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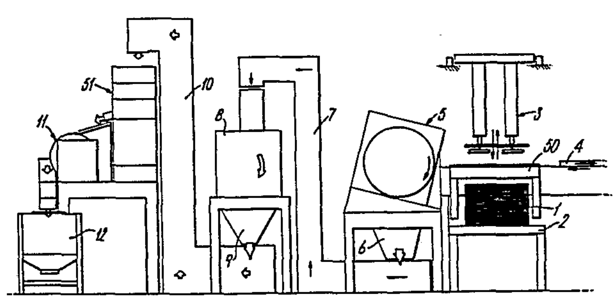
(54) **Granulation.**

(57) A process for granulating metal received in sheet form, such as cathode copper, operates in two stages. In the first (prime cutting) the sheet is advanced and pieces are taken from its leading edge by a shear comprising a rotor with at least one blade co-operating with a fixed blade across which the sheet metal is fed. In the second operation, (digestion) the pieces formed in the first operation are fed to a granulator (or to more than one granulator) of the kind comprising a rotor with at least one blade co-operating with at least one fixed blade to comminute the material repeatedly until the particles are small enough to pass through a screen bounding the working zone. The two operations can be optimised independently, and substantial energy saving is achieved compared with the direct feeding of the sheet metal to the granulator. In the case of copper, the extent of heating, which in conventional granulation may lead to surface oxidation, is greatly reduced.



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GRANULATION

This invention relates to the granulation of copper cathodes and of other metals received in sheet form.

The most efficient known process, at least for copper cathodes (our British Patent No. 2021974B) comprises comminuting the metal sheets by means of a granulator of the kind comprising a rotor with at least one blade co-operating with at least one fixed blade to comminute the material repeatedly until the particles are small enough to pass through a screen bounding the working zone.

It will be realised that this process comprises two distinct operations, hereinafter called respectively "prime cutting" and "digestion"; **prime cutting** takes pieces (usually narrow strip) from the leading edge of the sheet material and **digestion** makes random cuts through those pieces repeatedly until the resulting granules escape through the screen.

We have now discovered that a substantial improvement in energy efficiency can be obtained and deleterious heating of the metal being granulated can be greatly reduced by the separation of the prime cutting and digestion operations.

In accordance with the invention, therefore, a process of granulating metal received in a sheet form comprises a first, prime cutting, operation in which the sheet metal is advanced and pieces are taken from its leading edge by a shear comprising a rotor with at least one blade co-operating with a fixed blade across which the sheet metal is fed and a second, digestion, operation in which the pieces formed in the first operation are fed to at least one granulator of the kind comprising a rotor with at least one blade co-operating with at least one fixed blade to comminute the material repeatedly until the particles are small enough to pass through a screen bounding the working zone.

The basic design of the shear (without screen) and the granulator (with screen) may be the same, but the details of structure and working conditions can be optimised for the separate operations. In particular:

1. The blades of the shear and the granulator will usually both be divided, in the direction parallel to the rotation axis, into sections that are staggered round the circumference to reduce shock loading, and the blade segments of the shear may be shorter than those of the granulator to reduce shock loading still further.

2. At each particular point along the axial length of the respective machine, the number of cuts per unit time (which is proportional to the rotation speed, to the number of rotating blades and, ordinarily for the granulator only, to the number of fixed blades) may be higher for the granulator than for the shear; consequently prime cutting can be a continuous operation from beginning to end of each sheet to be granulated

without either feeding material to the granulator faster than it can be processed or producing metal dust through too low a rate of advance of the sheet material.

3. Blade angles and working clearances can be optimised independently for the two operations.

4. One shear can, if desired, feed two or more than two relatively small granulators (or, if it should be desired, two or more shears could feed one relatively large granulator).

5. Feed arrangements could be designed, if desired, to present relatively long narrow pieces formed by prime cutting to the granulator in such a way that the commonest orientation is perpendicular to the blades, reducing the frequency of unproductive lengthwise cuts; in most cases this is unnecessary because the granulator can be top-fed, and the pieces, being free to rotate, tend to be oriented perpendicular to the blades by the action of the blades themselves.

Because of these factors, the energy efficiency of the process may be significantly improved. Moreover, we have found that granules produced, from copper cathode at least, by the method of the invention have a substantially higher bulk density than those produced using a single sheet-fed granulator; it is assumed, but has not been confirmed, that this is associated with a higher proportion of relatively isotropic particles. The increased bulk density leads to additional energy saving when the granules are subsequently used as infeed to an extrusion process.

The size of the rotating shear may vary within the limits imposed by the size of the sheet to be granulated and the strength of its components, but it can be expected that the diameter of the rotor will almost always lie in the range from 0.25 to 0.5m; for shears within this range, at least, we very much prefer a blade arrangement that produces only one cut per rotation at any particular point along the length of the shear (i.e. along the width of the sheet).

To facilitate the use of very short blade segments on the shear rotor, when required or desired, we propose the use of a rotor made up of a plurality of plates stacked on each other in the axial dirction, at least one of the plates having in its circumference at least one pocket for a blade which pocket extends through the whole thickness of that plate, a blade being mounted in that pocket by a single screw and having its ends substantially coplanar with the major faces of that plate; and contiguous plates which bear on the major faces of that plate also bearing on the ends of the blade to confer additional rigidity on its mounting.

The contiguous plates, unless they are end plates, may be fitted with blades at other points around the circumference of the rotor, or (provided the metal to be sheared is britle enough) they may be spacer plates not fitted with blades. To maximise the moment of inertia, the plates are preferably solid and substantially circular apart from the blade pocket.

An equivalent monolithic rotor could be used equally effectively but presents certain manufacturing difficulties.

A similar rotor design may be used in the granulator also, but in that case it may be preferably for the circumference of each plate to be recessed as an aid to balancing and/or to provision of additional working volume between rotor and housing.

Depending on the speed of operation of the shear, it may be desirable to cool the cutting blades to reduce the rate at which their cutting edges become blunted; since contact with the copper or other metal being comminuted in the prime cutting operation will be short, the risk of the metal being overheated is relatively small, but may not always be negligible.

In the granulator used for the digestion operation, on the other hand, the substantial dwell time may lead to significant rises in the temperature of the metal, and cooling will almost always be required. Convective cooling by the use of a stream of air forced downwards through the granulator chamber so as to exit through the screen and/or a stream of water pumped through passages in the rotor and casing of the machine may be adequate to avoid overheating of any of the granules, but otherwise we prefer to use evaporative cooling. This requires the introduction into the granulator of an appropriate amount of at least one inert volatile substance. The amount is desirably such that the heat generated in the granulation process, plus any inflow of the ambient heat, is sufficient to evaporate (or sublime) substantially all of the volatile substance; and in the case of copper granulation it should also be such that evaporation (or sublimation) of the volatile substance is sufficient to keep the temperature of any substantial part of the copper from rising above 80°C (and preferably 70°C) for any significant length of time.

There are many volatile substances that might be technically satisfactory, but in view of environmental and economic restraints the preferred substances are water (free of deleterious contaminants), liquid nitrogen, sold carbon dioxide, and unseparated liquid air.

Of these, water is considered best because it is readily available, cheap, does not require insulated storage vessels and, having a boiling point above the working temperature, will evaporate preferentially when and where the temperature of the copper surface is highest (though it will be understood that much, or in some cases all, of the evaporation may take place separately from the copper surfaces).

De-ionised or otherwise purified water may be fed to the granulator as a liquid (or frozen) film on the surface of the copper, for example by feeding pickled cathodes still wet with rinsing water and/or by flowing a stream of water onto the copper close to the point where the initial cut is made; alternatively, or if a greater quantity of volatile substance is needed, water (or one of the alternatives discussed), may be injected separately into the granulator and/or into the air stream entering it, preferably as a fine spray.

It may be desirable to monitor the rate of feed of copper to the granulator and/or the power being expended by it and to adjust the rate of feed of water, or other volatile substance, accordingly. Even distribution is important as it is undesirable for even a few of the granules to emerge wet.

The invention will be further described, by way of example, with reference to the accompanying drawings in which:

Figure 1 is a diagrammatic side view of plant for carrying out the invention;

Figure 2 is a perspective view of a rotor for a shear suitable for use in performing the invention;

Figure 3 is a side view of the same rotor;

Figure 4 is an end view of the same rotor;

Figures 5 and 6 are cross-sections on the lines V-V and VI-VI in Figure 3 respectively, with some detail omitted for clarity; and

Figure 7 is a semi-diagrammatic cross-section through another design of rotor for a shear suitable for use in performing the invention, also showing the co-acting fixed blade.

The plant on Figure 1 produces copper granules for use, after appropriate heat treatment, as infeed for a continuous friction-actuated extrusion (Conform) process for the manufacture of copper wire.

The infeed to the plant of Figure 1 itself consists of copper cathodes, typically with an area of one metre square and thicknesses up to about 20 or 22 mm (14-day cathodes, that is cathodes of the thickness accumulated in 14 days continuous deposition under conventional copper-refining current-density and other conditions). After pickling, washing and any necessary pre-treatment (not shown) the cathodes are placed in a stack 1 on a support 2. At appropriate intervals, individual cathodes are taken from the stack by a lifting mechanism 3 and transferred (transversely to the plane of the figure) onto a feed table 50. A ram 4 now advances and pushes the cathode under spring-loaded or otherwise biassed gripping devices (which resist tilting or pulling-in of the cathodes) and through a simple slot into a rotary shear 5 which performs the prime cutting operation. The shear has a single continuous fixed blade which the cathode rests on at the entry slot and a single blade divided into short segments distributed round the rotor; this produces prime-cut pieces predominantly with lengths roughly equal to the length of the blade segments, widths (or thicknesses) equal to the thickness of the cathode (a dimension that varies considerably, both from cathode to cathode and between different parts of the same cathode) and thicknesses (or widths, if the cathode is thin) equal to the distance the cathode advances per revolution of the shear rotor (this dimension is also likely to vary significantly, particularly at the beginning and end of the cathode).

When the cathode is consumed, the ram 4 retracts and the feed cycle repeats, the shear 5 idling until the ram again advances far enough to push copper in to it.

Meanwhile, the prime cut pieces formed in the shear 5 immediately fall into a hopper 6 which discharges them to a bucket conveyor 7 (shown diagrammatically) which delivers them to at least one granulator 8, which may be of wholly conventional design - a Cumberland Model 37 granulator with its standard hopper feed is satisfactory.

The granulator 8 is cooled by blowing through it 1m^3/s of air into which deionised water may be injected in a fine spray at a rate of 1 litre for each 30kg of copper. This is sufficient to keep the average granule temperature down to about 40°C and substantially every granule below 70°C, substantially avoiding tarnishing, whilst on the other hand the heat generated is sufficient to evaporate all the water leaving the granules dry.

The granule discharges conventionally via hopper 9, a second bucket conveyor 10, sieving apparatus 51 (which separates oversize granules for recycling to the granulator and fines for disposal) and magnetic separation apparatus 11 to a receiver 12.

The preferred form of shear 5 is made by modifying a Cumberland Model 43 granulator so as to have only one fixed blade (located directly below the entry slot for the copper cathodes) and one revolving blade distributed in short segments around the rotor. Two suitable rotor designs are illustrated.

The relatively conventional rotor of figures 2-6 is of monolithic construction and is best visualised as a cylinder with major parts of its surface machined away to form ten segments 13-22 which are identical shape but each have a unique orientation. As best seen in Figure 5 the segments are bounded by five major plane faces 23-27, a portion 28 of the circumscribing cylindrical surface, and minor flat surfaces 30 and 31 which are at right angles to each other and form a pocket into whch a blade segment 32 is fixed with a pair of screws 33. Faces 23-27 form five of the six side faces of symmetrical (but non-regular) hexagonal prism having two angles of 72° (at 34 and 35) and four of 54°.

Segments 13 and 14 are relatively displaced by 180° and thus together form a hexagonal prism with two projections 36, 37 forming abutments for their respective blade segments 32, 38. Rotor segments 15 and 16 form a similar pair displaced 72° with respect to the first pair and so on for the other three pairs 17 and 18 (displaced 144° with respect to the first pair), 19 and 20 (216°) and 21 and 22 (288°). The result is that a cut is made at some point along the length of the rotor for every 36° of rotation (one tenth of a turn) but spacially adjacent cuts are always well separated in time. For clarity, Figure 4 is marked only with the numbers of the segments so as to bring out clearly the order in which the blades cut.

Figure 7 shows an alternative design in which the rotor is made up of a number of plates stacked together in an axial direction. Only three of the plates are shown, one in solid lines and the adjacent ones in broken lines. Apart from the end plates; which may be plain circular discs, all the plates are identical in shape but all differ in orientaton. The plate 38 shown in solid lines is basically circular but is eccentrically mounted with its centre at 39 whereas the rotation axis of the rotor is at 40. A recess for the blade 41 is formed with its abutment face 42 at the positon of maximum radius and shaped to provide working clearance in front of the blade; the axial length of each blade segment is substantially the same as the thickness of the plate. The depth x of the blade is so related to the eccentricity of the plates that adjacent plates 43, 44 (centred at 45 and 46 respectively) bear on respective ends of the blade segment 41, thus enabling it to be rigidly mounted with only one screw 47. This permits use of blade segments about half as long as the minimum required for the design of Figures 2-6.

Figure 7 also shows the fixed blade 48 of the shear and a copper cathode or other sheet 49 about to be advanced into a cutting position.

Example

Quantitative results are not yet available from the preferred form of plant so far described. the following example, based on preliminary work with existing plant, is given to indicate the potential of the invention.

A granulator constructed as described and illustrated by way of example in our European Patent Application Publication No. 94258 (a Cumberland Model 37 granulator with a modified feed arrangement to accept sheet input) was used conventionally to granulate copper half-cathodes nominally 500 mm wide by 1m long and varying in thickness in the range 5-12 mm. Two fixed blades and three rotating blades, each divided into five 180 mm long staggered segments, were fitted. The nominal rotor speed was 600 revolutions per minute. The half-cathodes were fed, short end leading, at a speed of 100 mm/s for a period of one second at intervals of 20 seconds. Nominal 3 mm granules were produced using a 6.5 mm screen at a rate of about 500 kg/hr. The mean actual energy consumption was about 66 kWh/tonne and the average temperature of the emerging granules, when operating without any cooling, was at 175°C. It is thought that a considerable part of the heat is generated in pieces of copper that are caught (one or more times) between a rotating blade and the leading edge of the copper cathode which overlies the fixed blade that makes the prime cuts and so makes that blade more of less ineffective in the subsequent granulation. The bulk density of the granules was found to vary in the range 3.3 - 3.6 tonne/m^3.

The granulator was now modified for operating the process of the present invention by removing the screen (thereby converting it to a shear) and fitting substantially only one blade to the rotor; this blade was divided into fifteen 65 mm-long segments staggered round the whole circumference of the rotor (overlapping axially by about 2 mm).

The half-cathodes were now fed at a speed of 35 mm/sec, continuously except as necessary to introduce new half-cathodes. This prime cutting operation produced pieces averaging 65 mm long by 5 - 12 mm wide by 3 mm thick at a throughput rate of about 800 kg/hr for an average energy consumption of about 20 kWh/tonne with only a modest temperature rise.

Half of these pieces (400 kg/hr) were fed to an unmodified Cumberland Model 37 granulator with the same blade arrangement as in the granulators of our European Patent Application referred to at the beginning of this Example but with a conventional hopper feed. All the copper was granulated to a nominal particle size of 3 mm for an energy consumption of about 30 kWh/tonne (making a total of 50 kWh/tonne for the shearing and granulating operations combined, a reduction of 24%); with no cooling the temperature of substantially all the emerging copper granules is below 90°C, so that relatively little cooling is needed to eliminate risk of surface oxidation. The bulk density of these granules was about 4.3 - 4.5 tonne /m^3.

In the granulation operation, both fixed blades function with comparable efficiency; and because the feed position is at the top of the rotor the risk of large pieces of copper becoming trapped in the clearance between the screen and the rotor is significantly reduced.

CLAIMS

1. A process of granulating metal received in a sheet form comprising a first, prime cutting, operation in which the sheet metal is advanced and pieces are taken from its leading edge by a shear comprising a rotor with at least one blade co-operating with a fixed blade across which the sheet metal is fed and a second, digestion, operation in which the pieces formed in the first operation are comminuted by a granulator of the kind comprising a rotor with at least one blade co-operating with at least one fixed blade to comminute the material repeatedly until the particles are small enough to pass through a screen bounding the working zone, characterised by the fact that said shear and said granulator are separate and distinct machines.

2. A method as claimed in Claim 1 comprising using a shear with blade segments shorter than those of the granulator.

3. A process as claimed in Claim 1 or Claim 2 in which the number of cuts per unit time is higher in the granulator than in the shear.

4. A process as claimed in Claim 3 in which the prime cutting operation is continuous.

5. A process as claimed in any one of the preceding claims distinguished by evaporative cooling of the granulator.

6. The use in a process claimed in any preceding claim of a shear having a rotor with substantially only one blade made up of segments distributed round its circumference.

7. The use in a process claimed in any one of the Claims 1-5 of a shear or a granulator having a rotor made up of a plurality of plates stacked on each other in the axial direction, at least one of the plates having in its circumference at least one pocket for a blade which pocket extends through the whole thickness of that plate, a blade being mounted in that pocket by a single screw and having its ends substantially coplanar with the major faces of that plate; and contiguous plates which bear on the major faces of that plate also bearing on the ends of the blade to confer additional rigidity on its mounting.

8. A process of granulating copper cathodes that is claimed in any one of the preceding claims.

9. Copper granules characterised in that they were actually made by and are the direct product of the process claimed in any one of the preceding claims.

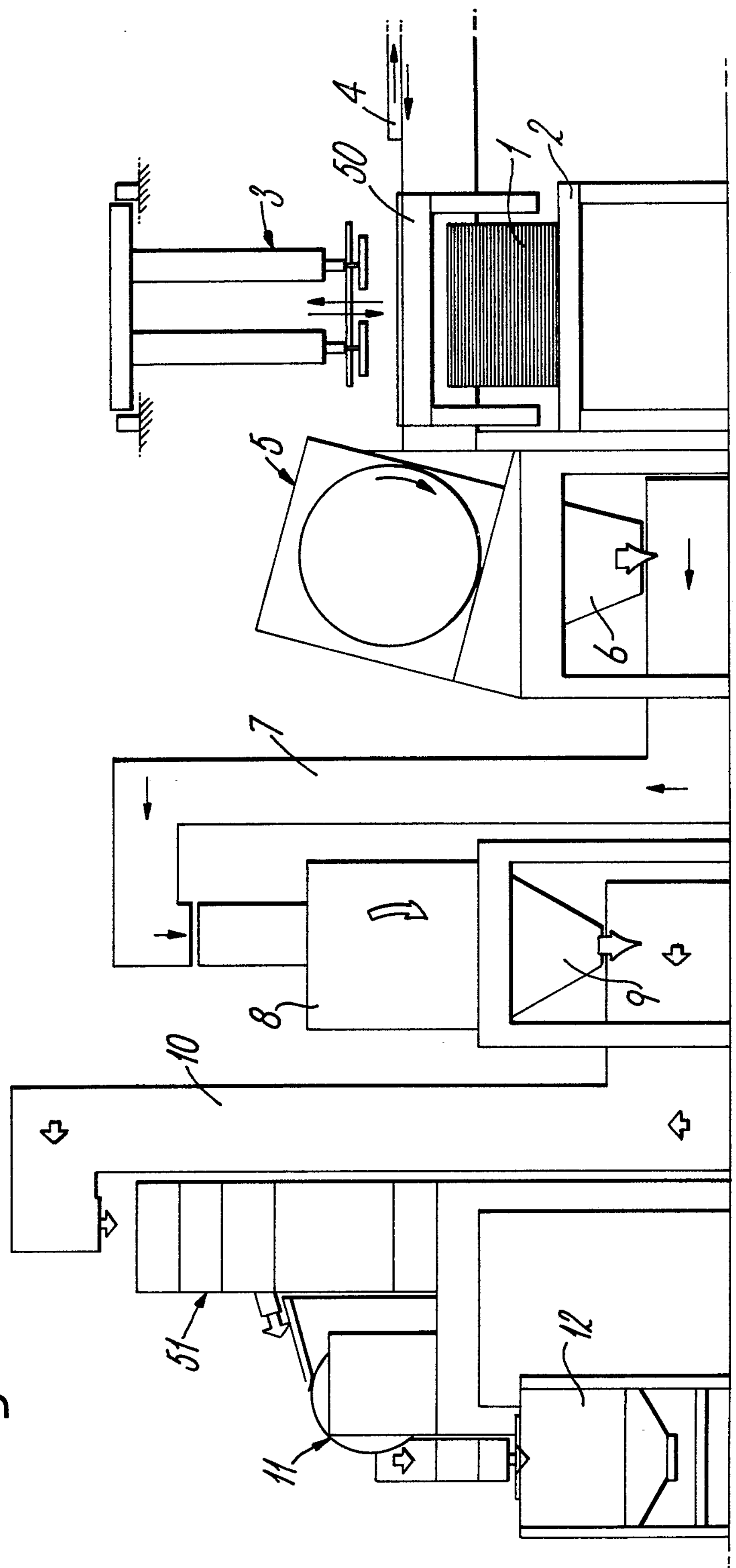


Fig.1.

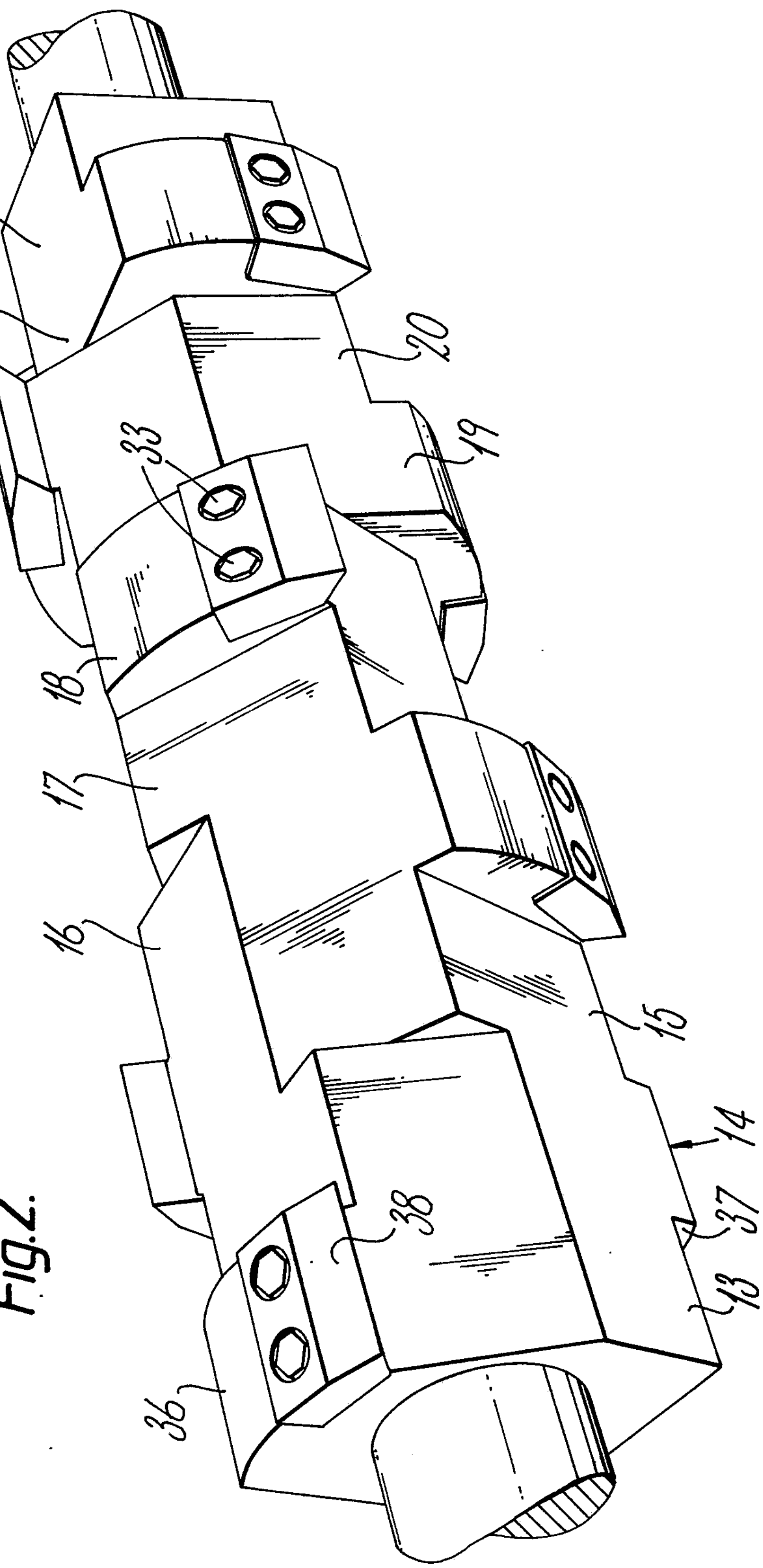


Fig.2.

Fig.3.

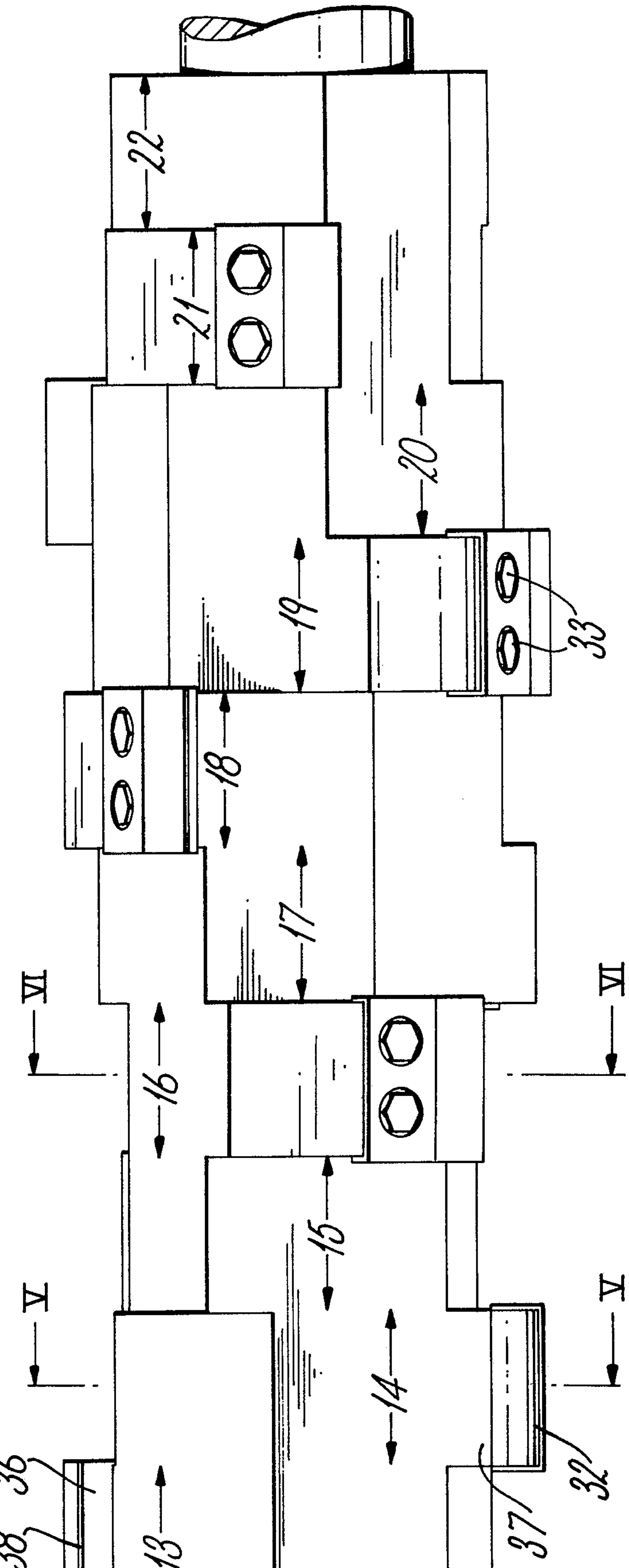


Fig.4.

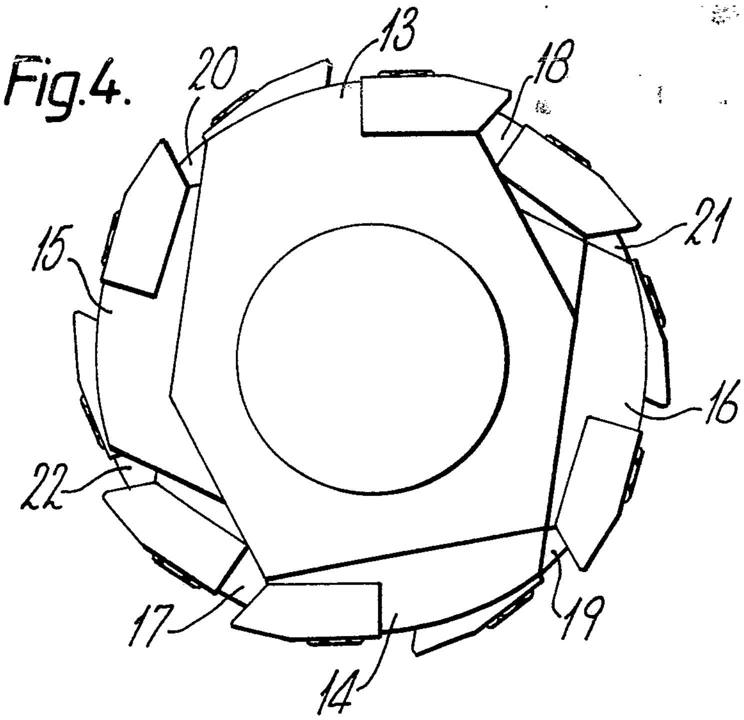


Fig.5.

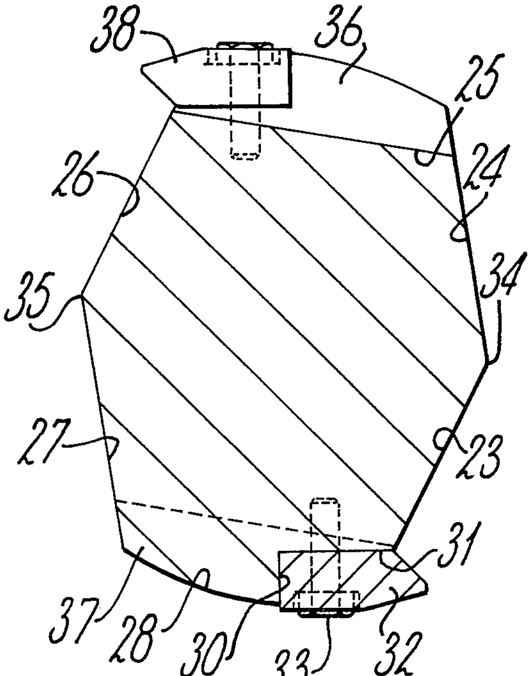
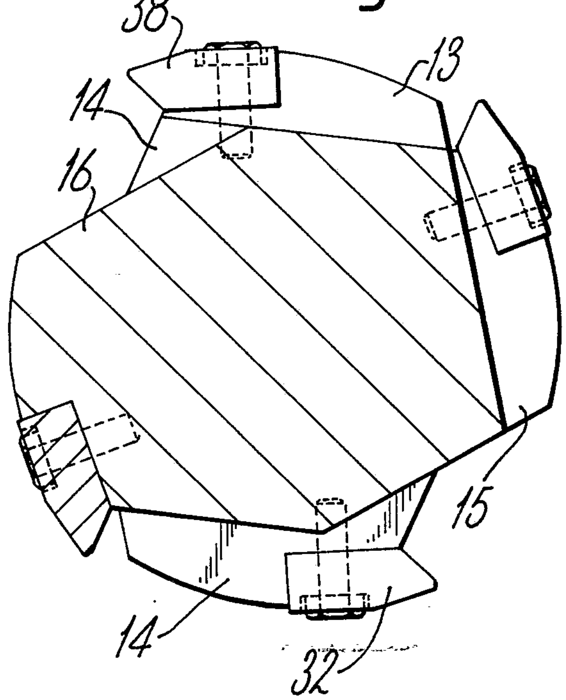


Fig.6.



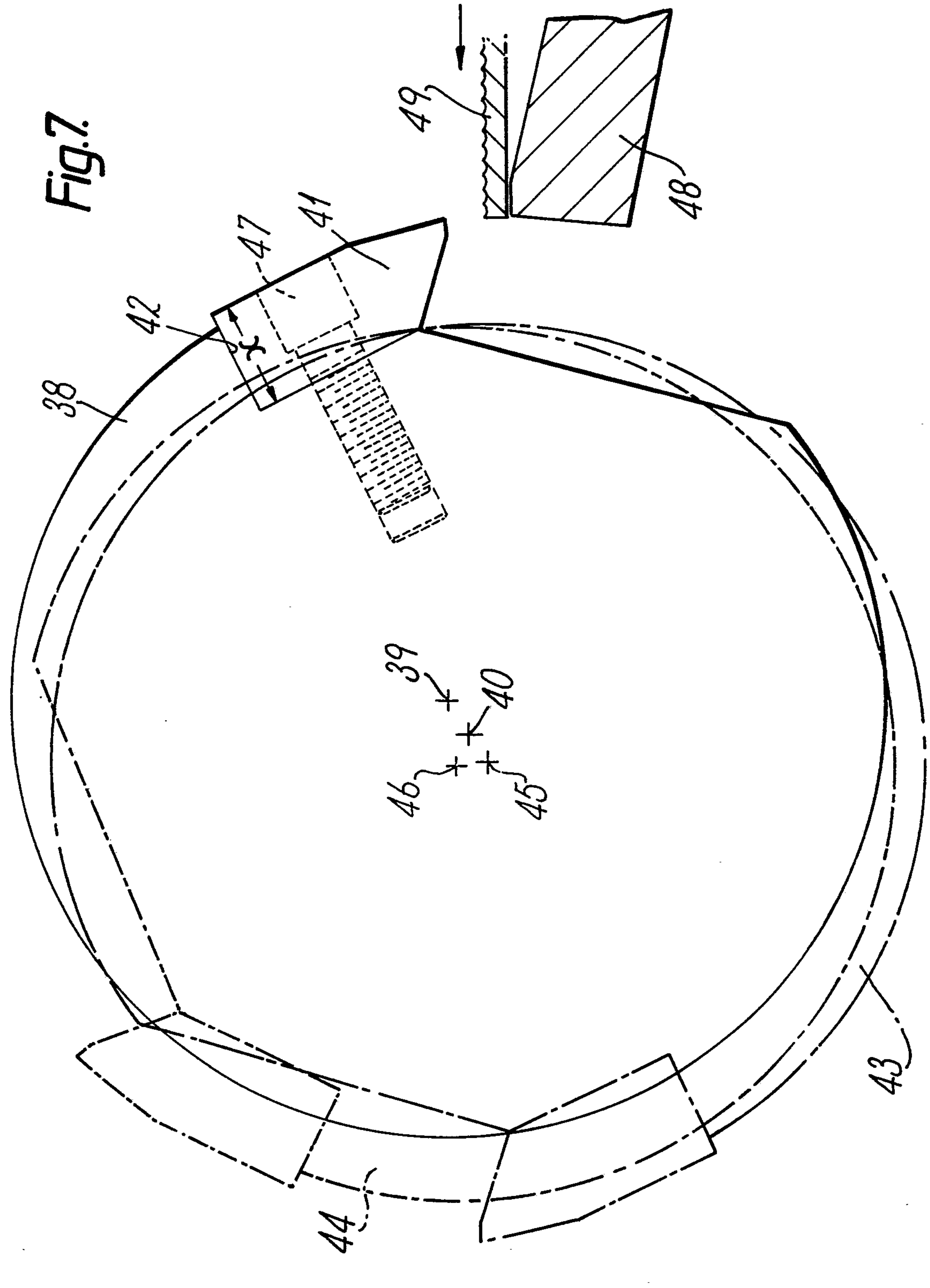


Fig.7