PROCESS FOR GRANULATING SHEET-LIKE MATERIAL

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ABSTRACT OF THE DISCLOSURE

Granulator device and method for quietly shearing brittle or stretchy materials such as various types of plastics as well as thin metal into small pieces which can be easily handled. A pair of meshing cutters used in the device comprise helical toothed members such as gears which have tooth shapes modified from a standard form so as to exert a scissors-type cutting action on work material fed to them as a continuous web, as individual pieces, or a combination of the two.

BACKGROUND OF THE INVENTION

Field of the invention

This invention relates to cutting devices for reducing relatively large and unwieldy pieces of webs or material to a size which can be handled readily. The invention particularly relates to a device for reducing a continuous web and/or cutouts of scrap material formed incident to an article forming operation to a size which can be easily handled and readily mixed with new material for reuse without the necessity for utilizing several handling and reduction steps.

Description of the prior art

Devices for reducing web or individual pieces of scrap material to a smaller more usable size are readily available. Many of such devices are commonly referred to as hammer mills and comprise a shaft rotating at high speed upon which is mounted a crushing element consisting of either fixed or pivoted hammers or cutters. Most such hammer mills reduce the material by impact while it is in suspension by driving it against a breaker plate where a great deal of reduction takes place. By placing a perforated cage or screen under the hammers the material will be acted upon by the hammers until it has been reduced to a small enough size to be discharged through the openings in the cage or screen. Although devices of the hammer mill variety are capable of granulating material, they suffer from the considerable disadvantage that the cutting operation produces an extremely high noise level due to the impact of the hammers on the material. The devices are also somewhat inefficient in their capacity to handle material since there are generally only a few blades on a cutter. Because of the extremely high noise level common to prior art granulators as well as their relatively large size it has been commonplace to locate the granulator equipment in a remote location relative to the article forming equipment to reduce the noise level with respect to the ears of workers associated with the article forming equipment. Obviously, by positioning the granulating equipment in a remote location it is necessary to either install a conveying system for carrying the material to be granulated to the granulators or else to collect it where it is produced and carry it to the granulators. In the case of scrap material in the form of a web from which articles have been punched, it is usually necessary in the absence of conveyor equipment, to wind the web material on reels and then carry it to the granulator where it is unwound.

These steps require the use of additional machines and personnel.

SUMMARY

It is an object of this invention to provide a granulating method which is extremely quiet and capable of being used in close relationship to a device producing scrap as a by-product of a forming operation.

A further object of this invention is to provide a granulating method which can receive and readily dispose of material fed to it either continuously in the form of a web, in batches including several thicknesses of material, or in a combination of continuous and batch-fed material.

Another object of the invention is to provide a granulating method which can handle either brittle or stretchy materials.

Another object of the invention is to provide a granulating method which has cutter members which are readily manufacturable on conventional lead forming equipment.

A further object of the invention is to provide a granulator method having cutters which can easily cut the work placed between them without excessive loading or wear and whose cutting ability increases when plural layers of work are presented to them at one time.

An additional object of the invention is to provide a granulator method which is extremely compact, efficient, and inexpensive to produce and maintain.

These objects are achieved by the granulator device of the present invention which preferably comprises two sets of cutters which are arranged to cut material fed into them into diagonal strips as it passes through the first set of cutters and into generally diamond-shaped or square pieces as the diagonal strips pass through the second set of cutters which have their cutting edges arranged at approximately right angles to the cutting edges of the first set of cutters. Each of the sets of cutters is comprised of a pair of cutter members having a plurality of helically arranged cutter teeth having the same lead angle but of opposite hand. The cutter members are preferably formed on lead cutting machines such as are commonly used to form gears or helical cutters. Hobbing and milling machines are examples of such machines. Where the cutters are formed on gear forming equipment they are given tooth shapes which differ considerably from the conventional involute tooth form.

In order to provide an effective shearing and penetrating action on one or more layers of material passing between the cutting teeth, the teeth on each cutter member are preferably quite thin at their tips. To permit cut stock to exit freely after cutting, the teeth are mounted to be only in slight overlapping engagement and of a size that they constitute only a small portion of the tooth space. The axes of the cutters are preferably mounted to provide profile contact at the tip of each gear but with only a slight degree of overlapping engagement of the teeth. The overlapping engagement must be sufficient to keep the teeth in mesh and permit one cutter member to drive the other. The overlap also permits the teeth to engage each other at a point spaced from a plane connecting their centers so that the teeth coast like a pair of scissors. Since the profiles of the teeth only contact at the tips, they stay in contact along their axial length as they rotate relative to each other. The cutting edges are in continuous contact along the lead and present no problem with loss of contact carryover since they have many pairs of corresponding teeth which are in engagement with at least one point on their mating surfaces at all times.

Although it is preferable to use two sets of cutters to cut the work to a desired size in a single pass and achieve
maximum handling capacity, it is also possible and often desirable to utilize only a single set of cutters. When a single set of cutters is used, it is necessary, if a small sized product is desired, to recirculate the cut strips and pieces. Recirculation, such as by means of a perforated and finly perforated screen will reduce the material to a size which will pass through the perforations. Such a system has less capacity than a system with a double set of cutters but has many advantages including: lower cost, requires less space, and has an ability to reduce the final product size to a dimension far less than the spacing of the cutter teeth by utilizing a finly perforated screen.

The teeth of each pair of cutters coat in the fashion of a pair of scissors in that the mating teeth move continuously in a radial contact with each other along the entire length of a line defined by the intersection of their tips and one side edge as the cutters rotate. The cutter teeth overlap each other over only a small portion of their length at any one time and are withdrawn from engagement as soon as they have performed their cutting function. The teeth of the cutters of the present invention may be quite easily sharpened by removing only a small amount of material from their outer diameters. However, sharpening is rarely necessary since the teeth have a very long life due to the fact that their extremely thin tips act to easily penetrate the material being cut and thus do not cause excessive radial loading of the teeth. Furthermore, once the teeth have penetrated the material they are movingly in sliding engagement with each other such that the main tangential loading consists merely of the force exerted by the driving gear on the driven gear to cause it to rotate. Although the driving force exerted by the driving teeth on the driven teeth is sufficient to maintain the cutting edges in contact, the teeth of the present invention may be operated to effect cutting fairly brittle materials like polystyrene plastic, it is sometimes desirable to apply a slight additional amount of tangential loading to the teeth to positively assure a cut on the first pass when cutting thin extremely elastic material such as polyethylene sheeting. Although such additional tangential loading could be applied by adding a drag effect to the driven cutter (such as by means of a friction clutch) such loading is not generally necessary if a recirculating screen is used because of the incompatibility of a severely severed material to be carried around the outside of the cutters and re-presented to them for cutting until it has been granulated to the desired size. Due to the particular design of the basic invention, it is quite possible that one cutter has very large spaces between its teeth a great number of layers of material can be accommodated between them. As the thicknesses of material in the tooth spaces build up due to the presence of incompletely severed material or multiple thicknesses of newly presented material, they exert a tangential force on the cutting edge which places them in tighter contact with each other and insures a severing of the work. This particular property of the cutting teeth renders them able to cut not only web stock of vastly differing materials which is fed to them continuously, but also permits them to cut small pieces of material which present themselves to the cutters in batches which sometimes include several overlapping layers.

The foregoing and other objects, features and advantages will be apparent from the following more particular description of a preferred embodiment of the granulator device of the invention and the cutters used therewith, as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a device incorporating two cooperating pairs of the cutter members of the invention and showing the cutting of a sheet of material into little pieces;
FIG. 2 is a top view of cutter members similar to those shown in FIGS. 1 and 3 but having their helical teeth in a herringbone pattern;
FIG. 3 is a perspective view of a modified form of the device shown in FIG. 1 wherein only one set of cooperating cutter members is used;
FIG. 4 is an enlarged sectional view showing the relationship of a pair of coacting cutters relative the material being cut, a plane perpendicular to the axes of a pair of cutters; and
FIG. 5 is an enlarged sectional view similar to FIG. 4 but showing the relationship of a pair of ordinary mating involute gears of the general type ordinarily produced by the tool used to produce the cutters of FIG. 4.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIG. 1, material to be granulated such as a web indicated generally at 10 is fed downwardly into the bite of intermeshing teeth 12 and 14 on an upper set of cutter members 16 and 18 respectively. Since the teeth 12 and 14 are arranged helically about the cutter members 16 and 18, they will progressively cut the material 10 into a plurality of parallel strips which will drop downwardly. The diagonal strips of material will then enter the bite of a second lower set of cutter members 22 and 24 which have helical cutter teeth 26 and 28 respectively arranged at approximately right angles to the cutter teeth 12 and 14. Because the teeth 26 and 28 are at an angle to the teeth in the first cutters, the parallel strips of material which leave the first set of cutters will be cut transversely and will emerge from the second set of cutters as little square or diamond-shaped chips 32.

FIG. 3 shows a modified form of an apparatus which is generally similar to the apparatus of FIG. 1 in that it utilizes a set of cooperating cutters members 36, 38 which may be identical to the cutter members 16, 18 or 22, 24 in a single pass through the cutters, a recirculating screen shown in FIG. 1. Inasmuch as material fed into the bite of cutters 36, 38 cannot be cut into small chips or squares 44 is placed around the cutter members in close proximity thereto. The screen 44, which has perforations or holes 46 around its entire lower portion serves as a guide or restraining member for keeping pieces of cut material which are not small enough to be discharged through holes 46 in contact with cutter teeth 50, 52 so that they will be carried around the cutters and presented to the bite of the cutter as many times as might be necessary to cause them to be cut into a size sufficiently small to be discharged through the holes in the screen. The spacing of the screen 44 from the cutters 38, 36 by a support bar 54 to form material accepting throats 55, 55' is somewhat critical. If the support bar 54 is too close to the cutters the throat 55 formed between the cutters and screen cannot accept the large volumes of material cut by the cutters at their maximum feed rate and the material may back up and either reduce the cutting rate or act like brakels to slow or stop the cutters. When the support bar 54 is too far from the cutters, a portion of the material to be recirculated may tend to mat upon the screen 44 and block the discharge of small pieces of material through the holes 46. At a proper spacing, the throats 55, 55' with the maximum output of the cutters 38, 36 but will insure that the material to be recirculated is held close enough to the cutter teeth 52, 50 so as to either be moved directly or indirectly by them. For the particular cutters shown in FIG. 4, a spacing of .0125 in. has been found to be quite suitable for use with material of a thickness of .02 in. In order to help prevent the recirculated pieces of material from flying upwardly out of the device, a pair of cover plates 56, 58 are mounted relative to the cutters. The cover plates 56, 58 also serve an added function of funneling material fed to the device into the bite of the cutters. The cover plates 56, 58 are especially useful for insuring continuous feeding of material through the apparatus when the material being cut is in the form of individual pieces fed in batches, as compared to continuous web material. Without some type of cover plates, such
material, especially if it is slippery, may occasionally lie over the bite of the rolls and form a bridge which will hold and prevent the feeding of additional pieces of material. The cover plates 56, 58 help prevent this "bridging" by deflecting the material dropped into the roll gap, to the sleeve to slide toward the bite at an angle rather than dropping with its plane surface horizontal. Since a single pair of cutters (FIG. 4) will tend, due to the helical pattern of its teeth, to drive the recirculated material in auger fashion to one end of the cutters, a stream of compressed air from nozzles 59, 60 may be utilized by cutting in the opposite direction between the cutters and the cover plates 56, 58 to redistribute the material and even out the cutting loads on the teeth. To avoid the use of air and achieve fairly even distribution, the cutters may be given a herringbone rather than a straight helical pattern as shown at 36, 38 in FIG. 2.

For the sake of simplicity, the representations of the invention as shown in FIGS. 1 and 3 have omitted many details such as the frame, bearings, mounting devices and drive means. It should be noted though, that the principles of the invention demand that only one of the pairs of cutters in each cutter set be driven and for this reason the cutting gear must be accurately spaced and rigidly mounted remote to each other. The mounting must permit the driving cutter to always maintain driving contact with the driven cutter even though the cutter teeth overlap but a very slight amount.

The particular shapes of the cutter in each cooperating set of cutters is not critical as long as cooperating teeth move into initial contact with each other along their lead lines at the intersection between their outer diameters and tooth profiles so as to provide a shearing action which is maintained continuously as new portions along the length of the tooth are brought into contact during rotation of the cutters.

In order to better explain the distinctions between cutter teeth such as those shown in FIG. 4 which have been formed by an ordinary gear forming hob and normal gears formed by a similar hob, a showing of the meshing relationship of ordinary gear teeth is set forth in FIG. 5. In FIG. 5, a tooth 62 of a driving gear 64 enters engagement with a tooth 66 of a driven gear 68 at a point 70 to its involute surface 72. The involute surface 72 of a tooth 62 then remains in sliding contact with the involute surface 74 on tooth 66 until the teeth move out of contact. It is easy to see that such a design could not effectively shear the involute surface and a rapid rounding over of the tip edges. Also, after severing, the severed material would most likely be jammed into the tooth space 76 as tooth 66 moves further and further into the tooth space. The jammed material would almost certainly remain in the tooth space and would build up until the gears 64 were forced apart and their cutting contact lost.

To achieve a cutting action which is much quieter, and far more efficient than a hammer mill, the cutters 16, 18 of the present invention are formed with a tooth shape quite different from the ordinary gear teeth of FIG. 5 so that their teeth 12, 14 respectively will shear the work material continuously at all times during their rotation and will move the work at their own rate of rotation. This is quite in contrast to a hammer mill where there are only two or three cutters and the cutting action is one of chopping or punching.

The desired cutting action can be achieved by forming the cooperating cutters in a variety of ways and each varying shape of cutter. Generally, these cutters may be used on any type of feed forming equipment which will produce helical gears or cutters. The particular shape shown in FIG. 4 can be produced with a standard hob by using over and undersized blanks.

To function in a granulating device in accordance with the invention, the cooperating cutters 16, 18 must have the same helical lead so that one cutter can drive the other and so that successive points along the line 72 on which the tooth form intersects the outer diameter on any tooth 12 will engage successive points on a similar line 74 on its mating tooth 14 as the cutters rotate and for the entire length of each tooth along the cutter body. The shape of the teeth must also be such that at the point of cutting, the cutting edges of the teeth will be moving past each other in a generally radial direction. Such a cutting action means that the teeth 14 need only exert the relatively small force on the work material which is necessary to shear it as compared to punching it or crushing it. Since this force is relatively small and transmitted substantially radially from the point of contact to the cutter body, the teeth may be made quite thin at their tips. As the tips are made thinner, their ability to penetrate the work increases and the cutting forces are reduced still further. The theoretical limit on the thickness of the tips of the teeth is controlled generally by the strength required to permit the driving teeth to drive the driven teeth. A further limitation on tip thickness can be introduced by the fact that the profiles of the teeth should be relieved back of their tips to insure that the respective teeth can only engage on their leading edges. Such relief also reduces the possibility of previously cut material getting between the teeth as they overlap after cutting in the region 78 and forcing the succeeding teeth out of engagement. Also, depending upon the particular type of tool and method used to form the cutter teeth, the teeth might have to be formed with an undercut back of the tip which would weaken the tip. Although thinner teeth perform more efficiently since they penetrate material with less effort than thicker teeth, it is possible for the width of the tooth at its maximum depth of penetration of a tooth space of a cooperating tooth to have a width not as great as 4 and the surface area of the tooth to tooth distance as measured on a circle through the teeth at the point of maximum penetration. For the teeth 14 shown in FIG. 4 this width figure would be about 15 percent as compared to a width of about 50 percent for a conventional gear tooth 62 as shown in FIG. 5.

Another important distinction of the cutters of the present invention is that they are mounted so that they have a limited amount of overlap. Some overlap is desired to permit cutter 18 to drive cutter 16 and to insure that the cutting edges 72, 74 will slide relative to each other to shear the work material. However, the overlap should be limited so that the tooth spaces 82, 84 will be kept relatively open after cutting to permit the cut pieces 10a, 10b and 10c of the material to assume the approximate positions shown in FIG. 4 wherein they can freely exit from the teeth and not become jammed in the tooth spaces 82, 84. A portion of each of one cutter into the tooth spaces of a mating cutter of about 25-35% has been found to give good results.

Occasionally, when the cutters 16, 18 are used with thin slippery material such as polyethylene, the driving force of cutter 18 on cutter 16 without some supplemental drag force added to cutter 16 may be insufficient to prevent the material from moving parallel to the sides of the teeth at points 72, 74, and being corrugated and carried around the cutters rather than cut and released.
Even though such a situation is rare, it is of no particular concern since it can be seen in FIG. 4 that if the layers of material 10 in tooth space 82 were multiplied so as to fill the tooth space entirely, additional layers would, in moving from space 82 to space 82', be compressed due to the fact that the teeth, 12, 14 are closer together than they are in tooth space 82. The material 10b being compressed would then exert a force to move teeth 12, 14 away from each other and thereby bring cutting edges 72, 74 into tighter contact whereby they would completely cut the next material contacted.

Although cutter members having the requirements set forth herein can be made by many processes, the particular properties of the cutters shown in FIG. 4 will be described. The process used to make the cutters was one of hobbing an oversized and an undersized blank with a single hob brought into the work to a point just short of "tapping" (touching the root of the hob to the work). To enable a comparison to be made between the hob produced cutters of FIG. 4 and a standard gear produced by the same hob, the table below includes data relating to such a gear also.

<table>
<thead>
<tr>
<th>Gear tooth data</th>
<th>Standard gear</th>
<th>Cutter 18</th>
<th>Cutter 14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of teeth</td>
<td>39</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>Normal diameter pitch</td>
<td>12</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>Pitch diameter</td>
<td>4.0000</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>Lead</td>
<td>12.5000</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>Helix angle, degrees</td>
<td>45</td>
<td>45 RH</td>
<td>45 L.H.</td>
</tr>
<tr>
<td>Normal pressure angle, degrees</td>
<td>20</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>Outer diameter of gear</td>
<td>4.1775</td>
<td>3.750</td>
<td>4.000</td>
</tr>
<tr>
<td>Root diameter</td>
<td>3.8130</td>
<td>3.250</td>
<td>4.000</td>
</tr>
<tr>
<td>Hobbing depth</td>
<td>.189</td>
<td>.200</td>
<td>.200</td>
</tr>
</tbody>
</table>

Although 12 pitch cutters have been described, it is possible to use various pitches depending on the size chip desired and the strength of the material being cut. A 12 pitch of cutters will provide a chip about 1/4 inch wide and is quite suitable for thin sheet material. For cutting up stronger or thicker material, such as thin metal or the sprues and gating material which results from a plastic molding operation, a lower pitch cutter is preferred for its extra strength. Although the particles produced with a low pitch cutter are much larger than with a cutter having a higher pitch, they can be recirculated to any size desired by use of an appropriate screen.

While the invention has been shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that variations in form and details may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. A process for granulating sheet-like material into small particles comprising the steps of: presenting a sheet of material to the bite of a pair of rotating, meshing, helically toothed cutter members, one of which drives the other; shearing said material continuously and simultaneously along a plurality of spaced parallel lines at an angle to its direction of movement into the bite of the cutter members to form it into a plurality of elongated strips; subsequently directing said sheared elongated strips into the bite of a pair of rotating, meshing, helically toothed cutter members, one of which drives the other; and shearing said plurality of elongated strips transversely.

2. The process of claim 1 wherein the material to be granulated is presented to a single pair of cutter members a plurality of times, said step of subsequently directing said elongated strips comprising guiding and carrying said elongated strips around the outer periphery of said cutter members for re-presentation thereby.

3. The process of claim 1 wherein the pair of cutter elements to which the strips are subsequently directed comprise an additional pair of cutter members having helical teeth arranged to shear material generally at right angles to the angle of shear produced by the helical teeth of the pair of cutter members to which the work is initially presented, mounting said additional pair of cutters immediately adjacent to and underneath the pair of cutter members to which the work is initially presented, whereby said plurality of elongated strips of material may freely fall into the bite of said additional pair of cutter members.

4. The process of claim 2 wherein particles sheared by the rotating cutter members are continually re-presented to the cutter members until they no longer exceed a predetermined size, the sheared particles which are smaller than said predetermined size being separated from the particles which exceed said predetermined size.

5. The process of claim 3 wherein portions of said elongated strips of material enter the bite of said additional pair of cutters before other portions of said elongated strips have been completely sheared by the initial set of cutters.

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