A system for manufacturing pluralities of consecutive sheets bearing successively varying arrangements of design features is disclosed. The system may include a pattern imparting roller having a substantially cylindrical acting surface reflecting features of a design pattern thereon, the design pattern having a machine direction repeat length; and a separating mechanism disposed downstream of the pattern imparting roller, configured to effect repeated and spaced cutting, perforating or scoring along separation lines, between portions of a material web, the separation lines being spaced apart on the web by sheet length measured along the machine direction. The sheet length is less than the design pattern repeat length.
BACKGROUND OF THE INVENTION

[0001] A variety of consumable cleaning products are currently marketed and sold in the form of sheets formed from web material.

[0002] These include, for example, household cleaning products such as dusting wipes, cleaning wipes and paper towels, and personal cleaning products such as bathroom tissue, facial tissue and wet wipes. The sheets may be provided on a continuous roll of a length of web material from which, for example, consecutive individual sheets may be separated by tearing along perforations across the width, and pulled away. The sheets may be provided in a continuous length that is folded in accordion-fashion, and thereby gathered into a consolidated structure resembling a stack, with individual sheets made separable via perforations across the width. The sheets may be provided in stacks of individually pre-cut, stacked sheets from which individual sheets may be drawn consecutively from the top or bottom of the stack. Individual sheets in a stack may be folded and stacked simply, or folded and interleaved to form a stack. In the latter example, interleaving and friction between consecutive sheets may be employed to cause leading sheets, as they are drawn from the stack, to partially draw with them consecutive following sheets, such that, for example, the following sheets are partially drawn through a dispensing opening in the dispenser or container in which the stack is provided and/or stored, for easy access when next needed.

[0003] Such sheet products may be formed of web materials, typically nonwoven web materials, such as webs formed of natural or synthetic fibers, such as cellulose pulp, polymeric fibers or combinations thereof.

[0004] To make them more attractive to the consumer market, manufacturers of such products often impart the web material from which they are formed, with visible features of decorative designs. The features may be imprinted, embossed, molded or imparted by any other means. Embossed or molded features may have x-y dimensions and visibility, but also may have perceptible z dimensions, thereby imparting visible and tactiley perceptible texture to the sheet product. Embossing or molding may be performed in a manner or by a technique that not only imparts the visual aspects of the chosen design, but also enhances characteristics such as sheet loft, absorbency, and/or texture that enhances wiping/cleaning efficacy. Embossing or molding may be done by a variety of techniques including rolling and hydroembossing.

[0005] While a variety of printed, embossed and/or molded designs have been imparted to sheet products, there is always room for improvement in techniques for imparting visual and aesthetic appeal to such products.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] FIG. 1 is a schematic side view of a roller embossing system and a web material.

[0007] FIG. 2 is a schematic side view of a hydroembossing system and a web material.

[0008] FIGS. 3A and 3B are schematic plan views of web material bearing features of a design pattern that repeats within a repeat length RL, with the variation of the design with respect to portions of the web of varying lengths SL between separation lines schematically represented by a sine curve.

[0009] FIGS. 4A-4D are schematic plan views of web material bearing features of a design pattern that repeats within a repeat length RL, with the variation of the design with respect to portions of the web of varying lengths SF between separation lines schematically represented by a sine curve.

[0010] FIG. 5 is a schematic top/plan view of an arrangement such as depicted in FIG. 2, including a view of web material bearing features of a design pattern that repeats along the machine and cross directions within repeat length RL and repeat width RW, with the variation of the design with respect to portions of the web of lengths SL and widths SW between separation lines schematically represented by a sine curve.

[0011] FIGS. 6A and 6B depict plan views of examples of design patterns wherein the pattern repeat lengths are greater than the sheet lengths, and reflecting examples of attributes that minimize the appearance of natural locations for separation lines.

[0012] FIG. 7 depicts a plan view of an example of a design pattern reflecting examples of attributes that minimize the appearance of natural locations for separation lines.

DESCRIPTION OF EXAMPLES

Definitions

[0013] As used in the following description, the following terms are deemed to have the meanings set forth:

[0014] “Associated sheets” means a plurality of sheets that are consecutively: stacked one on top of another, folded, interleaved and stacked one on top of the other, gathered on a roll, or gathered by accordion folding.

[0015] “At least partially separated” applies to and describes two portions of a web material at a location where they are divided by a complete cut, or by a partial cut, perforation or scoring along a separation line, at which the first portion may be separated from the second portion by application of tensile force to the first portion, either without tearing of the web material, or by tearing that propagates along the separation line.

[0016] With respect to features of a repeating design pattern imparted to sheets in a supply, the term “continuous” means that consecutive, congruous portions of the repeating pattern appear on consecutive sheets.

[0017] With respect to features of a decorative design borne by a sheet, wipe or web material, the term “imparting” includes printing the features on the material, impressing the features into the material, embossing the features onto/into the material, or any other technique or process for causing the material to bear visible and/or tactiley-perceptible features of the design.

[0018] “Machine direction,” with respect to a web material undergoing processing in a manufacturing or processing line that includes imparting the material with a design pattern, means generally parallel to the direction in which the material is conveyed through the line in the process(es) that cause the material to be imparted with a design pattern. In the same context, “cross direction” means generally perpendicular to the machine direction.
“Nonwoven web material” means web material formed of fibers that are neither woven nor knitted, including fibers formed of natural or synthetic materials, including but not limited to cellulose fibers, polymer fibers, and combinations thereof.

Sheet” is a portion of a nonwoven material web of one or both of length or width dimensions smaller than the greater length or width dimensions, respectively, of the nonwoven material web.

An “x-y dimension” is a dimension of a sheet or material web measured along a plane approximately defined by the sheet or web when laid and/or extended out flat and lying on a horizontal, planar surface.

“z-direction,” with respect to a material web or sheet, is the direction that is orthogonal to the plane approximately defined by the material web or sheet when laid out flat on horizontal, planar surface.

“Upstream” and “downstream” with respect to disposition of equipment in a manufacturing or processing line, relates to the direction of travel of the item being conveyed and/or processed in the line, with the movement of the item through the line being analogous to the movement of water in a stream.

A “wipe” is a sheet suitable for use in wiping and/or cleaning any surface. Non-limiting examples include skin cleansing wipes, baby wipes, paper towels, bath tissues, facial tissues, and household cleaning and/or dusting wipes.

Without intending to be bound by theory, it is believed, generally, that in a supply of sheets such as wipes bearing features of decorative images or patterns, whether provided in roll form, stack form or other form, variation from one sheet to the next in the supply is more aesthetically pleasing to consumers, than a supply in which the same features are substantially replicated on each sheet. Without intending to be bound by theory, it is believed that variation of the characteristics and/or arrangement of the features so that they are not substantially replicated on, at a minimum, two consecutive sheets in the supply, and more preferably not substantially replicated within greater numbers of consecutive sheets in the supply, is desirable.

It is possible, theoretically, to manufacture a supply of sheets on a roll or in a stack in which each sheet in the supply or a subset series thereof is decorated differently than its predecessor and successor, by simply individually imparting varying design features to successive sheets, using equipment adapted to impart successively varying features. For example, after sheets are manufactured, a first stamp may be used to impart features of a first design to a first sheet; a second stamp may be used to impart features of a second design to a second sheet; and a third stamp may be used to impart features of a third design to a third sheet; and so on, and the sheets may then be gathered on a roll, in a stack, etc. However, such a process would be inefficient and likely prohibitively costly in a competitive market.

For purposes of efficiency, most supplies of sheets bearing design features have the features imparted to the web material used to form the sheets, prior to the time the sheets are cut from the material, or perforations are made, or other means for separating individual sheets are employed. Typically, the design features are imparted by use of a roller or cylinder, e.g., a printing roller, an embossing roller, a hydro-embossing or hydromolding cylinder, etc. For embossing, the roller or cylinder will have an acting surface bearing 3-dimensional features corresponding to the desired design features to be imparted. For roller embossing, the roller or cylinder will be paired with an opposing roller or cylinder, the two meeting at a nip. As the web is passed through the nip, the features of the embossing roller are impressed into the web. For hydro-embossing, a bank or beam of water jets will be positioned adjacent the roller or cylinder, and arranged to direct jets of water toward the cylindrical surface of roller or cylinder. As the web is passed over the roller or cylinder and past the water jets, jets of water therefrom impact the web and urge and displace portions thereof to conform to the 3-dimensional features of the roller, thereby imparting the design features to the web material. Roller embossing is described in, for example, PCT Application Pub. No. WO 2008/107845, and references cited therein. Hydrombossing (also known as hydromolding) is described in, for example, U.S. Pat. App. Pub. No. 2007/0238383, and references cited therein.

Referring to FIG. 1, for example, a web material 10 may be conveyed into and through the nip between a pair of rollers including an embossing, printing or calender roller 100 and opposing roller 101. The roller 100 may have features of a decorative design reflected in lands 100a and depressions 100b, formed on its outer cylindrical surface by etching, machining or other forming technique. As it passes through the nip between rollers 100 and 101, the web material is imparted with printed, molded or embossed features 11 of the decorative design. Opposing roller 101 may be featureless, or may also have features reflecting a design formed on its rolling surface, which may be complementary or cooperative with the features on roller 100.

In another example schematically depicted in FIG. 2, a web material 10 may be rolled over the surface of a rotating hydrombossing drum or cylinder 102. Cylinder 102 may have formed on its outer surface features reflecting a decorative design, in lands 102a and depressions 102b, in the surface. As it contacts the surface of rolling cylinder 102 and travels around therewith, web material 10 may be passed under one or more banks of hydrombossing jets 103 that expel high-energy streams of water 104 at the web material. The streams 104 impinge the fibers of the material, thereby displacing portions of the fibers into the depressions 102b in the surface of the cylinder 102. When at least portions of the fibers remain so displaced following the process, the web material is imparted with hydrombossed features 11 of the decorative design.

The outer surface of roller 100 or cylinder 102 will have radius r. Accordingly, the circumference of the outer surface of roller 100 or cylinder 102 will be 2πr. It will be appreciated, then, that features of any decorative design reflected on the roller or cylinder surface will be imparted to the web material such that the design is repeated on the web material along the machine direction, at least, with each complete rotation of the roller or cylinder. On the web material, the repeat length will be, at most, approximately 2πr, and the repeat frequency will be, at least, approximately 1/2πr along the machine direction. Of course, the design may be created and features arranged on the roller or cylinder such that it repeats more than once about the circumference as well, and thus, has a repeat length RL shorter than 2πr and a frequency greater than 1/2πr along the machine direction.

In addition to a cylindrical roller or drum, a continuous belt adapted to impart features of a decorative design, and adapted to ride on pulleys, may be used for embossing, molding, printing, hydrombossing, etc. In this example, the
design pattern repeat length will be less than or equal to the running length of the belt (i.e., the length of the belt if it were cut along a line perpendicular to the machine direction, and laid out flat).

[0032] Referring to FIGS. 3A and 3B, the changing appearance of a design pattern imparted to a web along an x-axis parallel with the machine direction may be schematically represented by the changing position of a sine curve 200, where the y-axis would be perpendicular with the machine direction. In other words, each y value along the curve 200 corresponds with a particular arrangement of the pattern at a corresponding distance along the x-axis from a starting point. If the design pattern is imparted by use of cylinder or roller with its axis of rotation perpendicular to the machine direction, having outer surface radius r, pattern repeat length RL is necessarily less than or equal to approximately 2πr. The cycle of the sine curve 200 represents a cycle of the repeating design pattern, i.e., the wavelength of the sine curve represents pattern repeat length RL.

[0033] Still referring to FIGS. 3A and 3B, following the printing, embossing, molding hydroembossing or other process imparting features of the design pattern to the web material, the web material may be cut or perforated along separation lines 201 spaced apart by a distance representing the intended length SL of individual sheets 300, and the features of the design pattern through its cycle are continuous across a plurality of the sheets 300. Where SL is selected to be equal to or greater than pattern repeat length RL, features of the design will be substantially replicated on two consecutive sheets 300. This is illustrated by way of example in FIG. 3A, where it can be seen that SL is greater than RL, and each of the depicted consecutive sheets 300 includes more than an entire cycle of the sine curve 200.

[0034] In contrast, where SL is selected to be less than pattern repeat length RL, the design features will not be substantially replicated on two consecutive sheets 300. This is illustrated by way of example in FIG. 3B, where it can be seen that SL is less than RL, and each of any pair of two consecutive sheets 300 bears a differing, less-than-entire-cycle portion of sine curve 200.

[0035] In order to determine the number of sheets of length SL that will be present in a series of consecutive sheets before the pattern on a sheet is replicated by some succeeding sheet, relative the sheet separation lines 201, we first determine RL and SL. Next, we identify the lowest common factor (LCF) which, when multiplied by each of RL and SL, will yield the smallest possible integer in both multiplications. The LCF is the number by which RL and SL may both be multiplied such that the ratio RL/SL may be expressed as a ratio of the smallest possible integers. The integer resulting from the multiplication RL x LCF is the number of sheets N of length SL in a series that will be present in consecutive succession before the begins anew on the next successive sheet, relative the sheet separation lines 201.

[0036] For example, if RL = 100 cm, and SL = 21.5 cm,

the lowest common factor LCF that, when multiplied by both RL and SL, will yield integers for both multiplications is 2, i.e.,

RL x LCF = 100 cm x 2 = 200 cm, and

SL x LCF = 21.5 cm x 2 = 43 cm.

The number 2 is the lowest common factor LCF that, when multiplied by 100 and by 21.5, will yield an integer result (200 and 43, respectively) for each multiplication. Thus, RL/SL = 100/21.5 = 4.6237, and while 200 and 43 are the smallest possible integers that can be used to express the ratio.

[0037] The number of sheets N of length SL that will be present in succession in a series before the pattern is replicated on the next sheet following the series, relative sheet separation lines 201, is the product of RL and LCF, i.e.,

N = RL x LCF.

Thus, in the example above, series number N = 100 cm x 2 = 200. In other words, series number N is the numerator in the ratio of smallest possible integers, 200/43, equal to 100/21.5. The pattern as positioned on a first sheet in a series, relative the sheet separation lines 201, would only be replicated after a series of N = 200 succeeding sheets, i.e., on the 201st sheet.

[0038] LCF is not necessarily a whole number; it can be a fraction. For example, if RL = 100 cm and SL = 10 cm, RL/SL = 100/10, and LCF is 0.10 to yield RL/SL = 1/10, the equivalent ratio of smallest possible integers. In this example, N = 10.

[0039] Further examples in which SL is less than RL are presented in FIGS. 4A-4C.

[0040] In FIG. 4A, the ratio of RL/SL is 4/1. For these values, series number N = 4. In other words, the pattern as positioned on the sheets, relative the sheet separation lines 201, is replicated after a series of 4 sheets.

[0041] In FIG. 4B, the ratio of RL/SL is 2/1. For these values, series number N = 2. In other words, the pattern as positioned on the sheets, relative the sheet separation lines 201, is replicated after a series of 2 sheets.

[0042] In FIG. 4C, the ratio of RL/SL is 3/2. For these values, series number N = 3. In other words, the pattern as positioned on the sheets, relative the sheet separation lines 201, is replicated after a series of 3 sheets.

[0043] In FIG. 4D, the ratio of RL/SL is 10/9. For these values, series number N = 10. In other words, the pattern as positioned on the sheets, relative the sheet separation lines 201, is replicated after a series of 10 sheets.

[0044] To maintain a minimum degree of variation between successive sheets, it may be desired that series number N be no less than a minimum, e.g., no less than 2, more preferably no less than 3, still more preferably no less than 4, and even more preferably no less than 5. Accordingly, to achieve a variation such that, for example, N = 5 or greater, it must be possible to express the ratio RL/SL as a ratio of two integers in which the numerator is 5 or a greater integer. Thus, for example, if RL = 100 cm, to satisfy the condition SF can be any of 20 cm (RL/SL = 5/1); 40 cm (RL/SL = 5/2); 60 cm (RL/SL = 5/3) or 80 cm (RL/SL = 5/4), if N is to be 5. In further examples, if RL = 100 cm, SF can be 5 cm (RL/SL = 20/1); 10 cm (RL/SL = 10/1); 15 cm (RL/SL = 20/3); 19 cm (RL/SL = 10/19); 28.25 cm (RL/SL = 400/113); or 37.34 cm (RL/SL = 5,000/1,867).

[0045] Considering FIG. 4D (in which RL/SL = 10/9, N = 10; and the calculated value of RL/SL = 1.111), it can be seen that as the calculated value of the ratio RL/SL falls below 2, i.e., RL/SL < 2, and approaches 1, individual sheets include an increasing majority of the pattern repeat cycle. Thus, the level of visual differentiation among successive sheets becomes increasingly less substantial, regardless of the value of N. For this reason, it may be desired that the calculated value of the
ratio RL/SL be 2 or greater, or more preferably 3 or greater, even more preferably 4 or greater, or still more preferably 5 or greater. Expressed differently, it may be desired that SL be equal to or less than RL/2, or more preferably equal to or less than RL/3, even more preferably equal to or less than RL/4, or still more preferably equal to or less than RL/5. This feature may be desired by itself, or may be desired in combination with a minimum number for N, as described in the preceding paragraph.

Turning now to FIG. 5, it can be seen that a design pattern as reflected by features of a roller or cylinder 101 or 102, and as those features 11 are imparted to a web material 10, can repeat in both the machine direction MD and the cross direction, and can have a repeat length RL and repeat width RW along those directions, respectively. The schematic example depicted in FIG. 5 shows a design pattern in which RL/SL and RW/SW are each 8/1, and therefore, N=8 in both directions. The arrangement of the design pattern as it changes along each direction, again, can be schematically represented by sine curves 200. It can be appreciated that, depending upon the method of manufacture of the product, consecutive sheets 300 in a series may be cut and gathered into a supply according to their order along the machine direction or the cross direction.

For example, sheets 300a, 300b, 300c, 300d, etc., appearing in succession along the machine direction, may be cut or perforated along machine direction separation lines 201a, and gathered and collected into a supply with consecutive sheets presented according to the same order of succession (or the reverse thereof). As noted above, when the pattern repeat length is measured along the machine direction perpendicular with the axis of rotation of the imparting roller 101 or 102 having outer radius r the pattern repeat length RL is less than or equal to 2πr.

In another method of manufacturing, however, sheets 300e, 300f, 300g, 300h, etc., appearing in succession along the cross direction, may be cut or perforated along machine direction separation lines 201b, and may be gathered and collected into a supply with consecutive sheets presented according to the same order of succession in the cross direction (or the reverse thereof). Thus, the relationships between pattern repeat length RL, sheet length SL, and series number N, discussed above, can be applied also in the cross direction, wherein the same relationships exist between pattern repeat width RW, sheet width SW, and series number N (along the cross direction). A roller 101 or cylinder 102 will have a fixed axial acting length along which it bears features adapted to impart features of the selected design pattern to the web material. Therefore, the pattern repeat width RW is, at most, less than or equal to that axial acting length.

It will be appreciated that the designations of sheet length and width with respect to machine direction and cross direction herein are arbitrary, and can be interchangeable.

FIG. 5 reflects a design pattern that has design elements that are discontinuous in both the machine direction and cross direction. It is formed by series of discrete, individually identifiable design elements separated by linear pathways of substantially unadorned space between them. These pathways are arranged in the machine and cross directions. Separation lines 201a, 201b may be arranged along these pathways. It may be appreciated that a web bearing such a pattern may, most preferably, be cut into sheets along separation lines located in these unadorned pathways as suggested in FIG. 5. to cause discrete design elements to be approximately centered and appear balanced and/or symmetrical on the sheets, and/or to avoid dividing the discrete design elements, compromising their aesthetic appeal and/or creating a haphazard appearance in the separated sheet products. In order to maintain the centered, symmetrical and/or balanced locations of the discrete design elements relative the separation lines, it may be necessary to implement a system and method for maintaining alignment of the pattern relative the cutting/separating equipment, such as a registration system. A registration system may add complexity and cost to the manufacturing line.

However, another feature that may be imparted to a design pattern in combination with a repeat length in the machine or cross direction greater than sheet length or width, which may further include any of the mathematical relationships described above, is that the pattern may be composed and arranged such that there are no apparently natural pathways for the locations of separation lines. Examples of such patterns on portions of web are depicted in FIGS. 6A and 6B, shown with possible (but not necessarily preferred) locations of separation lines 201 superimposed thereon. Assuming that the patterns of FIGS. 6A and 6B are imparted to a web by using similar patterned cylindrical roller or drum, or a continuous belt, it can be appreciated from FIGS. 6A and 6B that the patterns of the depicted examples have machine direction repeat lengths that are greater than the sheet lengths SL of individual sheets. As suggested in the figures, a pattern may be configured to change in content and arrangement of particular design elements thereof, along one or both of machine direction MD and cross direction CD, and along its repeat length, such that consecutive individual sheets defined by separation lines 201 will have varying appearances, regardless of the particular locations of the separation lines. At the same time, the pattern may be configured such that there is no apparent natural line of demarcation between design elements (or groups or combinations of them) for a location of a separation line. Granting that individual perceptions may be subjective, the general result is that individual sheets are less likely to be perceived as having a haphazard appearance because of a perceived off-center, asymmetrical or unbalanced location of a design element relative the separation lines, regardless of where separation lines fall relative the pattern.

One way this may be accomplished is to arrange the pattern and its design elements such that there is no linear, continuous pathway along the pattern, along either or both the machine and cross directions, that is substantially devoid of adornment. In other words, regardless of the location at which a line is struck along the web in either or both the machine and cross directions, it necessarily crosses a design element at one or more locations along the pattern repeat length. (Herein, “design element" means any discrete visible feature comprising a deposit of ink, or any impression of a feature or image or portion thereof, that is imprinted on or embossed into the web.) It can be seen that the examples of patterns in FIGS. 6A and 6B have this attribute. As a result, there is no apparently natural pathway for the location of a machine direction or cross direction separation line.

Where a design pattern is imparted to a web by use of an embossing or bonding roller, it may be desirable particularly that no such unadorned pathway exists along the cross direction. The absence of such a corresponding pathway of depression between lands on the surface of an embossing roller may help reduce or eliminate periodic, abrupt changes
in the forces imposed on the roller surface and transferred through the roller to its axle and/or bearing mechanism, thereby reducing equipment wear and/or the need for shock-absorbing equipment. (Such periodic, abrupt changes in the forces would be caused by periodic changes in embossment pressure when a pathway of depression along the surface of the embossing roller, devoid of lands, extends in the cross direction along the length of the roller surface, and enters and exits the nip as the roller rotates.)

Still, when embossing is done via embossing or bonding roller, where it is desired for aesthetic design or other purposes that the pattern include such machine- or cross-direction unadorned pathways, another attribute that may be imparted to the pattern is to limit the width of such unadorned pathways so that they are not immediately noticeable and/or do not form apparent natural pathways for the location of separation lines. Referring to FIG. 7, for example, the depicted design has an unadorned cross-direction pathway between the depicted superimposed broken lines, oriented parallel to separation lines 201. The pathway has a width APW, in which no portion of a design element is present. It is believed that limiting the width of such a pathway to 7 percent or less, more preferably 5 percent or less, of the dimension of the sheet measured between the separation lines that are parallel to the pathway (in the example depicted in FIG. 7, the ratio APW/SL, expressed as a percentage) is effective for avoiding the appearance of a natural pathway for the location of a separation line, i.e., a division between sequential shorts. Where the design is imparted to the web by use of an embossing roller, limiting the width of a cross-direction unadorned pathway may also serve to minimize equipment wear from periodic abrupt changes in embossing pressure, as described above.

Referring again to FIGS. 6A and 6B, another attribute that may be imparted to a pattern to avoid giving individual sheets a haphazard appearance is to arrange series of substantially identical design elements along lines such as, for example, lines AL, that are neither perpendicular nor parallel with the machine and cross directions. It can be seen that this attribute has been imparted to at least portions of the patterns in the examples depicted in FIGS. 6A and 6B. It may be preferred that lines such as lines AL form angles with the machine direction between 10 degrees and 80 degrees, more preferably between 20 degrees and 70 degrees, even more preferably between 30 degrees and 60 degrees, and most preferably between 40 degrees and 50 degrees, for example, 45 degrees.

When a design pattern includes any realistic or fanciful image of all or a portion of a person, animal, anthropomorphic character or cartoon character, which image includes at least the head and/or face, another attribute that may be imparted to the pattern to avoid giving individual sheets a haphazard appearance is to limit the size of the image. It is believed that such an image is effectively limited in size when a rectangle drawn with its sides parallel to the machine and cross directions, and circumscribing the image in its congruous entirety, occupies no more than 10 percent of the area of the sheet as established by the separation lines. For example, the pattern depicted in FIG. 6A includes fanciful images of a bird, a giraffe and an elephant, each of which includes a head and/or face. None of the respective circumscribing rectangles CR drawn along the machine and cross directions occupies an area greater than 10 percent of the individual sheet area (SW x SL). Hence, the size of such an image measured as described is designated its “Occupied Rectangular Area.” It is believed that, where the image has an Occupied Rectangular Area that is no more than 10 percent of the sheet area for any particular such image present in the pattern, the likelihood that the sheet on which it partially or entirely falls will be perceived as haphazardly cut with respect to the pattern is greatly reduced. Such a size limit will be even more effective if it is less than 10 percent, for example, 8 percent, 6 percent or even 5 percent.

Thus, the design pattern may be configured such that separation lines may be spaced and located partially or completely independently of the dimensions of the pattern, reducing or eliminating the need for use of a registration system or other system for maintaining alignment of the pattern relative to the separation lines.

The following non-limiting examples of combinations of system features are contemplated:

1. A system for manufacturing pluralities of consecutive sheets bearing successively varying arrangements of design features, comprising:

2. a pattern imparting roller having a radius r, a rotation axis, an outer circumference 2πr, and a substantially cylindrical acting surface reflecting features of a design pattern thereon, a machine direction tangent to the acting surface and perpendicular to the rotation axis, and a cross direction parallel to the rotation axis, the acting surface having an axial acting surface length AL measured along the cross direction, the design pattern having a machine direction repeat length RLM; and

3. a separating mechanism disposed downstream of the pattern imparting roller, configured to effect repeated and spaced complete cutting, or repeated and spaced partial cutting, perforating or scoring along separation lines, between portions of a material web, the separation lines being spaced apart on the web by sheet length SL measured along the machine direction,

4. wherein SL is less than RLM; and

5. wherein the design pattern has one or more of the following attributes:

6. the design pattern has no linear, continuous unadorned pathway along the cross direction that has a pathway width greater than 7 percent of SL;

7. the design pattern includes series of similarly-shaped design elements along lines that are neither perpendicular nor parallel with the machine and cross directions; and

8. any image in the design pattern of all or a portion of a person, animal, anthropomorphic character or cartoon character including at least a head and/or face of the same, has an Occupied Rectangular Area of no more than 10 percent of the average sheet area.

9. The system of combination 1 wherein the repeat length RLM is less than or equal to 2πr, and the separation lines are perpendicular to the machine direction.

10. The system of either of combinations 1 or 2, wherein the value RLM/SL expressed as a ratio of lowest possible integers has a numerator of 4 or greater.

11. The system of combination 3, wherein the value RLM/SL expressed as a ratio of lowest possible integers has a numerator of 5 or greater.

12. The system of combination 1, wherein the calculated value of RLM/SL is equal to or greater than 3.
6. The system of combination 1, wherein the calculated value of RLM/SL is equal to or greater than 4.

7. The system of combination 3, wherein the calculated value of RLM/SL is equal to or greater than 3.

8. The system of combination 7, wherein the calculated value of RLM/SL is equal to or greater than 4.

9. A system for manufacturing pluralities of consecutive sheets bearing successively varying arrangements of design features, comprising:

- a pattern imparting roller having a radius \( r \), a rotation axis, an outer circumference \( 2\pi r \), substantially cylindrical acting surface reflecting features of a design pattern thereon, a machine direction tangent to the acting surface and perpendicular to the rotation axis, and a cross direction parallel to the rotation axis, the acting surface having an axial acting surface length \( AL \) measured along the cross direction, the design pattern having a cross direction repeat length \( RLC \); and

- a separating mechanism disposed downstream of the pattern imparting roller, configured to effect spaced complete cutting, or spaced partial cutting, perforating or scoring, along separation lines, between portions of a material web, the separation lines being spaced apart on the web by sheet length \( SL \) measured along the cross direction,

wherein \( SL \) is less than \( RLC \); and

wherein the design pattern has one or more of the following attributes:

- the design pattern has no linear, continuous unadorned pathway along the machine direction that has a pathway width greater than 7 percent of \( SL \);

- the design pattern includes series of similarly-shaped design elements along lines that are neither perpendicular nor parallel with the machine and cross directions; and

- any image in the design pattern of all or a portion of a person, animal, anthropomorphic character or cartoon character including at least a head and/or face of the same, has an Occupied Rectangular Area of no more than 10 percent of the average sheet area.

10. The system of combination 9 wherein the repeat length \( RLC \) is less than or equal to \( AL \), and the separation lines are parallel to the machine direction.

11. The system of either of combinations 9 or 10, wherein the value \( RLC/SL \) expressed as a ratio of lowest possible integers has a numerator of 4 or greater.

12. The system of combination 11, wherein the value \( RLC/SL \) expressed as a ratio of lowest possible integers has a numerator of 5 or greater.

13. The system of combination 9, wherein the calculated value of \( RLC/SL \) is equal to or greater than 3.

14. The system of combination 13, wherein the calculated value of \( RLC/SL \) is equal to or greater than 4.

15. The system of combination 11, wherein the calculated value of \( RLC/SL \) is equal to or greater than 3.

16. The system of combination 15, wherein the calculated value of \( RLC/SL \) is equal to or greater than 4.

The dimensions and values disclosed herein are not to be understood as being strictly limited to the exact numerical values recited. Instead, unless otherwise specified, each such dimension is intended to mean both the recited value and a functionally equivalent range surrounding that value. For example, a dimension disclosed as “40 mm” is intended to mean “about 40 mm”.

Every document cited herein, including any cross referenced or related patent or application is hereby incorporated herein by reference in its entirety unless expressly excluded or otherwise limited. The citation of any document is not an admission that it is prior art with respect to any invention disclosed or claimed herein or that it alone, or in any combination with any other reference or references, teaches, suggests or discloses any such invention. Further, to the extent that any meaning or definition of a term in this document conflicts with any meaning or definition of the same term in a document incorporated by reference, the meaning or definition assigned to that term in this document shall govern.

While particular embodiments of the present invention have been illustrated and described, it would be obvious to those skilled in the art that various other changes and modifications can be made without departing from the spirit and scope of the invention. It is therefore intended to cover in the appended claims all such changes and modifications that are within the scope of this invention.

1. A system for manufacturing pluralities of consecutive sheets bearing successively varying arrangements of design features, comprising:

- a pattern imparting roller having a radius \( r \), a rotation axis, an outer circumference \( 2\pi r \), and a substantially cylindrical acting surface reflecting features of a design pattern thereon, a machine direction tangent to the acting surface and perpendicular to the rotation axis, and a cross direction parallel to the rotation axis, the acting surface having an axial acting surface length \( AL \) measured along the cross direction, the design pattern having a machine direction repeat length \( RLM \); and

- a separating mechanism disposed downstream of the pattern imparting roller, configured to effect repeated and spaced complete cutting, or repeated and spaced partial cutting, perforating or scoring along separation lines, between portions of a material web, the separation lines being spaced apart on the web by sheet length \( SL \) measured along the machine direction,

wherein \( SL \) is less than \( RLM \); and

wherein the design pattern has the following attributes:

- the design pattern has no linear, continuous unadorned pathway along the cross direction that has a pathway width greater than 7 percent of \( SL \);

- the design pattern includes series of similarly-shaped design elements along lines that are neither perpendicular nor parallel with the machine and cross directions; and

- any image in the design pattern of all or a portion of a person, animal, anthropomorphic character or cartoon character including at least a head and/or face of the same, has an Occupied Rectangular Area of no more than 10 percent of the average sheet area.

2. The system of claim 1 wherein the repeat length \( RLM \) is less than or equal to \( 2\pi r \), and the separation lines are perpendicular to the machine direction.

3. The system of claim 1, wherein the value \( RLM/SL \) expressed as a ratio of lowest possible integers has a numerator of 4 or greater.

4. The system of claim 3, wherein the value \( RLM/SL \) expressed as a ratio of lowest possible integers has a numerator of 5 or greater.
5. The system of claim 1, wherein the calculated value of RLM/SL is equal to or greater than 3.

6. The system of claim 1, wherein the calculated value of RLM/SL is equal to or greater than 4.

7. The system of claim 3, wherein the calculated value of RLM/SL is equal to or greater than 3.

8. The system of claim 7, wherein the calculated value of RLM/SL is equal to or greater than 4.

9. A system for manufacturing pluralities of consecutive sheets bearing successively varying arrangements of design features, comprising:

   a pattern imparting roller having a radius \( r \), a rotation axis, an outer circumference \( 2\pi r \), a substantially cylindrical acting surface reflecting features of a design pattern thereon, a machine direction tangent to the acting surface and perpendicular to the rotation axis, and a cross direction parallel to the rotation axis, the acting surface having an axial acting surface length AL measured along the cross direction, the design pattern having a cross direction repeat length RLC; and

   a separating mechanism disposed downstream of the pattern imparting roller, configured to effect spaced complete cutting, or spaced partial cutting, perforating or scoring, along separation lines, between portions of a material web, the separation lines being spaced apart on the web by sheet length SL measured along the cross direction,

   wherein SL is less than RLC; and

   wherein the design pattern has the following attributes:

   the design pattern has no linear, continuous unadorned pathway along the machine direction that has a pathway width greater than 7 percent of SL;

   the design pattern includes series of similarly-shaped design elements along lines that are neither perpendicular nor parallel with the machine and cross directions; and

   any image in the design pattern of all or a portion of a person, animal, anthropomorphic character or cartoon character including at least a head and/or face of the same, has an Occupied Rectangular Area of no more than 10 percent of the average sheet area.

10. The system of claim 9 wherein the repeat length RLC is less than or equal to AL, and the separation lines are parallel to the machine direction.

11. The system of claim 9, wherein the value RLC/SL expressed as a ratio of lowest possible integers has a numerator of 4 or greater.

12. The system of claim 11, wherein the value RLC/SL expressed as a ratio of lowest possible integers has a numerator of 5 or greater.

13. The system of claim 9, wherein the calculated value of RLC/SL is equal to or greater than 3.

14. The system of claim 13, wherein the calculated value of RLC/SL is equal to or greater than 4.

15. The system of claim 11, wherein the calculated value of RLC/SL is equal to or greater than 3.

16. The system of claim 15, wherein the calculated value of RLC/SL is equal to or greater than 4.

* * * * *