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[54] METHOD OR PRODUCING STEEL FIBERS
6 Claims, 3 Drawing Figs.

[52]	U.S. Cl.....	225/4, 225/97, 225/103
[51]	Int. Cl.....	B26f 3/00
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ABSTRACT: A method of producing steel fibers from steel strip including the steps of advancing a steel strip of a width corresponding to the length of fibers formed therefrom to a support block so that a portion of the strip equal to the width of the fiber formed extends beyond the edge of the block and causing a fracturing means to strike the extending portion of strip so as to sever that portion from the remainder of the strip by means of brittle fracture, whereby to form a steel fiber. By continuously repeating the steps of the process a mass of fibers is produced.

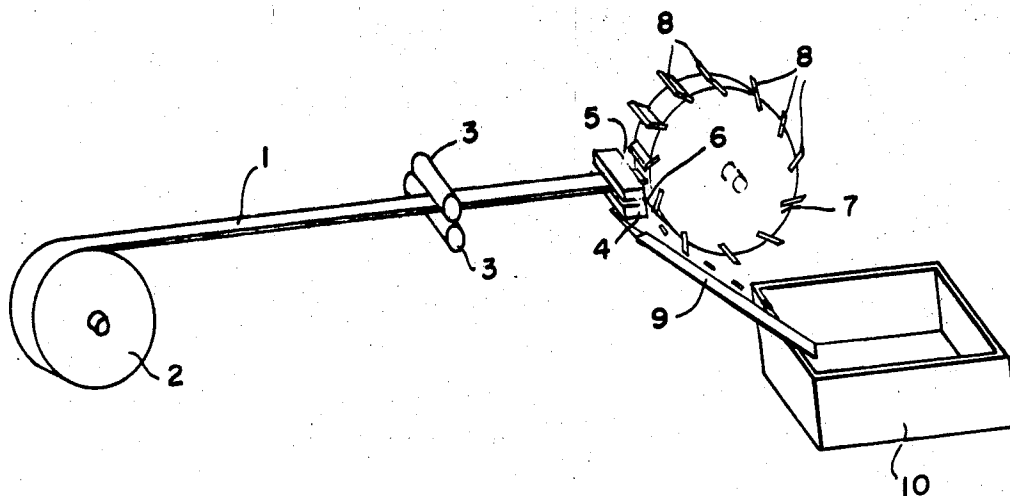


Fig. 1.

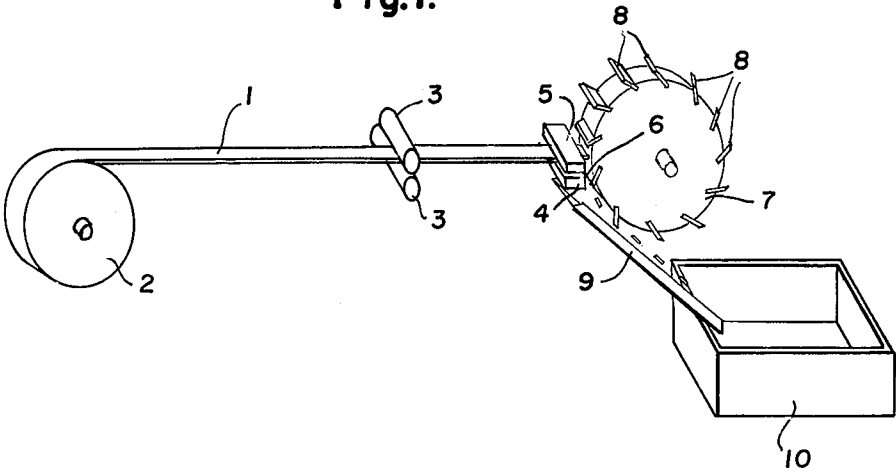


Fig. 2A.

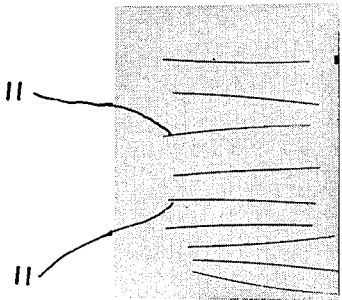
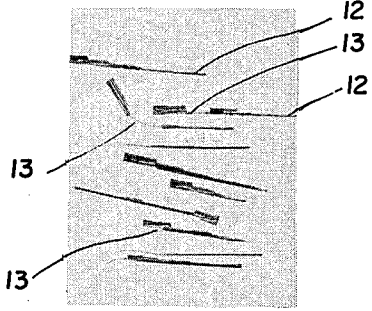


Fig. 2B



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METHOD OF PRODUCING STEEL FIBERS

This invention relates generally to a method of severing elements of relatively small size from a relatively large size workpiece and more particularly to a method of making steel fibers from steel strip.

It is recognized that the reinforcement of concrete with steel fibers increases the tensile strength of the concrete and in addition, the fibers are known to impart a significant degree of toughness to the concrete. Steel fibers having ultimate tensile strengths in excess of about 100,000 p.s.i. are generally preferred. The ductility requirements of steel fibers for reinforcing concrete are not severe because the concrete itself fractures at elongations of about 0.3 percent or less. It is, however, desirable to use steel fibers which have percent elongation values at least as high as that of the concrete matrix since concrete members containing such fibers are able to withstand a greater flexural load before breaking than members containing fibers of the same ultimate tensile strength but having lower percent elongation values. We have determined that in order to be especially effective as reinforcing material for concrete the steel fibers should possess certain additional properties. Thus, the fibers should have some degree of surface roughness so as to insure a good bond between the concrete and the fibers. If an adequate bond is not established the fibers will not act to reinforce the concrete to the extent desired. Thus, upon application of a strain sufficient to initiate cracking of a fiber reinforced concrete member, fibers which are well bonded to the concrete matrix will tend to arrest the cracks by holding the matrix together whereas fibers which are poorly bonded to the matrix will tend to pull out of the matrix and not hold the member together to the same extent. Consequently, the use of chopped wire as has been suggested in the prior art is not entirely satisfactory because the wire, having been formed by drawing wire rod, lacks the requisite degree of surface roughness to form a good bond with the concrete. In addition, an individual fiber should have a relatively uniform cross section and thus be free of notches and sharp changes in cross section since such defects result in stress concentrations in the fiber so as to adversely affect its strength and ductility. In addition to having properties desirable for reinforcing concrete, the fibers should be of a shape such that they may be readily handled. Thus the fibers should be relatively straight since curly fibers have a tendency to tangle and mass together and create handling and distributing problems. Further, while the fibers should have some degree of surface roughness as explained above, the fibers should not be so rough as to readily mass together thereby making it difficult to disperse the fibers in the concrete.

Prior art methods of making steel fibers which we are presently aware of are not individually capable of providing steel fibers having all the desired properties set out above. The method of the present invention, however, provides substantially straight steel fibers which have the requisite degree of surface roughness and which are free from notches and sharp changes in cross section.

The fibers are formed by causing a fracturing means to strike a supported section of steel strip of a width equal to the length of the fiber to be formed so as to sever a fiber therefrom by means of brittle fracture. This operation is rapidly repeated to produce fibers in quantity. In the preferred embodiment of our invention the strip when processed is at ambient temperature, which routinely is a normal shop temperature of about 70° F., and, therefore, the chemistry of the steel from which the strip is formed is adjusted so that the strip is capable of undergoing brittle fracture at ambient temperature. In the second embodiment of our invention, steel strip which is incapable of experiencing brittle fracture at ambient temperature is cooled prior to fracturing to a temperature where it can undergo brittle fracture when struck by the fracturing means.

An object of our invention is to produce steel fibers from steel strip. Another object of our invention is to so produce

the fibers by means of brittle fracture. Still another object of our invention is to produce steel fibers for use in reinforcing concrete. Yet another object of our invention is to produce straight steel fibers uniform in cross section and free from notches and sharp changes in cross section. A further object of our invention is to produce steel fibers having a degree of surface roughness such to insure good bonding to cement and good handling and distributing characteristics.

In the drawings:

FIG. 1 is a diagrammatic view representing the steps of the invention and illustrating the present preferred practice of producing steel fibers.

FIG. 2A is a photograph of steel fibers made according to the present invention.

FIG. 2B is a photograph of steel fibers which are not effective as reinforcing material for concrete.

In a presently preferred embodiment of the invention steel fibers are formed from steel strips having the following composition:

	C	Mn	P	S	N
25	0.06/0.12%	0.38/0.60%	0.055/0.065%	0.035%	0.008/0.12%

This steel is referred to as a high nitrogen steel. As a modification, the high nitrogen steel is rephosphorized to provide a phosphorus content of about 0.12/0.16 percent in the steel. The rephosphorized steel is referred to as a high phosphorus, high nitrogen steel and has substantially the same chemical composition as the high nitrogen steel except for the higher phosphorus content in the former.

The strips are formed by first cold-rolling a hot band approximately 90 percent to a thickness of about 0.010 inch and then slitting the cold-rolled sheet into strips about 1 inch wide. The strips are thereafter wound into coils. The strips are employed in the invention in a full hard condition. That is, the cold-rolled material is not annealed after being rolled to final gage. In processing the strip to fibers, the full hard strip 1 is advanced or fed from an uncoiler 2 by means of feed rollers 3—3 to support block 4 which includes a sharp edge 6. Mounted over support block 4 is a bar 5 which engages the upper surface of strip 1 and restrains upward movement of the strip. Positioned adjacent to the support block is a rotating cutter 7 which rotates in a counterclockwise direction and which includes a series of cutting tools 8—8 each having cutting edges at least as wide as the width of the strip. The cutting tools are arranged diagonally on the cutter 7 at an angle of about 1°. As the strip is continuously advanced it passes out over the end of the support block where it is supported and a cutting tool, as it moves downwardly past the support block, strikes the portion of the strip which extends beyond the block and severs that portion from the strip by means of brittle fracture so as to form a fiber. The fiber then drops on to a vibrating chute 9 from where it slides down into packing boxes 10. The feed rolls 3 and rotating cutter 7 are suitably driven, by means not shown, at a correlative rate so that the rate of advancement of the strip across the support block and the frequency of passage of the cutting tools by the support block produce one fiber 0.01 inch wide for each such passage of a cutting tool. The tensile strength of the fibers is about 135,000 p.s.i.

By adjusting the composition of the steel from which the strips are formed so as to provide a high phosphorus, high nitrogen steel or a high nitrogen steel, the impact of the fracturing means or cutting tools 8—8 severs fibers from the strips by means of brittle fracture over a wide strip temperature range including routine operating temperatures of about 70° F. As a result fibers 11—11 as illustrated in FIG. 2A are produced. As can be seen, these fibers are relatively straight and uniform in cross section. The fibers in addition exhibit the degree of surface roughness required for insuring good bond-

ing thereof to cement but do not contain any notches or sharp changes in cross section. The fibers 11—11 produced by brittle fracture are to be compared with the fibers 12—12 of FIG. 2B which result when fibers are processed from steel strip by shear fracture rather than brittle fracture. Such is the case, for example, when strip formed from ordinary aluminum killed or rimmed steels is used as the fiber forming material or when a high phosphorus, high nitrogen or a high nitrogen steel which as been annealed after being cold rolled to final gage is used. As can be seen from FIG. 2B, fibers formed by shear fracture tend to be of a highly irregular shape, containing notches and sharp changes in cross section as at 13—13. As can be understood, these features result in stress concentrations along the fiber whereby the fibers exhibit low strength and ductility. Thus although these fibers will adhere securely to concrete because of their extreme surface roughness, this advantage is more than offset by the fact that they will behave erratically and break under low loads. Further, the extreme surface roughness of these fibers causes the fibers to tangle and mass together so that they have an undesirably high bulk factor and are difficult to separate for proper distribution in concrete.

It is to be understood that in speaking of brittle fracture of the strip we mean a fracture which occurs at a low-energy impact level with a minimum of plastic deformation so as to produce a straight fiber of uniform cross section as illustrated in FIG. 2A. We mean to distinguish this type of fracture from shear fracture which is associated with higher energy absorption than brittle fracture and which results in a greater degree of plastic deformation so as to form steel fibers highly irregular in cross section as illustrated in FIG. 2B.

We have noted that under ideal conditions wherein extremely sharp cutting tools and a very sharp support block are employed, satisfactory steel fibers can be produced from aluminum killed steel strip by shear fracture. However, the strip deformation which occurs during the severing of the fibers by shear fracture causes excessive heat to be generated and the tools and support block wear rapidly even at low cutting speeds. As a result unsatisfactory fibers as illustrated in FIG. 2B are produced. On the other hand by using strip which undergoes brittle fracture as taught by the present invention, very little heat is generated during the production of fibers so that a long cutting tool life and support block life results.

Strip which undergoes shear fracture at routine operating temperatures can exhibit brittle fracture if sufficiently cooled; and according to a second embodiment of the invention the strip is cooled prior to fracturing to a temperature within the temperature range where it will undergo brittle fracture when

struck by a fracturing means. Cooling can be accomplished by storing the strips as coils in a cooling atmosphere prior to positioning them on uncoiler 2 or by passing the strip through a suitable cooling apparatus as it is advanced to the support block 4.

While the description of the process of the present invention has been made with reference to the production of fibers 0.01 inch $\times$ 0.01 inch $\times$ 1 inch, it is to be understood that various size fibers are produced by our process. Thus fibers having a cross section of 0.005 inch $\times$ 0.005 inch and a length of 0.5 inch as well as fibers having a cross section of 0.02 inch $\times$ 0.02 inch and a length of 2 inches are produced. Generally the length of a fiber is about one hundred times greater than its cross-sectional dimensions.

We prefer to use only a single strip at a time in our process rather than a stack of strips since fibers formed when using a stack of strips are inclined to be nonuniform in cross section and tend to cold-weld together.

Various modifications can be made in the present invention without departing from the spirit or scope thereof as defined in the appended claims.

We claim:

1. A method of producing steel fibers from a steel strip comprising, advancing steel strip of a width corresponding to the length of the fibers formed therefrom to a support block, supporting said strip on the block so that a portion of the strip equal to the width of the fiber to be formed extends beyond the edge of the block, severing said extending portion of strip from the remainder of the strip by means of brittle fracture so as to form a steel fiber by causing a fracturing means to strike said extending portion of strip, and thereafter repeating said advancing and severing steps.

2. The method of claim 1 wherein the strip is cooled prior to fracturing to a temperature within the temperature range where it undergoes brittle fracture when struck by the fracturing means.

3. The method of claim 1 wherein the fibers are of a size 1 inch $\times$ 0.01 inch $\times$ 0.01 inch.

4. The method of claim 1 wherein the strip is at ambient temperature and the composition of the strip is such to cause it to fracture in a brittle fashion at that temperature when struck by said fracturing means.

5. The method of claim 4 wherein the steel strip is full hard and contains about 0.12 percent to 0.16 percent phosphorus and about 0.008 percent to 0.012 percent nitrogen.

6. The method of claim 4 wherein the steel strip is full hard and contains about 0.008 percent to 0.012 percent nitrogen.