Aug. 16, 1966 M. MAKANSI 3,266,969

TUFTING PROCESS AND PRODUCTS HAVING TUFTED STRUCTURES

Filed Sept. 10, 1962

3 Sheets-Sheet 1

FIG. 1a FIG. 1b FIG. 1c

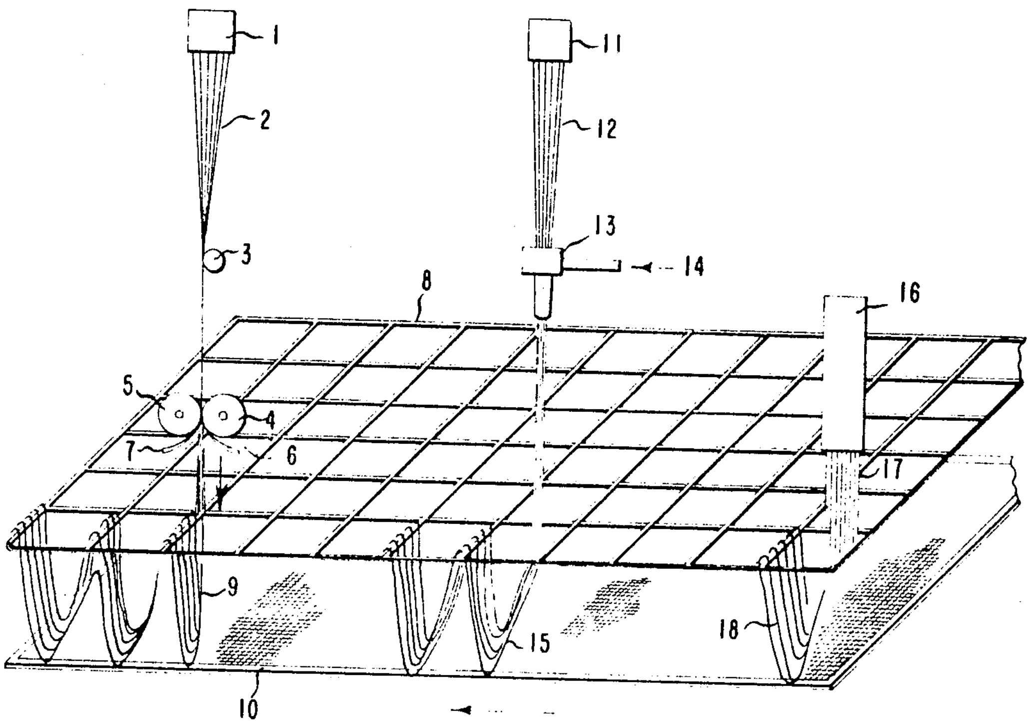
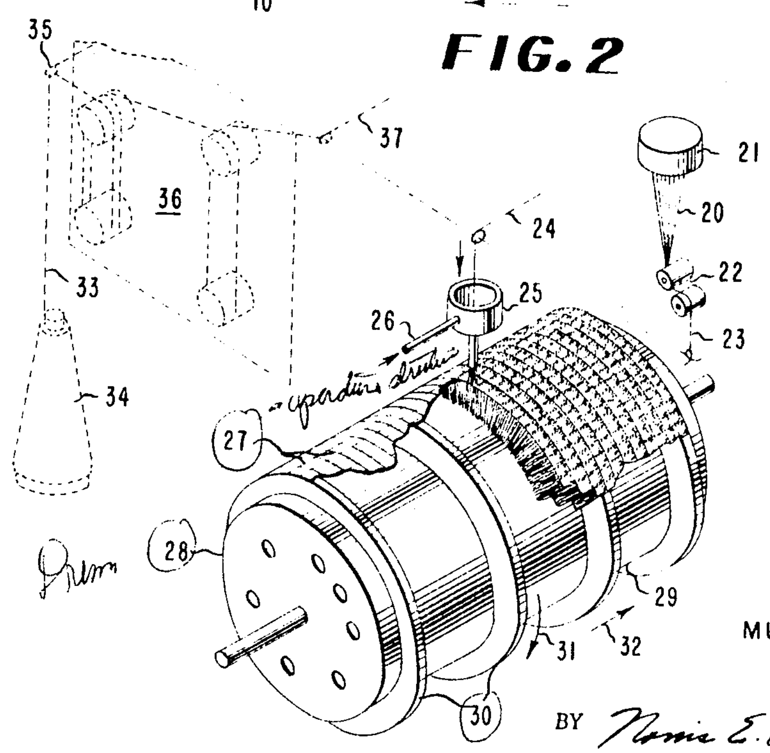


FIG. 2



INVENTOR
MUNZER MAKANSI

BY Norris E. Ruckman

ATTORNEY

FIG. 3

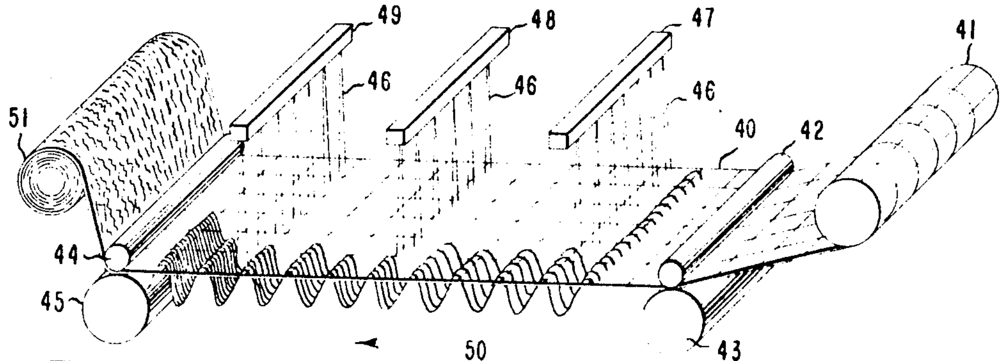


FIG. 4

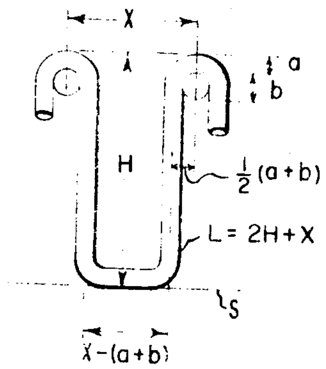


FIG. 5

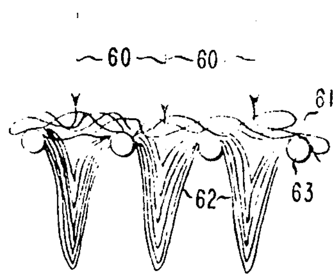


FIG. 6

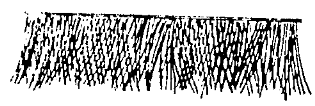


FIG. 7

FIG. 8

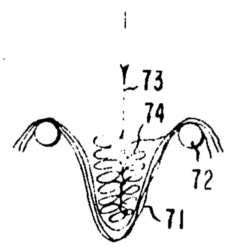


FIG. 9

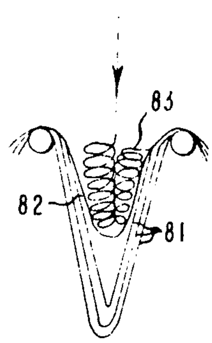
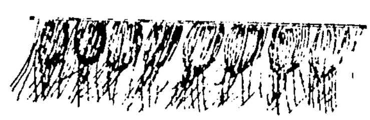


FIG. 10



INVENTOR
MUNZER MAKANSI

BY Norris E. Ruckman

ATTORNEY

Aug. 16, 1966 M. MAKANSI 3,266,969

TUFTING PROCESS AND PRODUCTS HAVING TUFTED STRUCTURES

Filed Sept 10, 1962

3 Sheets-Sheet 3

FIG. 11

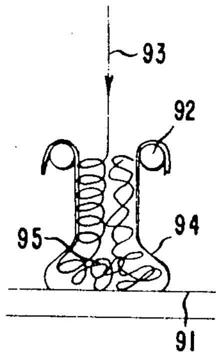


FIG. 12

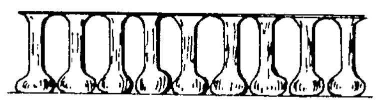


FIG. 13

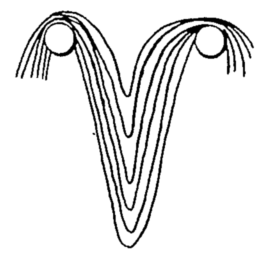
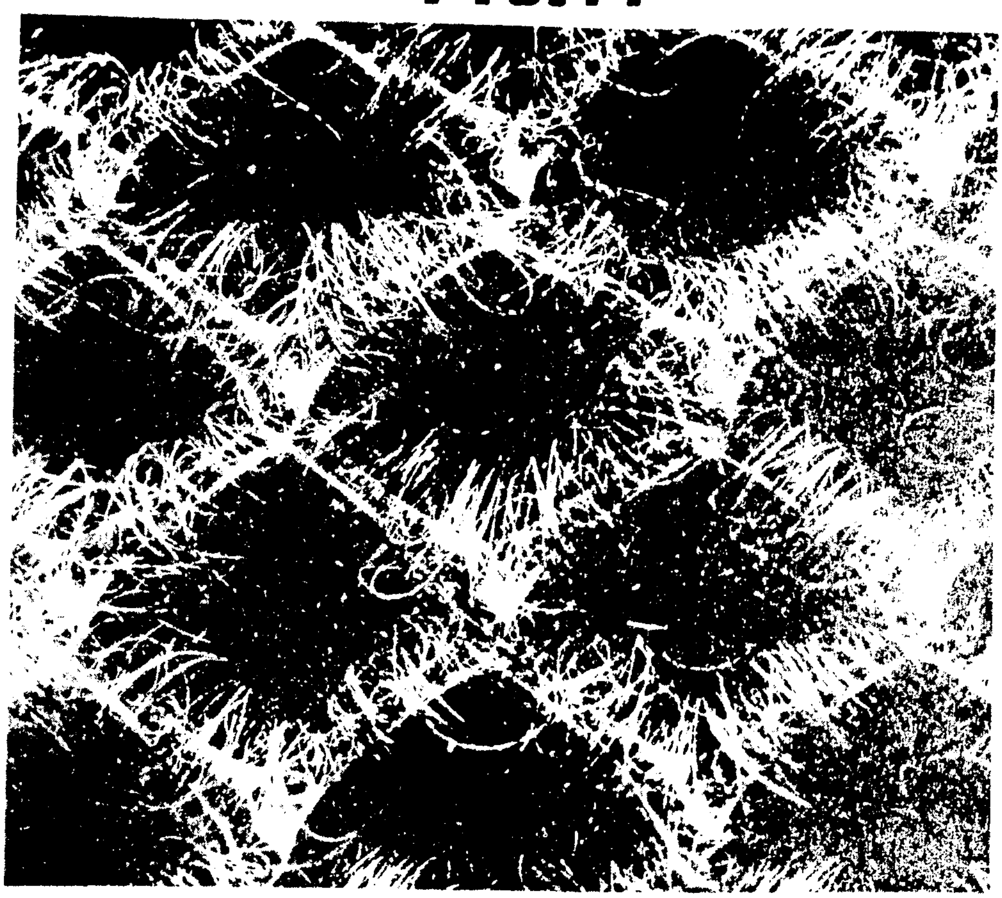


FIG. 14



INVENTOR
MUNZER MAKANSI

BY

ATTORNEY

United States Patent Office

3,266,969

Patented August 16, 1966

3,266,969

TUFTING PROCESS AND PRODUCTS HAVING TUFTED STRUCTURES

Munzer Makansi, Wilmington, Del., assignor to E. I. du Pont de Nemours and Company, Wilmington, Del., a corporation of Delaware

Filed Sept. 10, 1962, Ser. No. 222,707
41 Claims. (Cl. 161—63)

This invention relates to a novel process for the production of tufted structures and to tufted structures so produced.

Tufted or pile-surfaced structures have been made in the past by a variety of processes. Commonly, such structures are made by a needle tufting operation, in which a series of reciprocating needles are used to force loops of yarn through a ground fabric, generally burlap or the like, the loop being held in place on the underside of the fabric by a hook or like element until the needle passes on to the next tufting point. According to this type of tufting process, a loop of the pile-forming yarn is inserted at each point penetrated by the needle. Because of the complexity of the tufting equipment, such tufting processes are expensive and are not adaptable to the production of a variety of tufted products.

There are also practical limitations regarding the nature of tufts produced by needle tufting. A needle will penetrate where it contacts the fabric, without regard for the fabric weave, and it is impractical to operate the process so that the needles strike only between yarns. As a result, tufts will be produced by splitting single yarns and many apertures between yarns will be missed. The penetrations are not closely spaced, so dense tufting is achieved by forcing large tufts through the fabric. A tuft mushrooms out from a crowded tuft base where the legs of a strand loop are pressed together in tangential contact.

Tufts can also be formed by blowing yarns through apertures with a jet of air. However, it is difficult to accomplish desirable tufting in this manner. Although sufficiently high tufting forces can be obtained from a high velocity air jet, the flow is turbulent and the useful force is dissipated within less than one inch from the nozzle exit. This is not overcome by increasing the air pressure supplied to the jet, because velocities greater than sonic velocity cannot be achieved within the jet and air issuing from the nozzle under pressure expands in all directions. As a result, the strand is whipped about violently. This effect is utilized, as disclosed in Breen U.S. Patent No. 2,783,609, of March 5, 1957, to bulk or texturize yarn. FIGURES 1 and 3 of the patent, based on high speed photographs, show yarn filaments being separated from each other and formed into convolutions by the turbulent air stream. When attempting to form tufts by blowing strands through apertures of a fabric, this effect interferes to such an extent that flooding of the fabric surface takes place before desirable tufts can be formed.

This flooding, i.e., depositing strands on the surface rather than forcing them through apertures of the fabric, can be overcome by locating the jet sufficiently close to the fabric and using a jet having an exit orifice smaller than the fabric apertures. Most of the turbulence then occurs after a strand loop has passed through the aperture, but the turbulent action nevertheless interferes with regular tufting. Furthermore, the force of the air stream applies tension to the feed end of the loop and also to the leg leading to the loop already produced in another aperture, which tends to withdraw the previous loop partially from its aperture. This generally results in tufts of irregular appearance and non-uniform characteristics within the tufted area.

It is an object of this invention to provide a novel,

rapid, inexpensive, and versatile tufting process. It is a further object of this invention to provide a process for tufting continuous filaments, yarns, threads and like filamentary strands into an apertured structure. It is a further object of this invention to provide a tufting process which can be adapted to produce a variety of tuft-types ranging from fine fur-like tufts to dense, compact tufts, and combinations thereof. A further object of this invention is to provide novel tufted structures. Other objects of this invention will become apparent in the course of the following specification and claims.

These and other objects of this invention are accomplished by a process in which continuous filamentary strands are tufted through an apertured structure by means of their own momentum. More specifically, the process of this invention comprises imparting a propelling force to continuous filamentary strands to forward said strands continuously toward an apertured structure at a velocity which provides sufficient inertial momentum to force the strands through the openings of the structure, while employing relative lateral movement between said strands and said apertured structure to cause said strands to penetrate successive openings of the structure and suspend themselves from the walls of the openings, thereby forming loops or tufts in the openings of said apertured structure.

The tufting process may be carried out to produce tufts uniformly over the entire apertured structure or in a programmed manner to produce a pattern of tufts in selected areas of the apertured structure.

By "filamentary strand" is meant any continuous filament, yarn, fiber, thread, roving, fibrillated strand or the like. The filamentary strands may consist of any natural or synthetic, organic or inorganic material, or combinations thereof.

By "apertured structure" is meant any open mesh, perforated, or louvered structure, consisting of a structural portion defining a plurality of openings, the openings being square, rectangular, rhombic, triangular, circular, etc. Suitable apertured structures includes netting, screening, woven scrims, perforated plates or sheets, honeycomb, an array of wires, yarns, blades and like arranged to define any shape and/or size openings, etc. The "apertured structure" may form a permanent part of the tufted product or may subsequently be removed. The apertured structure may be planar or may be preshaped to a three-dimensional contour for producing a tufted structure ready for use on a contoured surface.

The filamentary strands may be propelled by any desired means, including fluid jets (air jets, steam jets, or hydraulic jets), mechanically driven pinch rolls, and gravity fields. Air or steam jets, etc., should be spaced from the apertured structure by a sufficient distance to avoid the turbulent effects discussed previously; the spacing is preferably at least one inch.

In a preferred embodiment of this invention, the tufting process is integrated with the production and/or processing of filamentary strands, utilizing the momentum gained during such production and/or processing to produce tufted structures directly from a spinning, drawing, bulking, crimping or other operation.

Alternatively, filaments, yarns, and the like originating from wound bobbins, spools, etc., may be converted into tufted structures by the process of this invention.

A further embodiment of this invention is the production of a unitary, self-supporting tufted structure having a permanent backing consisting of filamentary strands which are continuous with the filamentary strands of the tufts. Such products may be made by first forming a tufted structure and then continuing to deposit filamentary strands on the surface thereof until a web of randomly entangled strands of any desired thickness is obtained.

Any type of filamentary strand may be tufted by the process of this invention under the proper conditions of intensity and uniformity of the momentum field, relative velocities of the strand and the apertured structure, and the size and shape of the openings of the apertured structure, as will be more fully explained hereinafter.

Tuft height may be varied by varying the velocities of either the filamentary strands and/or the apertured structure and/or by varying the size of the openings of the apertured structure. Tuft height may also be controlled by placing a deflecting surface, hereinafter referred to as a "stopper screen" beneath and parallel to the apertured structure during the tufting process. The presence of the stopper screen thus prevents the filamentary strands from travelling the full distance permitted by their momentum and by their residence time in the aperture. By using a stopper screen having a series of depressions and elevations arranged in a given pattern, tufted structures with varying tuft heights corresponding to any desired pattern may be obtained. If desired, suction may be applied under the stopper screen in order to aid tuft formation and to further improve uniformity and tuft density distribution.

Tuft density may be controlled and/or increased by tufting the filamentary strands into an elastomeric apertured structure in the stretched state and subsequently relaxing the apertured structure after tufting has been completed. Alternatively, the filamentary strands may be tufted into an apertured structure composed of a shrinkable material, followed by shrinking the apertured structure upon completion of the tufting process. Tuft density may also be increased by using shrinkable and/or crimpable strands as the tuft-forming elements, and subsequently subjecting the tufted structure to an after-treatment to effect shrinking and/or crimping of the tuft strands. If desired, a fluid stream may be directed against the apertured structure ahead of the strand to open up the base of the tufted loops to permit tufting of more strands in the same aperture. In another variation of the invention, filamentary strands are tufted into an apertured structure consisting of an array of parallel or converging blades, wires or the like, to produce structures consisting of parallel or converging rows of tuft loops. By the use of reeds, combs or other means, the individual tuft loops may be moved closer together or farther apart, while still supported by the apertured structure, thereby offering an additional method for varying tuft density.

Process conditions may be varied to produce different types of tufts, including fine fur-like tufts, compact discrete tufts, tufts having balled tips, and combinations thereof. The filamentary strands and/or the apertured structure and/or the stopper screen may be electrically charged to enhance strand separation, tuft uniformity, and to anchor the tufts more firmly on the apertured structure during tufting.

The filamentary strands may be bonded to the apertured structure by a variety of process modifications. Thus, strands may be heated to temperatures high enough to soften them temporarily so that they become anchored to the apertured structure during tufting. Alternatively, the strands may be composed wholly or in part of heat-softenable materials, which are subsequently fused to the apertured structure by applying heat to the back of the tufted structure. Bonding may also be achieved by applying a resinous binder or adhesive to the back of the tufted structure or by depositing fusible fibers, fibrids, binder particles, etc., to the back of the tufted structure, followed by heating to effect bonding. If desired, an additional permanent backing may be applied to the back of the tufted structure. Such a backing may consist of a nonwoven mat, web or the like, fabrics, films, etc., and may be bonded thereto by any suitable means.

In general, the tufted structures of this invention comprise an apertured tuft-supporting member and a plurality of filamentary strands looped into and out of apertures of said member to form tufts projecting only from said apertures. In one embodiment of this invention, the tufted structures comprise an open mesh tuft-supporting member and a plurality of tufts formed from filamentary strands projecting only from the meshes of said member. By "open mesh" member is meant a structure, the apertures of which are defined by intersecting or crossing linear elements.

In a particular embodiment of this invention, there is provided a tufted structure comprising an apertured tuft-supporting member and a plurality of tuft-forming filamentary strands, said strands being looped into and out of said apertured structure to form a plurality of tufts projecting from one surface of said apertured structure, the strands of each tuft being shared with those of adjoining tufts in all planar directions of the structure.

In a still further embodiment of this invention, there is provided a self-supporting unitary tufted structure comprising (1) a permanent backing member consisting of randomly interlaced continuous filamentary strands, (2) an intermediate member consisting of an apertured, tuft-supporting member, and (3) a pile portion consisting of a plurality of tufts formed from filamentary strands suspended from said apertures, the strands of said pile portion being continuous with the strands of said backing portion.

If desired, a separate permanent backing material of any type may be applied to the non-pile surface of said tufted structure in a subsequent processing step by any suitable means.

After formation of the tufted structure and/or after application of a permanent backing, the apertured supporting member may subsequently be removed to provide a sheet structure consisting of a planar portion and a pile portion projecting therefrom.

If desired, a separate permanent backing material of duced in one step by simultaneously tufting through two or more apertured structures, which are arranged parallel to one another but spaced apart, and subsequently cutting the tufted product between any two apertured structures.

Different types and/or colored strands may be used in the production of a single tufted structure, optionally in conjunction with a programmed strand traverse, to produce tufted structures having a programmed surface, hand, aesthetics or color pattern.

The tufted structures of this invention may be subjected to various after-treatments, such as dyeing, embossing, etc., to produce a patterned or otherwise modified structure.

The tuft loops may be sheared or otherwise cut, either during or after production of the tufted structure, to produce a cut pile surface.

Both sides of an apertured structure may be provided with tufts, if desired, by directing strands into different cells of the apertured structure from opposite sides thereof. Alternatively, loops can be pushed back from the tufted side.

The tufted structures produced by this invention are useful as pile products of all types including furs, fleeces, floor coverings, towels, blankets, etc. In addition, they may be used as stuffing materials, padding, filters, liners, etc. Depending on the end use, it may be desirable to apply a permanent backing to one or both sides of the tufted structure.

The process of this invention and its application will be better understood by reference to the following figures and subsequent discussion.

FIGURE 1 is a schematic isometric view of apparatus for the production of tufted structures directly from a spinning source.

FIGURE 2 is a schematic isometric view of apparatus for the production of tufted structures on a revolving drum.

FIGURE 3 is a schematic isometric view of apparatus for the continuous production of tufted structures.

FIGURE 4 is an idealized model illustrating the formation of a single tuft loop in a single cell of an apertured structure.

FIGURE 5 is a graphic cross-sectional illustration of the production of a self-backed tufted structure.

FIGURE 6 is a graphic cross-sectional view of fine, fur-like tufts consisting of a plurality of individual tuft loops.

FIGURE 7 is a graphic cross-sectional view of dense discrete tufts consisting of a plurality of individual tuft loops.

FIGURE 8 is a graphic cross-sectional illustration of the production of a special type of dense discrete tuft.

FIGURE 9 is a graphic cross-sectional illustration of the production of a special type of fleece tuft.

FIGURE 10 is a graphic cross-sectional view of the fleece-like tufts referred to in FIGURE 9.

FIGURE 11 is a graphic cross-sectional illustration of the production of a special type of balled-tip tuft.

FIGURE 12 is a graphic cross-sectional view of the balled-tip tufts referred to in FIGURE 11.

FIGURE 13 is a graphic cross-sectional illustration of fine, fur-like tufts which vary in density from the base to the tip of the tuft.

FIGURE 14 is a photograph (magnification 10 times) of the non-pile side of a tufted structure, illustrating the sharing of tuft strands.

Referring now more particularly to the drawings, FIGURE 1*a* illustrates the preparation of a tufted structure in association with a conventional spin-drawing operation. Freshly-formed filaments **2** emerging from the spinneret **1** are passed around snubbing pin **3** and fed into the nip of draw rolls **4** and **5**. Suitably, tapered guides **6** and **7** are placed beneath the draw rolls at their nip to prevent the filaments from becoming wrapped around the draw rolls. The filaments **2** issuing from the nip of the draw rolls **4** and **5** continue to travel in a direction generally tangential to the draw rolls into contact with apertured structure **8** which is arranged to be moved by suitable means (not shown) in a generally horizontal direction as indicated by the arrow. As the filaments **2** traverse the apertured structure **8**, the filaments simultaneously suspend themselves from the walls of the apertured structure and form loops or tufts **9** within each aperture thereof. If desired, a stopper screen **10** is placed beneath and spaced a given distance from apertured structure **8** in order to control tuft height and type.

In FIGURE 1(*b*), freshly-formed filaments **12** emerging from spinneret **11** are passed through aspirator jet **13** to which a suitable fluid is supplied under pressure through inlet **14**. The filaments **12** emerging from aspirator jet **13** traverse the apertured structure **8** forming tufts **15** therein as described above.

In FIGURE 1(*c*), filaments **17** emerging directly from spinneret **16** are directed into contact with apertured structure **8** to form loops or tufts **18** therein as described above.

FIGURE 2 illustrates the continuous production of a tufted structure from yarns wound on a cone or from filaments directly from a spinning source. In the production of the filament tufted structure, freshly-formed filaments **20** issuing from spinneret **21** are fed over snubbing pins **22** through a series of guides **23** and **24** into aspirator jet **25**. Fluid under pressure is supplied to aspirator jet **25** through inlet **26** and the filaments emerging from the aspirator jet are directed into contact with apertured structure **27** mounted on a revolving drum **28**. Apertured structure **27** is held tautly and spaced a given distance from drum surface **29** by means of vanes **30** secured on drum surface **29**. The drum surface serves in effect as a stopper screen, which can be used to control tuft height and type, if desired. The drum is mounted to be rotated in the direction indicated by arrow **31**. Simultaneously, the drum is moved horizontally in the direction indicated by arrow **32**. As the filaments issuing from aspirator jet **25** traverse the apertured structure **27**, the filaments simultaneously suspend themselves from the walls of the apertured structure and form tufts within the apertures thereof. The apertured structure is subsequently slit along a line generally parallel to the drum axis and removed from the drum to provide an open width tufted structure.

In the production of a yarn tufted structure, the yarn **33** is fed from a cone **34** through yarn guide **35** to feed rolls generally indicated at **36**. From the feed rolls the yarn is fed through guides **37** and **24** into aspirator jet **25**. Yarn emerging from the aspirator jet **25** is directed into contact with the apertured structure **27** to produce a tufted structure as described above.

FIGURE 3 is a schematic view of apparatus for the continuous production of the tufted structures. Wire screen or other suitable apertured structure **40** from supply roll **41** is fed in a horizontal direction between two sets of forwarding rolls **42, 43**, and **44, 45** so as to be maintained taut during passage through the tufting zone. A plurality of filaments **46** propelled from supply sources **47, 48** and **49** progressively arranged along the path of traverse of the screen **40**, is directed into contact with screen **40** as it moves along the path indicated by arrow **50**. The completed tufted structure emerging from the nip of rolls **44** and **45** is continuously wound up into package **51**.

If desired, a permanent backing is applied to the tufted structure at the end of the tufting zone before passage through the nip of rolls **44** and **45** and the resulting structure is continuously wound up into package **51**.

In a variation of the above process, the apertured structure is arranged to traverse the tufting zone in the manner of a conveyor belt. Upon completion of tufting, a permanent backing is continuously applied to the tufted structure. After application of the permanent backing, air under pressure is directed against the tufts from the underside of the apertured structure to force the tufts back through the apertures thereof. Alternatively, mechanical means such as peeling rolls may be used to separate the apertured structure from the permanently-backed tufted product. The resulting tufted structure consisting of the backing member with a plurality of tufts projecting from one surface thereof is continuously wound into a package while the apertured conveyor is returned to the tufting zone for further tufting.

In the production of tufted structures utilizing the described apparatus of FIGURES 1 to 3 in the absence of a stopper screen, tuft height is dependent on the velocities of the filamentary strands and apertured structure, respectively, and on the cell size of the openings in the apertured structure in the direction of traverse of the apertured structure.

The relationship of these variables to tuft height may be better understood by the following discussion with reference to FIGURE 4. FIGURE 4 is an idealized model illustrating the formation of a single strand loop in a single cell of an apertured structure, the loop being restrained by the presence of a stopper screen positioned so as to support the loop at its tip without causing undue buckling or distention of the loop. In this figure X refers to the center-to-center distance between the walls of a single cell in the direction of traverse, L refers to the length of strand in the loop, H refers to tuft height, S refers to the stopper screen, and *a* and *b* refer to the diameter of the strand and the cell wall, respectively. In the case where the cell wall is of non-round cross-section, *b* refers to the dimension of the cell wall in the direction of traverse. From the figure, the center-to-center distance between the legs of the strand loop is seen to be $X-(a+b)$. The distance between the center of one strand leg and the center of the cell wall from which it is suspended is seen to be $\frac{1}{2}(a+b)$. Therefore, from the geometry of the figure:

$$H=\tfrac{1}{2}[L-\{X-(a+b)\}-(a+b)]$$

or

$$H=\tfrac{1}{2}(L-X)$$

In the production of a tufted structure, the time interval available for tuft formation is equivalent to the distance X divided by the velocity of the apertured structure V_a or to the length L of the strand in the loop divided by the velocity of the strand V_y, thus:

$$\frac{X}{V_a}=\frac{L}{V_y} \text{ or } L=\frac{XV_y}{V_a}$$

Substituting for L in the equation above, tuft height is seen to be:

$$H=\tfrac{1}{2}X\left(\frac{V_y}{V_a}-1\right)$$

By varying the process conditions, any size, shape and type of filamentary strands may be tufted into apertured structures having a variety of cell sizes and cell cross-sections, providing that (1) the velocity of the filamentary strands is sufficient to cause the strands to travel beyond the plane of the apertured structure to a distance equal to the desired tuft height, (2) the ratio of the velocity of the strands to that of the apertured structure is at least about 2, and (3) the cell size of the apertured structure in the direction of traverse is at least twice the diameter of the strand.

Other factors which affect the ability to form tufts in a given aperture include the modulus of the filamentary strand, its diameter, and the friction coefficient between the strand and the surfaces it contacts. In general, for a given set of process conditions, strands having a lower modulus and/or smaller diameter may be continuously tufted at lower minimum strand velocities. However, the modulus of any strand may be temporarily reduced during tufting, for example by heating or plasticizing the strand to permit the strand to be tufted under conditions otherwise not possible.

Similarly, as the coefficient of friction between the strand and the cell wall increases, it is possible to tuft continuously at higher maximum strand velocities. If desired, the coefficient of friction may be increased during tufting, for example by spraying the strand and/or apertured structure with dilute adhesive, to permit tufting at higher maximum strand velocities.

Tuftability may also be improved by increasing the uniformity and intensity of the momentum field of the propelled strands. Uniformity may be increased by propelling all strands from a given source so that the strands are substantially parallel to one another, travel at substantially the same velocity, and/or have substantially the same denier. Intensity may be increased by directing the strands to travel in a closely-spaced relationship. Uniformity and intensity may also be improved by reducing any external disturbances, such as excessive air turbulence around the propelled strands, or excessive gas expansion in the tufting region, which may deflect or otherwise alter or hinder the movement of the strands during their course of travel toward the apertured structure.

The tufting process may be varied to insert a single strand loop or a plurality of strand loops in each cell. The multi-loop tuft may be produced by traversing a given cell with a multi-strand stream and/or multi-streams in a single pass. Alternatively, successive passes may be used to increase the number of tuft loops per cell. The tufting process may be continued until each cell is saturated with tuft strand, i.e., no additional tuft strands can penetrate the cell, or it may be stopped before cell saturation occurs depending on the desired product.

In a particular embodiment of this invention, tufted structures are obtained wherein individual strands of each tuft are shared with those of all adjacent tufts in all planar directions of the structure. This type of tuft sharing is produced by traversing the apertured structure with a multi-strand stream or streams along a path which permits the strands to traverse all walls of each cell. The production of this type of structure may be enhanced by imparting an electric charge to the strands prior to tufting whereby individual strands of the stream repel each other and become uniformly distributed over a wider area of the apertured structure.

In another embodiment of this invention, the tufting process is continued until the cells of the apertured structure are saturated with already tufted strands, whereupon the apertured structure is again passed into the path of propelled strands. The new incident strands are unable to penetrate the saturated cells and deflect from the surface thereof to become deposited in random laydown manner on the non-pile surface of the apertured structure. The non-woven mat thus formed may be bonded, either subsequently or during its formation, to the non-pile surface of the apertured structure to produce a non-woven tufted structure having a pile surface and a permanent backing, the strands of the pile surface being continuous with the strands of the backing. If desired, the non-woven batt of random strands may be deposited on the upper surface of the apertured structure at any stage prior to complete saturation of the cells of the apertured structure by varying the process conditions. Thus at any stage of tufting, the velocity of the strands may be reduced so that new incident strands no longer have sufficient momentum to penetrate the cells of the apertured structure, whereupon the incident strands become deposited in random laydown manner as previously described. Alternatively, when tufting in a fluid atmosphere, such as air, the apertured structure may be moved further from the strand source at any stage of tufting, so that the momentum field intensity of new incident streams is insufficient to carry the strands beyond the plane of the structure but permits them to deposit in the form of a non-woven mat on the upper surface of the apertured structure. Production of such structures is diagrammatically illustrated in FIGURE 5, in which a plurality of tufts **62** are first formed in the cells of apertured structure **63** whereupon additional incident strands **60** are deposited on the non-pile surface of the apertured structure to form a non-woven mat **61**.

The tufting process of this invention may be used to produce a wide variety of tuft types by varying the tufting strands and/or the process conditions.

Fine, fur-like tufts with constant density along the tuft height of the type illustrated in FIGURE 6 may be produced by propelling a plurality of filaments, fibers or other strands so as to enter the cells of an apertured structure in one or more passes. Similiarly, fine fur-like tufts with uniformly increasing density from the tip of the tuft to the base may be produced by reducing the velocity of the propelled strands in successive passes. This type of tuft is illustrated in FIGURE 13.

Dense, discrete tufts consisting of a single loop of yarn or like heavier denier filamentary strand may be made by propelling the yarn so as to successively penetrate and form a loop in each aperture along the path of travel of the yarn. Dense, discrete tufts consisting of a plurality of loops may be made by propelling a continuous strand bundle so as to traverse the cells of a given aperture row along the center line of the row. This type of tuft is diagrammatically depicted in FIGURE 7.

If desired, process conditions may be varied so as to restrict further free tufting at some stage of the tufting process to produce special types of tufts. Thus the cells of an apertured structure may be partially filled with strand loops of a given tuft height in an initial pass. In a subsequent pass, new incident strands may be propelled at a higher velocity than that of the strands in the first pass or the velocity of the apertured structure may be reduced. Under these conditions, the initially formed loops serve as a pocket or "stopper screen" preventing the new incident strands from traveling to the full distance permitted by their momentum and thereby forcing them to curl or ball up within the pocket formed by the shorter loops. The formation of dense discrete tufts by this method is diagrammatically depicted in FIGURE 8, in which short tuft loops **71** are initially formed in the cells of apertured structure **72** whereupon incident strands **73** enter the cell and curl into a dense mass **74** within the pocket formed by the loops.

In a variation of the above process, referring to FIGURE 9, process conditions are varied in three successive passes to produce first a plurality of long tuft loops **81**, then a plurality of short tuft loops **82**, and finally a dense curled mass **83**. The resulting tufted structure has a fleece-like pile of the type illustrated in FIGURE 10, wherein the individual tufts consist of a dense base portion and a fine, fur-like terminal portion.

Tufts having "balled" tips may be produced by the process of this invention by propelling partially softened strands into the cells of an apertured structure and utilizing a stopper screen to prevent the strands from traveling to the full distance permitted by their momentum. The strands may be softened, for example, by passing them through an aspirator jet **13** as shown in FIGURE 1(b) and supplying hot gas or steam through inlet **14** to partially soften or plasticize the strands. The production of tufts having balled tips is diagrammatically illustrated in FIGURE 11 wherein a stopper screen **91** is held beneath the apertured structure **92** to prevent the incident partially softened strands from taking a free course, whereby the initial strand loops **94** are deflected and caused to buckle by the stopper screen. As an additional strand enters the cell it is looped or curled into a dense mass **95** within the initially formed loops **94**. The stopper screen is maintained in contact with the loops until the heat-softened strands cool and become set in the configuration depicted in FIGURE 12.

The production of various types of tufted structures by the process of this invention will be explained more thoroughly in the following examples.

EXAMPLE I

This example illustrates the production of a tufted structure having fleece-like tufts.

Using apparatus of the type shown in FIGURE 1(*b*) and comprising a spinneret having 17 orifices (0.009 inch), filaments are spun from polyethylene terephthalate at a temperature of 284° C. and a throughput rate of 15 grams per minute. The filaments are spun into a quiescent atmosphere at ambient temperature of 25° C. and relative humidity (70%) and led into an aspirator jet of the type constructed so as to provide an annular stream of high velocity air or other suitable fluid in a direction co-current with that of the filaments. The aspirator jet imparts a certain amount of tension to each of the spinning filaments, which tension serves to attenuate and hence orient them. The jet also serves to provide additional forwarding impetus to the filaments. The aspirator jet is located 90 inches beneath the spinneret and air at a temperature of 140° C. and 60 lbs./sq. in. gauge pressure is fed to the jet. The filaments emerge from the jet at a velocity of 12,000 feet per minute.

A six-mesh plastic netting having a plurality of rhombic-shaped cells is used as the apertured structure. The cells are so arranged that a line can be drawn parallel to the lengthwise direction of the netting to intersect opposite vertices of each cell in a given row of cells. The netting is moved horizontally back and forth in a direction corresponding to its lengthwise direction at a distance of approximately two inches beneath the tip of the aspirator jet. By travsering in this manner, long filament loops are formed in the largest dimension of each cell, i.e., between opposite vertices of the rhombus in the direction of traverse of the netting. Progressively shorter loops are formed laterally of the first mentioned

loops as the cell size diminishes toward the remaining opposite vertices of the cell. The latter short loops serve as a stopper screen during further tufting causing additional incident fibers to curl and ball-up within the restraining pocket formed by them.

After several passes the netting is removed and examined. The resulting tufts have an over-all tuft height of approximately two inches and each tuft consists of a dense portion near the netting and a fluffy portion at the tip of the tuft. The pile surface of the resulting tufted structure thus has the appearance of long hair fur. By shearing the resulting tufted structure to a pile height of approximately ¼ inch, i.e., corresponding to the dense portion of the tufts, a rug-like structure having a dense pile surface is obtained.

EXAMPLE II

This example illustrates the production of a rug-like tufted structure to which a permanent backing is applied.

A tufted structure is first produced by the procedure of Example I using ½-inch thick, ⅛-inch cell size honeycomb as the apertured structure and using a 40-mesh wire screen as a stopper screen placed against the bottom side of the honeycomb. The resulting tufts have an over-all height of ½ inch and are fur-like.

After completion of tufting, a sheet of linear polyethylene foam is adhesively bonded to the non-pile surface of the tufted honeycomb. The honeycomb is then removed from the composite by blowing air under pressure against the pile surface of the structure to force the pile tufts back through the cells of the honeycomb. The resulting tufted structure consisting of foam backing having a pile surface on one side thereof simulates a rug with a pile having the appearance of lamb fur. A portion of this tufted structure is subsequently pressed to a thickness of ¼ inch, whereby a very dense highly uniform pile is obtained.

EXAMPLE III

This example illustrates the production of a rug having a self-backing produced directly under a spinneret.

Using apparatus of the type shown in FIGURE 1*b*, two-component, post-crimpable filaments are spun from polyhexamethylene adipamide and a 50/50 copolymer of polyhexamethylene adipamide and polyhexamethylene sebacamide utilizing a spinneret having 11 orifices (0.009 inch). The filaments are spun at a temperature of 289° C. and a throughput rate of 14 grams per minute into a quiescent atmosphere at ambient temperature (25° C.) and relative humidity (70%). They are then led into an aspirator jet, located 108 inches below the spinneret, to which air is fed at a pressure of 90 lbs./sq. in. gauge. The velocity of the filaments emerging from the aspirator jet is 15,000 feet per minute.

A specially constructed apertured structure, consisting of 860 denier, high tenacity nylon yarns mounted on a wooden frame and spaced $\frac{1}{10}$ inch apart so as to form a square network held tautly by the frame, is then pased horizontally beneath the aspirator jet about 1.5 inches beneath the jet until tufts having a height of about ¼ inch are produced in every cell thereof. The tufting process is continued until no additional tufting filaments will enter the cells.

When this stage is reached, several additional passes are made under the jet until a non-woven web, approximately $\frac{1}{16}$-inch thick and consisting of randomly interlaced filaments, is deposited on the surface thereof. The non-pile surface of the resulting structure is then hot-pressed at 230° C. by contacting it with heated platens to melt the copolyamide segments of the filaments and form a coherent bonded backing. The yarn grid is then removed by forcing the tufts back through the cells thereof. The resulting rug-like structure consists of a non-woven backing and a plurality of dense, discrete tufts forming a pile on one surface thereof, the filaments of the tufts being continuous with those of the backing.

A portion of the above structure is then subjected to steam relaxation in a steam bath supplied with 15 p.s.i. saturated steam. The action of the steam serves to crimp the filaments and thereby increases the density of the over-all structure.

EXAMPLE IV

This example illustrates the production of a tufted structure wherein the fibers of each tuft are shared with those of adjoining tufts in all directions.

Utilizing the apparatus depicted in FIGURE 2, polyethylene terephthalate filaments are spun from a spinneret having 34 orifices (0.009 inch) at a temperature of 284° C. and throughput rate of 25.2 grams per minute. The filaments are spun into a quiescent atmosphere at ambient temperature (25° C.) and relative humidity (70%) and led into an aspirator jet located 104 inches below the spinneret. Air at a pressure of 96 lbs./sq. in. gauge and a temperature of 25° C. is fed into the jet inlet and the filaments emerge from the jet at a velocity of 7,000 feet per minute. A 5.5 mesh plastic netting is longitudinally traversed under the jet at a distance of approximately 2½ inches below the tip of the jet at a velocity of 450 feet per minute. The netting is mounted on the revolving drum as shown in FIGURE 2 and spaced approximately ½ inch from the drum surface.

The calculated height of the tufts which would be formed under these process conditions in the absence of a stopper screen is approximately one inch. Since the filaments are prevented from traveling their full distance by the drum surface and because of the diagonal geometry of the cells, the resulting tufts are of the fleece type depicted in FIGURE 10. In traversing the drum, the filaments have crossed over all walls of each cell thereby forming shared tufts as illustrated in FIGURE 14, showing the reverse side of this structure.

EXAMPLE V

This example illustrates the production of a tufted structure having fine, fur-like tufts of uniform height and non-varying tuft density made on a wire screen as the apertured structure.

Using apparatus of the type shown in FIGURE 2 and comprising a spinneret having 17 orifices (0.009 inch diameter), filaments are spun from polyethylene terephthalate at a temperature of 284° C. and a throughput rate of 15 grams per minute. The filaments are spun into a quiescent atmosphere at a temperature of 25° C. and relative humidity of 70% and led to a jet of the type constructed so as to provide an annular stream of high velocity air or other suitable fluid in a direction cocurrent with that of the filaments. The jet imparts a certain amount of tension to each of the spinning filaments, which tension serves to provide additional forwarding impetus to the filaments. The jet is located beneath the spinneret, the distance between the spinneret and the entrance to the jet being 104 inches. The jet itself including its tail pipe is 16 inches long. The inner diameter of the jet and tail pipe is ³⁄₃₂ inch. Air at a temperature of 25° C. and 60 lbs./sq. in. gauge pressure is fed to the jet. The filaments emerge from the jet with a denier/filament of 2.3 and at a velocity of 10,130 feet per minute.

A woven, 8-mesh wire screen with square cells, having a cell size of 0.125 inch measured between the axes of two parallel wires of the cell and a wire diameter of 0.032 inch, is used as the apertured structure. The screen is mounted on a revolving drum to assume the shape of a cylinder having a diameter of 12 inches and an axial length of 21 inches and separated by a distance of one inch from the drum surface by means of vanes. The drum surface is a 40-mesh wire screen. The apertured structure is oriented so that one cell wall is parallel to the axis of the cylinder and the other is perpendicular to it. The drum is placed on a table traversing back and forth in the direction of the cylinder axis at a speed of about 10 feet per minute and is directly beneath the jet so that there is a distance of 2 inches between the jet exit and the apertured structure, the jet being pointed in a direction perpendicular to the surface of the apertured structure. The drum is rotated at a speed of 204 r.p.m., corresponding to 640 feet per minute linear traveling sped of the cells relative to the stationary jet.

The process is continued for several passes under the jet, after which the screen is removed and examined. The resulting tufts are uniform, fluffy and have an overall height of one inch. Each tuft consists of a plurality of individual filament loops. The pile surface of the resulting tufted structure has the appearance of long hair fur, even though the individual loops are not cut.

EXAMPLE VI

This example illustrates the use of lanced foam sheets as an apertured structure and the production of tufts with balled tips. This structure is particularly suitable in stuffing end uses, for it combines the cushioning properties of both foam and fiberfill with controlled proportions and controlled geometrical orientations.

Using apparatus of the type shown in FIGURE 1(*b*), polyethylene terephthalate polymer is spun from a spinneret having 20 holes (0.009") at a throughput rate of 25 grams per minute. Air pressure of 40 p.s.i.g. is supplied to the air jet which in turn propels the spun fibers to a velocity of 9,500 ft. per minute. The fibers as they emerge from the jet have a denier per filament of 3.9.

Lanced linear polypropylene foam sheet is used as the apertured structure. It has the following characteristics:

	In.
Sheet thickness	0.45
Length of lanced slots in the relaxed condition	¹¹⁄₁₆
Spacing between successive lanced slots in the direction of the slot	³⁄₁₆
Perpendicular distance between slots (cell wall thickness)	³⁄₃₂
Maximum cell wall thickness at points of cell contact	³⁄₁₆
Sample size	8 x 8

The lanced sheet is tufted while in the stretched configuration so that the cell opening is between ⅛ inch to ¼ inch and the cell shape is hexagonal.

The above apertured structure is passed by hand back and forth under the jet at a distance of 2.0 inches from it, initially with high speed and later with lower speed to produce balled tip tufts. The resulting tufted structure is of the balled tip type with the tuft height ranging from 1.0 inch to 2.0 inches.

EXAMPLE VII

This example illustrates the production of a tufted structure using a set of pinch rolls to propel the yarn directly against the apertured structure.

Using apparatus of the type shown in FIGURE 1*a*, a two-ply twisted 550-denier acrylic staple yarn originating from a cone is led through the nip of two contacting rolls running at a surface speed of 5,400 feet per minute. The yarn emerges from the nip very smoothly in the direction of a straight line mutually tangent to both rolls. A three-mesh, square wire screen is used as the apertured structure and is reciprocated by hand back and forth in a plane perpendicular to the propelled yarn and at a distance of one foot from the nip. The yarn, which has gained momentum purely by the mechanical action of the rolls, penetrates the openings of the screen and forms looped tufts therein as described previously. The tufts are about 0.5 inch long and are twisted 180° at the base due to the relatively high twist already existing in the yarn.

Similar results are obtained using rayon tire cord, and using continuous filament nylon yarn.

EXAMPLE VIII

This example illustrates the production of a tufted structure having dense, discrete, short tufts.

The spinning and propelling conditons of this example are the same as those of Example IV. The apertured structure consists of nylon netting, the cells of which are hexagonal and uniform in size, measuring 0.11 inch between any two parallel walls of the cell. The netting is mounted on a revolving drum at a distance of about 0.3 inch from the stopper screen. The surface velocity of the drum is 550 feet per minute. These conditions normally lead to a tuft height of 0.67 inch but the presence of the stopper screen at a distance of 0.3 inch causes the formation of dense, discrete tufts containing balled-up filaments within the initially-formed tuft loops. The cross-sectional shape of each tuft at its base is hexagonal, corresponding to the shape of the cells of the apertured structure. The filaments in each tuft are shared with those of adjoining tufts in all planar directions of the structure.

EXAMPLE IX

This example illustrates the production of a tufted structure having tufts with balled tips.

The process of Example I is repeated with the exception that the velocity of the filaments is approximately 7,000 feet per minute and that of the apertured structure is approximately 50 feet per minute. The stopper screen is spaced about 0.75 inch away from the apertured structure.

The calculated tuft height under these tufting conditions is about 11 inches but, because the stopper screen is located at a distance of only .75 inch from the apertured structure, the heat-softened filaments buckle severely, curl on themselves and ball-up on impact with the stopper screen. The stopper screen is maintained in contact with the tufts until the heat-softened filaments cool and become set in their buckled configuration. The resulting tufted structure contains tufts having a straight base and dense, balled tips. If a single tuft loop is forcefully removed from the tuft, it is observed to have a length of approximately 11 inches, corresponding to the calculated tuft height.

EXAMPLE X

This example illustrates the manipulation of process variable to form a tufted structure having fleece-like tufts in an apertured structure with rectangular cells and subsequent shrinkage of the tufted structure to produce a rug having dense, discrete tufts.

Using apparatus and spinning conditions of the type described in Example V, the tufting process is carried out as follows:

The apertured structure consists of a woven scrim constructed from 75-denier, 0.001-inch thick post-shrinkable polyethylene terephthalate yarn capable of a linear shrinkage of about 20%. The aperture cross-section is rectangular, having a length of 0.25 inch in the rotational direction of the apertured structure and a width of 0.14 inch. During tufting, the rotational velocity of the apertured structure is first maintained at 1650 feet per minute for a few passes to produce relatively short tufts having a height of approximately 0.8 inch. The velocity of the apertured structure is then decreased to 870 feet per minute in order to produce tufts having a height of 1.5 inch under conditions of free tufting. The initially-formed tuft loops serve as a pocket or "stopper screen," causing the new incident filaments to buckle upon themselves to form a dense mass within the pockets. A small number of the incident fibers penetrate beyond the pockets to form a very low density, fluffy, fur-like layer above the discrete tufts. The basis weight of the tufts produced in this structure is about 6.0 oz./yd.^{2} A thin layer of rubber latex is then applied on the non-tuft side of the structure to bond the tufts more firmly to themselves and to the apertured structure at the base.

A portion of the above tufted structure is then subjected, while the latex is wet, to a steam-relaxation treatment to allow the fiber in both the tufts and the apertured structure to shrink and crimp. The resulting rug-like structure is about 50% smaller in area, has a basis weight of 13 oz./yd.^{2} and uniform, discrete tufts having a tuft height of about 0.4 inch.

EXAMPLE XI

This example illustrates the manipulation of the process variables to form a tufted structure having fur-like tufts, the density of each tuft increasing gradually from the tip towards the base.

Using apparatus and spinning conditions similar to those described in Example V, polyethylene terephthalate polymer is spun from a spinneret having 23 holes (0.009 inch) at a throughput rate of 15 grams per minute. Air pressure of 60 lbs./sq. in. gauge is supplied to the air jet, which in turn propels the spun filaments to a velocity of 8040 feet per minute. The fibers, as they emerge from the jet, have a denier per filament of 2.4 and are capable of a linear shrinkage in steam of 53%.

A scrim constructed from highly shrinkable 150-denier, 0.0015-inch thick polyethylene terephthalate yarn and consisting of square cells (0.165 inch) with one side of the cell oriented in the rotational direction and the other side perpendicular to it, is used as the apertured structure. The scrim yarns are capable of a 56% linear shrinkage in steam.

The velocity of the apertured structure is gradually increased during the run from 630 feet per minute to 1170 feet per minute. This corresponds to the formation of tuft elements varying in height from about 1 inch to 0.5 inch progressively, with the longest tuft loops being formed first. The resulting structure contains tufts which are fluffy and fur-like, the density of each tuft gradually decreasing from the base toward the tip of the tuft.

The resulting tufted structure is removed and an aqueous suspension of rubber latex is applied to the non-tuft side of the structure. While the latex is still wet, the structure is relaxed in a steam bath to shrink and crimp the fibers of both the tufts and the apertured structure. The resulting tufted structures has an area about 80% smaller than the original area and the tufts are dense and uniform. The pile surface has a height of about 0.4 inch and the appearance of dense fur.

EXAMPLE XII

This example illustrates the production of a tufted structure from filaments having a low coefficient of friction.

Using apparatus of the type depicted in FIGURE 2, polytetrafluoroethylene continuous filament yarn, having a totol denier of 400 and consisting of 60 filaments, originating from a cone, is propelled by means of feed rolls to a velocity of 750 feet per minute. An air jet and guides are used to direct the yarn into contact with a rotating apertured structure. The air pressure in the jet is 40 lbs./sq. in. gauge, which is just sufficient to maintain a taut yarn line. The apertured structure consists of a yarn scrim having cells of rectangular cross-section (0.25 inch by 0.15 inch). The cell length is oriented in the rotational direction. The scrim yarns are 75 denier (0.001 inch thick) polyethylene terephthalate yarns, capable of a 20% linear shrinkage in steam. The apertured structure is rotated at a linear speed of 84 feet per minute and is spaced a distance of 1 inch from a stopper screen. During tufting a dilute solution of a pressure-sensitive adhesive is continuously sprayed on the apertured structure to increase the interfacial friction between the tufting filaments and the scrim yarns.

Tufting is continued until all apertures of the scrim have been filled with dense tufts having a tuft height of about 1 inch, each tuft consisting of a plurality of filament loops. Latex is then applied to the non-tufted side and the structure is steam-relaxed to shrink it 20% linearly. The final tufted product has a pile resembling curly hair and having a soft, supple hand similar to that of camel hair or vicuna fur.

EXAMPLE XIII

This example illustrates the production of a tufted structure having two different types of tuft fiber in each and every cell thereof. The two types of tuft fiber are different in their chemical structure and in their physical and geometrical properties as well as in the tuft height and type.

Using the apparatus and the apertured structure described in Example XII, with the apertured structure running at a linear velocity of 342 feet per minute, two different continuous filament yarns, originating from separate cones, are plied together on the run and fed directly through guides and feed rolls to the air jet at a velocity of 1710 feet per minute. One yarn is a brown 50 denier, 7 filament, zero twist continuous filament polytetrafluoroethylene yarn. The other is a white 40 denier, 13 filament, textured nylon continuous filament yarn. A dilute solution of pressure-sensitive adhesive is sprayed continuously on the apertured structure during tufting to increase the interfacial friction between the polytetrafluoroethylene yarns and the scrim yarns. The resulting structure is latexed and steam relaxed as in Example XII and then allowed to dry in an oven at 110° C. The relaxation and drying treatment causes the textured nylon portion of the tuft to crimp and to lose some height while the polytetrafluoroethylene component of the tuft retains its original height of approximately 0.8 inch.

The resulting structure has a dense, fur-like pile with a suppleness and hand intermediate those of the individual yarns. Each tuft consists of a plurality of loops of straight brown polytetrafluoroethylene filaments having a tuft height of about 0.8 inch and curly, fluffy loops of white crimped textured nylon yarn having a tuft height of about 0.5 inch.

EXAMPLE XIV

This example illustrates the tufting of highly bulked, retractable yarn to produce a tufted structure having a pile resembling Persian lamb fur.

Using the apparatus of FIGURE 2, a 70 denier, two-ply, packaged-dyed nylon textured yarn, which is retractable due to its high crimp level, originating from a cone, is propelled by means of feed rolls to a velocity of 5,450 feet per minute. An air jet and guides are used to direct the yarn perpendicularly against the surface of an apertured structure, mounted on a drum rotating at 500 feet per minute. The apertured structure is a scrim constructed from 75 denier (0.001 inch thick) polyethylene terephthalate yarn capable of a 20% linear shrinkage in steam. The cells of the scrim are rectangular (0.1 inch by 0.15 inch) and the scrim is mounted on the drum with the 0.1 inch cell dimension in the direction of rotation. The scrim is spaced 0.5 inch from a stopper screen.

The tufting process is continued to form tufts in all cells of the scrim, each tuft consisting of loops having a tuft height of approximately ½ inch when pulled taut. In the retracted state, the tuft loops are shorter, bulky and very distinct. The tufted structure is then permitted to relax for several hours at room temperature, whereupon the yarn retracts still further producing a pile composed of grossly crimped and curled fibers resembling Persian lamb fur. Basis weight of the structure is 4 oz./yd.^{2}. A portion of the structure is then steam-relaxed whereupon the basis weight is increased to 6 oz./yd.^{2} and the pile surface resembles a dense, tightly curled Persian lamb fur.

EXAMPLE XV

This example illustrates the production of a permanently-backed tufted structure by tufting into an array of parallel blades.

Steel blades (10" x ½" x 1⁄32") are arranged parallel to one another to form a reed-like structure, the aperture of which are narrow slots 7⁄32 inch wide and ½ inch deep. This structure is mounted on a traversing table spaced from the surface thereof. The assembly is traversed at a velocity of 42 feet per minute in a direction perpendicular to the blade length and two feet per minute parallel to it.

A 1300 denier, 68 filament bulked nylon carpet yarn is withdrawn from a cone and propeller by feed rolls to a velocity of 760 feet per minute. A stationary air jet, located 1 inch above the top surface of the apertured structure and supplied with air at 90 lbs./sq. in. gauge, is used to direct the yarn against the apertured structure.

As the apertured structure traverses under the jet, the yarn loops into the spaces between blades to form tufts about 1.7 inches high suspended from the top surfaces of the blades. After several passes, the top surfaces of the blades are substantially covered with yarn segments extending in criss-cross pattern along each blade due to the zig-zag motion of the traversing table. A combing device is then used to move the tufts along the blades to one side of the apertured structure and the tufting and combing steps are repeated three times to produce a very densely tufted final structure.

While still on the aperture structure, the tufts are sheared to a height of about 1 inch and a methylethyl ketone solution of a vinyl chloride/vinyl acetate copolymer is added to the non-pile side to bond the fibers at the base of the tufts. A woven burlap fabric is then laminated to the non-pile side of the structure using a rubber latex adhesive, followed by curing under a pressure of 150 lbs./sq. in. The burlap-backed structure is then manually removed from the array of blades and is observed to be a very high density, rug-like product having a cut pile height of one inch. The base of each tuft is rectangular, corresponding to the dimensions of the aperture slot in which it was formed. The rug-like structure is subsequently handwashed several times with soap and water and tumble dried in an automatic dryer using a "hot" setting without damaging or changing the coherence, strength or appearance of the tufts.

EXAMPLE XVI

This example illustrates the production of a leather-backed tufted structure having a very dense pile resembling lamb's fur.

Following the procedure of Example II, two-component, post-crimpable filaments are spun from polyhexamethylene adipamide and a 50/50 copolymer of polyhexamethylene adipamide and polyhexamethylene sebacamide are propelled against an apertured structure located 1 inch below the air jet.

The aperture structure is a woven fabric constructed from spandex elastomeric yarn and has square apertures ⅛ inch wide in the relaxed state. The fabric is stretched and mounted on a rigid frame thereby increasing the cell size to 0.33 inch. The apertured structure is then passed back and forth beneath the jet at high speed for several passes to form tufts as described previously. The resulting tufted structure is then allowed to relax, whereby the tuft density is increased 7.5 times and the structure has a basis weight of 27 oz./yd.^{2}. A 1⁄16 inch thick synthetic leather substrate is then bonded non-pile side of the structure. The pile surface resembles dense lamb's fur.

EXAMPLE XVII

This example illustrates the production of a tufted structure, having tufts of varying type and height produced simultaneously.

The tufting process is carried out using apparatus of the type shown in FIGURE 1*b*, the spining conditions of Example V, and an apertured structure consisting of 4-mesh polyethylene plastic netting containing rhombic-shaped cell. The netting is mounted against a corrugated stopper screen having 10 corrugations per foot and a maximum corrugation height of 0.5 inch. The distance between the netting and the corrugated stopper screen varies regularly from a minimum of about 0.1 inch to a maximum of about 0.6 inch.

The tufted structure obtained by this process contains parallel rows of short, discrete tufts (approximately 0.1 inch high) containing balled-up filaments within the initially formed loops, the rows being spaced approximately 1.25 inches apart. Laterally of these rows, tuft height and type changes gradually until, at a point midway between any two rows of short tufts, there is a row of fine, fur-like tufts approximately 0.6 inch high.

EXAMPLE XVIII

This example illustrates the production of a tufted structure from a staple fiber roving.

The procedure of Example XVII is repeated except that a 10-mesh wire screen is used as the apertured structure and a loosely twisted roving of 2½-inch staple is used as the tufting strand. The final tufted product is similar in appearance to that of Example XVII.

EXAMPLE XIX

This example illustrates the production of a tufted structure, having tufts of different cross-sectional shape produced simultaneously.

Using apparatus of the type shown in FIGURE 1*b* and the spinning conditions of Example V, tufting is carried out using an apertured structure consisting of a perforated polyethylene molded sheet, having 0.4 x 0.4 inch sqare, 0.2 x 0.7 inch rectangular, and 0.5 x 0.5 x 0.8 inch triangular apertures. A stopper screen is placed 0.5 inch from the apertured structure. The tufted product contains discrete, 0.5 inch high tufts of the balled tip type, each tuft having a square, rectangular or triangular cross-section at its tip and at its base, corresponding to the shape of the aperture in which it was formed.

EXAMPLE XX

This example illustrates the production of a tufted structure using a non-compressible fluid to direct the strands against the apertured structure.

Using guides and feed rolls as shown in FIGURE 2, a 40-denier textured nylon yarn is propelled by the feed rolls to a velocity of 540 feet per minute. The yarn is directed by means of guides to enter the suction inlet on the side of a polyethylene laboratory aspirator jet and emerges from the exit end of the jet. The jet is connected to a 70 lbs./sq. in. tap-water line through a pressure gauge to measure pressure drop across the jet. The jet and water flow characteristics are:

Water inelt (inside diameter)	0.0168″.
Water outlet (inside diameter)	0.25″.
Length of taper (inside diameter)	1.5″.
Length of tail section	3.7″.
Over-all length	5.5″.
Water pressure drop	7.0 p.s.i.
Volume flow rate	6 liters/minute.
Average water inlet velocity	1,395 ft./min.
Average water exit velocity	630 ft./min.
Type of flow	Turbulent.

An 8-mesh wire screen is reciprocated horizontally by hand under the jet at a distance of ½ inch from it. After several passes the tufted structure is removed and found to have a plurality of uniformly distributed tufts protruding from the bottom side of the screen. The reciprocating action of the hand traverse produces a harmonic motion with the velocity being maximum at the center of the stroke and zero at the end of the stroke. The resulting tufts thus vary uniformly in height in the direction of motion of the screen, being approximately 1 inch high at the center and 3 inches high near the edges of the screen.

In addition, it is observed that tufts from several adjoining apertures have become grouped together under the influence of the surface tension of the water. The larger tufts, thus formed, are distributed uniformly over the surface of the screen and remain after drying of the structure. If desired, they may be stabilized in this configuration by applying a binder adhesive after their formation or mixing a binder adhesive with the fluid during their formation, followed by drying. Alternatively, the unstabilized tufts may be loosened by brushing or the like to produce a fluffy pile surface.

EXAMPLE XXI

This example illustrates the manipulation of process variables to increase the maximum possible tuft density in a given apertured structure.

Using the apparatus of FIGURE 2, a 200 denier, 20 filament, trilobal cross-section, continuous filament nylon yarn is propelled by feed rolls to a velocity of 3600 feet per minute. The yarn is led from the feed rolls into a jet of the type described in Example V, supplied with room temperature air at 90 lbs./sq. in. gauge. The yarn emerging from the jet is directed into contact with a rotating apertured structure consisting of a scrim of non-shrinkable nylon yarn, the scrim having cells of rectangular cross-section measuring 0.25 inch in the direction of rotation and 0.11 inch in the other direction. The apertured structure is rotated at a velocity of 240 feet per minute and is spaced 1½ inches from the jet. A stopper screen is spaced 1 inch from the apertured structure.

After several passes it is observed that the yarn has begun to pile up on the scrim surface, thereby inhibiting further tufting. The run is terminated when about 25% of the surface of the scrim is flooded with piled-up yarn. The tufted structure is then removed and found to have a tuft basis weight of 22 oz./yd.^{2}.

The above experiment is then repeated except that superheated steam is admitted to the jet at 90 lbs./sq. in. gauge instead of air. The steam temperature in the insulated line leading to the jet is continuously measured by a thermocouple inserted in the line approximately 2 feet from the jet. The steam temperature is 160° C. at the beginning of the run and 195° C. at the end of the run. The hot steam serves to soften the yarn.

Tufting is continued until a very dense tufted structure is obtained. The run is then terminated arbitrarily even though no flooding has occurred. The resulting tufted structure has a pile height of approximately 1 inch and a tuft basis weight of 30 oz./yd.^{2}. Thus by reducing the modulus of the yarn by heat-softening, tuftability is increased at least 1.5-fold.

EXAMPLE XXII

This example illustrates tufting a single filament and a multifilament strand, respectively, into various apertured structures using a given set of process conditions.

An apparatus consisting of a spinning and propelling unit of the type described in Example V is used to produce 34 filaments having a denier of 3.2 per filament at a throughput rate of 25 grams per minute. The apertured structure is passed back and forth, by hand, under the jet exit at a distance of about 1½ inches from the exit and in a direction perpendicular to the jet. In the first series, the whole ensemble of 34 filaments is passed through a single jet and directed against various apertured structures having different cell sizes and shapes. In the second series, a single filament is passed through the jet and directed against apertured structures having different cell sizes. The apertured structures used are described in the following tables:

Table I.—Series 1—Multifilament strand

Apertured Structure	Cell Shape	Size of Opening (in.)	Cell Wall Thickness (in.) [1]	Ratio of Opening to Wall Thickness
Wire screen	Square	0.033	0.017	1.95
Do	do	0.040	0.023	1.70
Do	do	0.093	0.032	2.90
Do	do	0.270	0.062	4.35
Perforated plate	Circular	0.094	0.094	1.00
Do	do	0.125	0.125	1.00
Do	do	0.156	0.031	5.00
Do	do	0.500	0.188	2.66

[1] In the direction of traverse.

Table II.—Series 2—Single filament

Apertured Structure	Cell Shape	Size of Opening (in.)	Cell Wall Thickness (in.) [1]	Ratio of Opening to Wall Thickness
Wire screen	Square	0.012	0.009	1.33
Do	do	0.014	0.010	1.40
Do	do	0.020	0.012	1.65
Do	do	0.033	0.017	1.95

[1] In the direction of traverse.

In all cases, tufting proceeds continuously illustrating the possibility of utilizing one set of process conditions to produce tufts in various apertured structures. In general, it is observed that the ease of tufting and the tuft density are greater as the ratio of the cell opening to the cell wall thickness increases.

Since many different embodiments of the invention may be made without departing from the spirit and scope thereof, it is to be understood that the invention is not limited by the specific illustrations except to the extent defined in the following claims.

I claim:

1. A process for inserting loops of a continuous filamentary strand through openings of an apertured structure to produce a tufted product without the use of needles which comprises continuously forwarding the strand in an axial direction to travel in a predetermined free path for a distance of at least one inch toward one face of the apertured structure at a velocity (V_y) which provides sufficient inertial momentum to force loops of the strand through openings of the apertured structure, supporting the structure so that a portion to be tufted intercepts said free path of the strand, with the opposite face of the portion out of contact with any surface inserting tuft loops through openings of the structure solely by inertial momentum of the strand, and intercepting said path with successive portions of the structure to produce a series of tufts.

2. A process as defined in claim **1** wherein said path is intercepted with successive portions of the apertured structure by moving the structure at a subsantially constant velocity (V_a) and the strand velocity (V_y) is at least twice velocity (V_a).

3. A process as defined in claim **1** wherein the strand velocity (V_y) is at least twice the velocity (V_a) at which the relative positions of the strand path and the structure are changed, and the path of the strand is traversed over the apertured structure.

4. A process as defined in claim **3** wherein the apertured structure is moved at substantially constant velocity and the path of the strand is traversed to product tufts uniformly throughout the area of the structure traversed.

5. A process as defined in claim **3** wherein the path of the strand is traversed in a programmed manner to produce a pattern of tufts in the apertured structure.

6. A process for forming dense tufts in openings of an apertured structure which comprises treating the structure in a plurality of passes by the process defined in claim **1** to insert tuft loops repeatedly through the tufted openings of said apertured structure, the structure initially intercepting the strand path at a predetermined velocity relative to the strand velocity to form loops of predetermined tuft height and the structure subsequently intercepting at reduced velocity to cause strand loops to curl into a dense mass within the initial loops.

7. A process for forming fur-like tufts in openings of an apertured structure which comprises treating the structure in a plurality of passes by the process defined in claim **1** to insert tuft loops repeatedly through the tufted openings of said apertured structure, the structure initially intercepting the strand path at a predetermined velocity relative to the strand velocity to form loops of predetermined tuft height and the structure subsequently intercepting at increased velocity to form smaller loops within the initial loops.

8. A process for forming tufts with a dense base portion and a fur-like terminal portion which comprises treating the structure in a plurality of passes by the process defined in claim **1** to insert tuft loops repeatedly through the tufted openings of said apertured structure, the structure initially intercepting the strand path at a predetermined velocity relative to the strand velocity to form loops of predetermined tuft height, the structure subsequently intercepting at increased velocity to form smaller loops within the initial loops, and the structure finally intercepting at reduced velocity to cause strand loops to curl into a dense mass within said smaller loops.

9. A process as defined in claim **3** wherein the portion of the apertured structure being tufted is supported over a stopper surface which is spaced from the structure at a distance (H) to control the tuft height by stopping the strand at a uniform distance after passage through the openings of the structure, and said strand velocity (V_y) is at least equal to

$$\left(\frac{2H}{X}+1\right)(V_a)$$

where X is the center-to-center distance between adjacent openings in the apertured structure.

10. A process as defined in claim **9** wherein the strand velocity (V_y) is

$$1.5 \text{ to } 100 \text{ times } \left(\frac{2H}{X}+1\right)(V_a)$$

to cause the strand to buckle against said stopper surface after passing through the openings of the structure.

11. A process as defined in claim **10** wherein the strand is heat-set in said buckled configuration to form tufts having balled-up tips.

12. A process as defined in claim **1** wherein the strand is composed of a thermoplastic material, and is softened by heating to a temperature above room temperature and below the melting point when forwarded against the apertured structure.

13. A process as defined in claim **1** wherein a patterned three-dimensional tufted product is produced by stopping the strand loops against a patterned surface after passage through the apertured structure to produce tufts of varying heights.

14. A process as defined in claim 1 wherein the tuft loops are stopped against a screen spaced from the apertured structure and reduced pressure is provided on the opposite face of the screen.

15. A process as defined in claim 1 wherein the apertured structure is preshaped to a three-dimensional contour to produce a tufted product suitable for use on a contoured surface.

16. A process as defined in claim 1 wherein substantially all openings of the apertured structure are filled with tufts of the strand material.

17. A process as defined in claim 16 wherein a backing layer of strand material is deposited on the face opposite to the tufted face of the apertured structure.

18. A process as defined in claim 17 wherein the strand material comprises low and high melting fibers and the lower melting fibers are subsequently fused to bond the higher melting fibers.

19. A process as defined in claim 1 wherein the apertured structure is an open mesh fabric.

20. A process as defined in claim 1 wherein strands are forwarded simultaneously toward both faces of the apertured structure to insert tuft loops in two directions.

21. A process as defined in claim 1 wherein the apertured structure is shrinkable and the tufted product is shrunk to increase the tuft density.

22. A process as defined in claim 1 wherein the strand material is post-deformable and the tufted product is after-treated to increase the tuft density.

23. A process as defined in claim 1 wherein the openings of the apertured structure are slots formed by generally parallel elements, the strand is applied so as to form tuft loops over the elements, and the elements are subsequently removed from the tufted product.

24. A process as defined in claim 1 wherein the strand is tufted into an apertured structure of generally parallel elements to produce rows of loops suspended from said elements and the tuft density is altered by moving strand loops along the elements after initial formation of tufts.

25. A process for producing a tufted structure, using a temporary apertured support, which comprises forwarding a continuous filamentary strand in an axial direction with a fluid jet toward an apertured support, spaced at least one inch away, to travel in a predetermined free path toward the face of the apertured support at a velocity which provides sufficient inertial momentum to force loops of the strand into openings of the apertured support, intercepting said path of the strand with a portion of the support so as to insert tuft loops in openings of the support solely by inertial momentum of the strand, intercepting said path with successive portions of the support to produce a series of tufts joined at the base by strands on said face of the support, applying a permanent backing layer on the face of the support to hold the bases of the tufts in position, and removing the temporary support to provide a tufted structure having a pile surface on the backing layer.

26. A tufted structure comprising an apertured, tuft-supporting member having filamentary strand loops projecting from openings of the apertured member to form tufts, each tuft being composed of a plurality of strand loops with legs of the loops passing through the opening, the loops inside of the tuft being curled into a dense mass of balled-up filaments within a pocket formed by outer loops.

27. A tufted structure comprising an apertured, tuft-supporting member having filamentary strand loops projecting from openings of the apertured member to form tufts, each tuft being composed of a plurality of strand loops with legs of the loops passing through the opening, the loops inside of the tuft being curled into a dense mass within a pocket formed by short tuft loops which are surrounded by longer loops on the outside of the tuft to provide tufts having a fur-like terminal portion and a dense base portion.

28. A tufted structure comprising an apertured, tuft-supporting member having filamentary strand loops projecting from openings of the apertured member to form tufts, the tufts having balled tips of entangled strands, said loops projecting only from openings originally present in the apertured member, being present in substantially all of said openings which are within a tufted area and, the loops inside of tufts being curled into dense masses which are surrounded by buckled loops on the outside of the tufts.

29. A tufted structure comprising an apertured, tuft-supporting member having filamentary strand loops projecting from openings of the apertured member to form tufts, each tuft being composed of a plurality of strand loops with the legs of the loops passing through the opening, the strand loops being of successively shorter length from the outside to the inside of the tuft to provide fur-like tufts which increase in density from tuft tip to tuft base.

30. A tufted structure comprising an apertured, tuft-supporting member having filamentary strand loops projecting from openings of the apertured member to form tufts, said loops projecting only from openings originally present in the apertured member and being present in substantially all of said openings which are within a tufted area, the two legs of each strand loop separating from each other at the back face of the apertured member opposite the tuft and proceeding in different directions to other tufted openings, there being a plurality of said strands separating in a substantially uniform distribution around each tufted opening.

31. A tufted structure as defined in claim 30 wherein the two legs of each strand loop are free from tangential contact within the tufted openings of the apertured member.

32. A tufted structure as defined in claim 30 wherein substantially all of the tuft-forming strands loop completely into and out of the openings of the apertured member.

33. A tufted structure as defined in claim 30 wherein the back face of the apertured member is free from flooding by tuft-forming strands, i.e., strands passing over an opening rather than contributing to tuft formation at the opening.

34. A tufted structure as defined in claim 30 wherein the tufts have uniform characteristics within each tufted area, the cross-sectional shape of the base of each tuft is geometrically similar to the opening in the apertured member, and the base of each tuft has a greater dimension than the distance between adjacent tufts.

35. A tufted structure as defined in claim 30 wherein strands of each tuft are shared with those forming adjoining tufts in all directions.

36. A tufted structure as defined in claim 30 wherein the tufts have balled-up higher density tips of entangled strands.

37. A tufted structure as defined in claim 30 wherein the tuft tips are thinner and of lower density than the tuft bases, providing a fur-like structure.

38. A tufted structure as defined in claim 30 wherein the tuft heights vary in a three-dimensional pattern.

39. A tufted structure as defined in claim 30 wherein the apertured member has a three-dimensional shaped contour.

40. A tufted structure as defined in claim 30 wherein tuft loops protrude from both faces of the apertured member.

41. A self-supporting unitary tufted structure comprising a permanent backing layer of randomly interlaced continuously filamentary strands, an intermediate apertured tuft-supporting member, and a pile portion of tufts formed by filamentary strands passing through openings of the intermediate member, the tuft strands being con-

tinuous with the backing layer strands and proceeding from each tufted opening to all adjacent tufted openings in all planar directions of the structure.

References Cited by the Examiner

UNITED STATES PATENTS

2,636,460	4/1953	Seiderman	156—72
2,671,494	3/1954	Coulliette	156—435
2,725,835	12/1955	Mather	161—62
2,754,578	7/1956	Groat	161—62
2,900,700	8/1959	Frickert	28—73
3,039,170	6/1962	Marshall	28—1
3,075,867	1/1963	Cochran	156—72
3,078,543	2/1963	Bloch	161—62
3,145,446	8/1964	Sussman	156—72 X

EARL M. BERGERT, *Primary Examiner.*

HAROLD ANSHER, ALEXANDER WYMAN, *Examiners.*