrations upon the electrodes comprising cranked levers, said electrodes being mounted on said levers.

13. Apparatus according to claim 5; said means for impressing the vibrations upon the electrodes comprising electrodynamic vibrators and cranked levers, said electrodes being mounted on said levers, said levers being connected through rod linkage with the electro-dynamic vibrators.

14. Apparatus according to claim 5; said means for impressing the vibrations upon the electrodes comprising loaded cranked levers carrying said electrodes and means operatively connected to vibrate the levers whereby to transmit the vibrations to the said electrodes.

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