Title: METHODS FOR CREATING AND CUTTING SHEET MATERIALS

Abstract: A preprinted sheet (12) is caused to advance along a predetermined path passing through one or two creasing machines (30, 60) which in succession place two arrays of straight creases (17, 18) on the sheet, producing a grid of crease lines in two perpendicular directions. The crease lines are placed at predetermined distances with respect to reference points (16) located on the sheet, for example reference marks printed on one surface of the sheet. The reference points are detected by optical devices (50) operatively associated with corresponding orientation devices (40) which correctly orientate the sheets in transit towards the creasing machines. Finally a cutting machine (90) cuts the edges or other parts of the sheet (12) using reference points already used to form the crease lines. In this way the cuts are made with absolute accuracy with respect to the crease lines.
Methods for creasing and cutting sheet materials

Technical field

This invention relates to the processing of sheets of cardboard, paper and similar materials. In particular, the invention relates to the creasing and cutting of sheets and cardboard into complex shapes.

Prior art

Creasing and cutting are mainly effected using automated presses known as die cutting machines. These machines use a flat die comprising one or more blades or having a cutting profile which reproduces a particular shape. Non-cutting blades known as creasing blades, which bring about localised crushing of the cardboard so that it can be subsequently folded along specific lines, can also be inserted into the die.

A die of the abovementioned type has a high production rate when making identical cuts, but carries high costs. In the cardboard technology sector the advent of digital pressing has appreciably increased the requirement for pressing small quantities in each production run. It is therefore appropriate to abandon high processing speed and pay more attention to greater machine flexibility for quickly changing production from one format to another. It is also desirable to eliminate the cost of the die; in fact with small production runs the cost of the die has a substantial effect on the cost of pressing an individual sheet.

The creases obtained using a die inevitably bring about two-dimensional or diagonal shortening of the sheet, which is uncontrollable and difficult to calculate accurately in advance. Diagonal deformation of the sheet has the result that successive cutting of the sheet after creasing is not carried out with high accuracy with respect to the crease lines.

Digital cutting and creasing machines using laser technology have recently appeared on the market. These machines have produced cardboard technology products in particularly complex and personalised shapes in short production runs, for example cardboard
packaging or labels having internal cut-outs. The creases obtained using laser technology are produced by burning a groove into one surface of the sheet, creating weaknesses in the sheet which may be undesirable. In addition to this, laser technology is effective in producing creases in relatively thin sheets of cardboard, but does not yield optimum results over a specific cardboard weight.

Creasing machines having a pair of backing rotating cylinders which have corresponding matching male/female creasing dies of polymerisable material, through which the individual sheets which have to be creased are passed, are also known. The creases obtained with rotating cylinder machines of this type suffer distortion in a “diagonal” direction, that is having both a longitudinal and a transverse component. In addition to this these machines have a dead time, which it is desirable to eliminate or at least reduce, to allow the creasing dies to polymerise.

Finally, stack creasing machines and rotary creasing machines which produce straight creases quickly and economically are known.

Summary of the invention

A first object of this invention is to provide creases in sheet materials which can then undergo a subsequent cutting operation carried out accurately with respect to the creases.

Another object of this invention is to carry out creasing operations quickly and economically. It is also desirable that creasing operations be carried out flexibly, that is with the possibility of quickly changing to the production of different formats.

These and other objects and advantages, which will be better understood herein after are accomplished, according to one aspect of the invention, through a method as defined in the appended claims.

To sum up, a preprinted sheet is caused to advance along a predetermined path, passing through one or two creasing machines that impart two sets of straight creases on the sheet
in succession, producing a pattern of crease lines in two perpendicular directions. The crease lines are spaced at predetermined distances with respect to reference points located on the sheet, for example reference points along their edges and reference marks printed onto one surface of the sheets. The reference marks are detected by optical devices operatively associated with corresponding orientation devices. The orientation devices correctly orientate the sheets as they travel towards the creasing machines. Finally a laser machine cuts the edges or other parts of the sheet, using reference points already used to form the crease lines as reference points. In this way the cuts are made with absolute accuracy with respect to the crease lines.

Brief description of the drawings

Some preferred but not limiting embodiments of a method according to the invention will now be described. Reference will be made to the appended drawings in which:

Figures 1 and 2 are perspective views diagrammatically illustrating a first embodiment of a method for processing sheet materials;

Figure 3 is a diagrammatical perspective view of some elements which may be used as devices to orientate a sheet in some embodiments of the method;

Figures 4 and 5 are diagrammatical lateral views of the components in Figure 3, illustrated at two successive times;

Figure 6 is a perspective view diagrammatically illustrating a second embodiment of a method for the processing of sheet materials;

Figures 7 and 8 are perspective views diagrammatically illustrating a third embodiment of the method;

Figure 9 is a diagrammatical perspective view illustrating a sheet of material bearing creases and reference marks for forming them;

Figures 10 and 11 are diagrammatical lateral views of two successive operating stages in which creases are produced in a sheet of the type illustrated in Figure 9; and

Figures 12 and 13 are perspective views diagrammatically illustrating a fourth embodiment of the method.
Detailed description

With reference initially to Figures 1 and 2, some of the components of a set of machines for creasing and cutting sheet materials are illustrated. A first creasing machine 30, a second creasing machine 60 and a processing machine 90 for cutting sheets are shown diagrammatically in succession.

Preferably, the processing machine 90 (or sheet cutting machine) is a laser processing machine. The choice of using a laser machine for cutting the sheets is an advantage, but should not be construed as limiting the implementation of this method.

The two creasing machines impart a first array of parallel creases in a given direction and a second array of creases perpendicular to that given direction respectively on a sheet, thus producing a grid of sheet lines according to a predetermined pattern. After creasing, the laser processing machine makes cuts of complex shapes around the sheet and optionally cuts within the sheet and/or creases in directions different from those of the creases made by the two creasing machines.

This method is not limited to use on paper and cardboard, but may also find useful application in the processing of sheets of other materials, such as for example leather, fabrics, rubbers, plastics, etc.

Creasing machines 30, 60 and cutting machine 90 together determine a path for the advancement of sheets 12. The path starts at an upstream station where there is provided a sheet feeder 11 which takes one sheet 12 at a time from the top of a stack 13 of preprinted sheets of card or cardboard and transfers the sheet to a conveyor system 21, 22, 25, 26. The conveyor system is used to transfer the sheets one at a time from sheet feeder device 11 to a final station where processing machine 90 is located.

In accordance with the embodiment shown in Figures 1 and 2, the conveyor system defines an L-shaped path for the sheets in which a first straight section extending in a first direction A is followed by a second straight section extending in a second direction B
perpendicular to the first direction.

Each sheet 12 has a leading edge 14 and a top surface or upwardly facing surface 15 on which marks diagrammatically represented by 16 or other reference marks may be printed. These reference marks may be used to determine the precise position and orientation of the sheet, so that creasing and subsequent cutting may be performed as explained above. The term “leading” used here to define edge 14 refers to first direction A in which the sheets advance. Terms such as “longitudinal” or “transverse” will be interpreted with reference to the instantaneous direction of advancement of the sheet.

In the embodiment of Figures 1 and 2 a belt conveyor system comprising a plurality of successive parallel motor-driven belts is illustrated. As an alternative, a roller conveyor system providing a plurality of motor-driven rubber-coated rollers or a mixed conveyor system with rollers and belts may be used. The conveyor system illustrated comprises a first set 21 of motor-driven parallel belts extending in first direction A, circulating in transversely spaced parallel planes. The first set of conveyor belts receives one sheet 12 at a time from sheet feeder device 11 and causes it to advance in first direction A towards first creasing machine 30 which imparts a first array or plurality of straight parallel creases 17 (Figure 2) on each arriving sheet 12. The crease lines 17 in the first array are spaced apart in first direction A, and extend parallel to leading edge 14 of the sheet.

Creasing machine 30 in the embodiment illustrated is a stack creasing machine, which is in itself known, comprising a straight blade 31 extending perpendicularly to the first direction and operated vertically by a linear activator 32. Blade 31 acts together with a lower backing blade 33 having an upwardly facing straight groove 34 extending perpendicularly to the first direction. A roller creasing machine which is in itself known (not illustrated) may be used as an alternative to a stack creasing machine.

Immediately upstream of creasing machine 30 there is an orientation device 40 which acts to orientate sheet 12 arriving at creasing machine 30 in relation to a predetermined direction. The orientating device causes the sheet to rotate in a horizontal plane, if necessary, through an angle which is determined individually for each sheet so that the
sheet may be accurately orientated with respect to creasing machine 30.

Orientating device 40 includes two motor-driven rollers 41, 42, which may be operated independently of each other and which are spaced apart in a transverse direction with respect to the first direction. Motor-driven rollers 41, 42 are respectively able to rotate with respect to two parallel or coinciding axes which are transverse with respect to the first direction of advancement. The two motor-driven rollers are configured so as to roll on one surface of sheets 12 (in this embodiment the lower surface, not illustrated) advancing towards creasing machine 30.

Each of the two motor-driven rollers 41, 42 acts together with a corresponding backing roller 43, 44 mounted so as to move vertically and resiliently stressed towards the corresponding motor-driven roller. The two backing rollers 43, 44 are intended to roll on upper surface 15 of sheets 12 advancing towards creasing machine 30 so as to hold the transiting sheets in contact with both motor-driven rollers 41, 42 before the sheets reach the creasing machine.

Motor-driven rollers 41, 42 are each controlled in rotation by a corresponding electric motor 47, 48, preferably a stepping electric motor. Each electric motor may be controlled individually and be driven in a different way from the electric motor driving the other motor-driven roller, so as to produce differential advancement between two transversely spaced zones on the same sheet 12, and therefore rotate the sheet through a desired angle in the horizontal plane.

Differential control of the two electric motors may be brought about in different ways, in order to produce desired rotation of a sheet. For example, each electric motor may be suitably stopped or driven in a differential way with respect to the other electric motor. In one possible embodiment rotation of the sheet in the horizontal plane may be brought about by stopping one of the two electric motors, and therefore one of the motor-driven rollers, while the other electric motor continues to rotate through a specified angle. In this way the sheet is held stationary on one side, while on the opposite side it is still caused to advance through a specified distance. As an alternative, the direction of rotation of one of
the two motors may be reversed so as to cause part of the sheet to move backwards while
the opposite side of the sheet is held stopped (stopping the motor and the corresponding
roller) or caused to advance in a controlled way. In a different embodiment, one of the two
electric motors may be slowed or accelerated with respect to the other electric motor in
such a way as to make two transversely spaced parts of the same sheet advance (or move
backwards) in a differential way, with consequent rotation of the sheet through a specified
angle.

Backing rollers 43, 44 may be idling rollers or independently motor-driven rollers, or
rollers drawn in rotation by the corresponding motor-driven roller, or by means of a
transmission, for example a gear transmission.

According to the embodiment illustrated in Figures 1 and 2, detection devices capable of
detecting the advancement of a sheet in two transversely spaced positions on the sheet may
be provided.

In the embodiment in Figures 1 and 2, two encoders 49, 59, with corresponding wheels 45,
46 in contact with the sheet are used as devices for detecting advancement. The two
encoders are preferably mounted adjacent to each motor-driven roller 41, 42, and more
preferably immediately upstream therefrom.

Immediately upstream of creasing machine 30 there is provided an optical detection device
50 to detect the angular orientation, in a horizontal plane, of sheet 12 arriving at creasing
machine 30.

According to an embodiment, optical detection device 50 comprises two photocells (or
other equivalent photodetectors), one 51 on the right and one 52 on the left, transversely
spaced with respect to the first direction of advancement. As an alternative optical
detection device 50 may comprise a television camera or a photographic camera.

The two photocells 51, 52 are used to
- detect the positions of two respective transversely spaced points on leading edge 14
of sheet 12 in transit towards creasing machine 30; or
- detect the positions of two transversely spaced reference marks 16a, 16b on the sheet 12.

The two reference marks 16a and 16b are sufficiently apart from each other to allow the orientation of the sheet to be checked. In other words they are sufficiently far apart to make it possible to check whether leading edge 14 of the sheet is perpendicular to direction of advancement A of the sheet towards first creasing machine 30.

In the examples illustrated herein, reference marks 16 are printed on upwardly facing surface 15 and optical detection device 50 is located above the path of the sheets. As an alternative, reference marks 16 may be printed on the underside of the sheets and the optical detection device may be located beneath the path of the sheets.

Rotational movements of the two motor-driven rollers 41, 42 are controlled through commands passed to motors 47, 48 from an electronic processing unit (not illustrated) - typically a PLC or Programmable Logic Controller or PC (Personal Computer) - which supervises the operation of all the other motor/actuator components described here. In particular the electronic control and processing unit is intended to
- acquire signals indicating the positions of two transversely spaced points along leading edge 14 of a sheet, or two reference marks 16a, 16b on sheet 12, by optical detection device 50;
- process the signals received by optical detection device 50 and generate an item of data indicating the instantaneous angular orientation of sheet 12 with respect to a given direction, for example with respect to first direction A;
- on the basis of the angular orientation data, generate a corresponding signal correcting differential advancement in order to produce differential advancement between two transversely spaced zones of the same sheet 12 and therefore rotate the sheet through a desired angle in the horizontal plane;
- send the correction signal to at least one of motors 47, 48 to control the rotation of at least one of the two motor-driven rollers 41, 42 and consequently produce differential advancement between two transversely spaced zones in the same sheet 12, and therefore
rotate the sheet through a desired angle, bringing about rotation of sheet 12 in the horizontal plane such as to align the said two points on the leading edge or the said two reference marks perpendicularly to aforesaid given direction A, that is parallel to the blade of first creasing machine 30;
- acquire advancement signals from encoders 45, 46 to detect the advancement of sheet 12 in two transversely spaced positions on the sheet; and
- check from the advancement signals generated by encoders 45, 46 that a differential advancement has in fact been imparted on the sheet between two transversely spaced zones on the same sheet 12 in accordance with the correction signal.

As illustrated in Figures 3, 4 and 5, the system controlling the advancement of sheet F with the addition of an encoder and its wheel 45 eliminates adjustments and corresponding wastage, always ensuring that the distance travelled by sheet 12 is monitored, independently of all geometrical and consistency variables between the various sheets.

Rollers 41, 43 which form part of the same pair of backing rollers are resiliently stressed upwards with a fixed pressure appropriate to the advancement of sheets 12. Wheel 45 of the encoder is resiliently stressed against sheet 12 with a fixed minimum pressure sufficient not to cause wheel 45 to slip as sheet 12 advances. If sheet 12 has variations in thickness, shown diagrammatically as 12a in Figure 5, these cause a variation in the radii R and R1 of rollers 41, 43, or slippage between these two rollers. Wheel 45 of the encoder is not affected by such variations in thickness and therefore determines the precise distance travelled by sheet 12, and through corresponding encoder 49 sends the distance data to the processor (PLC). The latter compares the distance data measured with preset theoretical data and varies the rotation speed of rotor 47 connected to resolver 58. As a consequence, rollers 41 and 43 proceed with variable controlled motion, rending the travel of sheets which differ from each other the same, regardless of the presence of any local variations in thickness.

A unit for monitoring advancement of the type illustrated in Figures 3-5 may also be applied in a different technical context from the methods described here, for example to adjust the orientation of a sheet of material which has to undergo any form of cardboard technology processing, and therefore not necessarily to produce a pattern of perpendicular
creases. The monitoring unit acts to bring about differential advancement between two transversely spaced zones of the same sheet as it advances in a conveyor system, and therefore rotation of the sheet through a desired angle in the horizontal plane. According to an embodiment, the unit comprises:

- two motor-driven rollers 41, 42 which rotate with respect to two parallel or coincident axes running transversely with respect to the direction in which the sheets are caused to advance, and spaced apart in a transverse direction;
- two electric motors, which may be controlled independently of each other, to drive the respective motor-driven rollers in rotation; and preferably for each motor-driven roller, a corresponding encoder 49, 59 which rotates as one with a wheel capable of rolling on the sheets in positions which are respectively longitudinally aligned with the motor-driven rollers.

Reference number 22 indicates a second plurality of motor-driven parallel belts extending in first direction A which run in transversely spaced parallel planes. The second set of conveyor belts receives individual sheets 12 which have passed through creasing machine 30 and causes them to advance in first direction A to a straight stop edge 23. Edge 23 extends perpendicularly to first direction A and parallel to second direction B, into which sheets 12 are deviated after they have reached edge 23.

Edge 23 is located in the station intermediate between the two creasing machines where sheet 12 undergoes a deviation in travel.

Numeral 53 indicates a further functional photodetector device, in this embodiment a television camera or photographic camera. Photodetector 53 may be mounted above the path followed by the sheets to detect their angular orientation downstream from first creasing machine 30. Photodetector 53 carries out a quality check, checking that the creases made have actually been made in accordance with design requirements, and transmits position or angular orientation data for sheets 12 to the electronic unit.

Adjacent to edge 23 there is a thruster member 24 which extends in second direction B to displace the sheets abutting against edge 23 of second set of belts 22 towards a third set of
parallel motor-driven belts 25.

Belts 25 extend in second direction B. Belts 25 receive one sheet 12 at a time from thruster member 24 and cause it to advance in second direction B towards second creasing machine 60, which lays down a second array of straight parallel creases 18 on each sheet (Figure 2). Creases 18 in the second array are spaced apart in second direction B and extend perpendicularly to creases 17 of the first array, previously imparted by first creasing machine 30.

The second creasing machine 60 in the embodiment illustrated is a stack creasing machine similar to first creasing machine 30, provided with a straight blade 61 extending perpendicularly to the latter and driven vertically by a linear actuator 62. Blade 61 acts together with lower backing blade 63 which has a straight upwardly facing groove 64 extending perpendicularly to the second direction. A rotary creasing machine may be used as an alternative to stack creasing machine 60.

Similarly to what is provided downstream from first creasing machine 30, again downstream from second creasing machine 60 there is provided an orientation device 70 which orientates individual sheets 12 arriving at second creasing machine 60, causing them to rotate if necessary through an angle determined on an individual basis for each sheet so as to orientate it accurately with respect to second creasing machine 60.

Orientating device 70 includes two motor-driven rollers 71, 72, operated independently of each other and spaced apart in a transverse direction with respect to second direction B. Motor-driven rollers 71, 72 can rotate respectively with respect to two parallel or coincident axes running transversely with respect to second direction of advancement B. The two motor-driven rollers 71, 72 are configured to rotate on the undersurface of the sheets advancing towards second creasing machine 60.

Each of the two motor-driven rollers 71, 72 acts together with a corresponding backing roller 73, 74 mounted so as to be vertically movable and resiliently stressed towards the corresponding motor-driven roller. The two backing rollers 73, 74 are intended to roll on
the top surface of sheets 12 advancing towards second creasing machine 60 so as to hold
the sheets in transit in contact with both motor-driven rollers 71, 72.

Motor-driven rollers 71, 72 are each controlled in rotation by a corresponding electric
motor 77, 78, preferably a stepping electric motor, in the same ways as described above for
motor-driven rollers 41, 42. Each electric motor 77, 78 may be controlled individually and
is operated differently from the electric motor driving the other motor-driven roller so as to
produce differential advancement between two transversely spaced zones of the same sheet
12 and therefore rotate the sheet through a desired angle in the horizontal plane.

Detection devices 75, 76 capable of detecting the advancement of a sheet at two
transversely spaced positions on the sheet itself are provided. Preferably, these
advancement detection devices use two encoders 75, 76 with wheels in contact with the
sheet. The two encoders are preferably mounted adjacent to each motor-driven roller 71,
72 and more preferably immediately upstream thereof.

Immediately upstream of creasing machine 60 there is an optical detection device 80 for
detecting the angular orientation, in a horizontal plane, of sheet 12 arriving at creasing
machine 60.

In accordance with an embodiment optical detection device 80 may comprise two
photocells (or other equivalent photodetectors), one 81 on the right and one 82 on the left,
transversely spaced with respect to the second direction of advancement. As an alternative
optical detection device 80 may comprise a television camera or a photographic camera.

Optical detection device 80 is used to
- detect the positions of two respective transversely spaced points on one (lateral)
  edge 19 of sheet 12 arriving at creasing machine 60; or
- detect the positions of two reference marks 16c, 16d transversely spaced on the
  sheet 12.

The rotary movements of the two motor-driven rollers 71, 72 are controlled by an
electronic processing unit (not illustrated) to ensure that the sheet is angularly orientated
with accuracy, positioning creases 17 of the first array perpendicular to blade 61 of the second creasing machine. More particularly the electronic processing unit

- acquires signals from optical detection device 80 indicating the positions of two transversely spaced points along a lateral edge 19 of the sheet, or two reference marks 16c, 16d on sheet 12;
- processes the signals received from optical detection device 80 and generates data indicating the instantaneous angular orientation of sheet 12 with respect to a given direction, for example with respect to second direction B;
- on the basis of the angular orientation data generates a corresponding differential advancement correction signal to produce differential advancement between two transversely spaced zones of the same sheet 12 and thus rotate the sheet through a desired angle in the horizontal plane;
- sends the correction signal to at least one of motors 77, 78 to control the rotation of at least one of the two motor-driven rollers 71, 72 and consequently give rise to differential advancement between the two transversely spaced zones of the same sheet 12 and therefore rotate the sheet through a desired angle, bringing about rotation of sheet 12 in the horizontal plane such as to align the said two points on the lateral edge of the said two reference marks perpendicularly to the aforesaid second given direction B, that is parallel to the blade of second creasing machine 60;
- acquire advancement signals from encoder 45, 46 to detect the advancement of sheet 12 in two transversely spaced positions of the sheet; and
- establish from the advancement signals generated by encoders 75, 76 that differential advancement has effectively been imparted to the sheet between two transversely spaced zones on the same sheet 12 in accordance with the correction signal.

83 indicates a further optional photodetector device, a television camera or photographic camera in this embodiment. Photodetector 83 may be mounted above the path followed by the sheets to check that creases 17, 18 are perpendicular to each other.

Downstream from second creasing machine 60 there is a further set 26 of motor-driven parallel belts extending in first direction B which run in transversely spaced parallel planes. Set of conveyor belts 26 receives individual sheets 12 which have passed through creasing machine 60 and causes them to advance in second direction A to cutting machine 90.
In cutting machine 90 the individual sheets may be cut and optionally may receive creases along oblique or curved crease lines, or in any case lines having a course which is neither perpendicular nor parallel to first direction A, or creases of secondary importance, which have a lesser effect on the quality of the product.

It will be appreciated that the creases made along parallel lines according to this method cause shortening of a linear type in only one direction perpendicular to the direction in which the crease lines extend. Parallel crease lines do not give rise to oblique or diagonal shortening. The linear shortening depends on various factors, including the thickness or weight of the sheet, the number of creases, or the inking, and is knowable and quantifiable. Advantageously, these geometrical shortening data may be taken into account as input data during the stage of programming the electronic control unit. The shortening data are related to reference points on the sheet that are known to and detected accurately by the photodetectors; this makes it possible to make the crease lines in extremely precise and known positions. Subsequent operations carried out by the cutting machine are carried out using the same points along the edges of the sheet or the same marks printed on the sheet and used to make the crease lines as a reference. As a consequence the cuts made by the cutting machine are made with absolute accuracy with respect to the crease lines previously placed on the sheet by the two creasing machines 30 and 60.

The method makes it possible to pass quickly from the production of a sheet having a different format through simple reprogramming of the data entered into the electronic control unit. The dead times due to changing conventional dies are eliminated.

Figure 6 illustrates another alternative embodiment of the method. On the basis of the variant in Figure 6, sheets 12 are caused to advance along a single direction of linear advancement from sheet feeder device 11 to cutting machine 90. In an intermediate position between first creasing machine 30 and second creasing machine 60 there is a rotation station 85.

Sheets 12 on which the first array of creases 17 have been placed by first creasing machine 30 pass in direction A from second set of motor-driven parallel belts 22 to a set of motor-
driven conveyor rollers 86 which are transverse with respect to direction of advancement A.

A rotation element 87, placed on rollers 86 in a lateral position with respect to a median line of advancement engages upper surface 15 of each sheet passing over rollers 86 and causes it to rotate through 90° in a horizontal plane (arrow C). A straight longitudinal edge (not shown) may be placed along one side of rotation station 86. Rotation element 87 may for example comprise a pin (of for example rubber or other high friction material) which on each occasion is wedged against an eccentric or lateral point on sheet 12 advancing on rollers 86 and disengages after the sheet has been caused to rotate. As an alternative the rotation element may comprise a rotary clamp (not illustrated) which rotates sheet 12 through 90° in the horizontal plane.

From rotation station 85 individual sheets 12 reach a set of motor-driven parallel belts 25 extending in direction of advancement A. As described in the case of Figures 1 and 2, belts 25 cause the sheets to advance towards second creasing machine 60, which places a second array of straight parallel creases 18 on each sheet extending perpendicularly to creases 17 of the first array previously produced by first creasing machine 30. Subsequently the individual sheets are fed to cutting machine 90 in the same way as takes place in the embodiment in Figures 1 and 2.

As a difference from the embodiments illustrated here the blades of creasing machines 31, 61 may be short with respect to the sheets when it is desired to produce partial creases.

With reference now to Figures 7 and 8, one embodiment of this invention provides for the use of a single creasing machine which produces the first array of crease lines 17 and subsequently the second array of crease lines 18 perpendicular to lines 17 of the first array. In ways similar to those described for the embodiments in Figures 1-2, a preprinted sheet 12 (Figure 7) is caused to advance along a predetermined path and pass through creasing machine 30 which successively produces a first array of straight creases 17 on the sheet. Sheets 12 which have received the first array of crease lines are again fed to sheet feeder device 11 rotated through 90° (Figure 8). The sheets are then caused to pass through the
creasing machine again, receiving a second array of crease lines 18 perpendicular to first crease lines 17. Thus a grid of crease lines in two perpendicular directions is obtained on each sheet. Again in this embodiment the crease lines are imparted at predetermined distances with respect to reference points located on the sheet (for example reference points along their edges or reference marks printed on one surface of the sheets). The reference points are detected by optical devices 50, operatively associated with corresponding orientation devices 40 similar to those described with reference to Figures 1-2. The sheets with the grid of perpendicular crease lines are then fed to cutting machine 90 in a similar way to what occurs in the embodiments in Figures 1-2.

With reference to Figures 9-11, these illustrate a further embodiment of this invention in which advancement of the individual sheets is detected without the encoders with wheels illustrated in Figures 1-8. According to the variant in Figures 9-11 advancement of the sheets is detected through one or more optical detectors which detect the passage of pairs of notches or reference marks printed on the sheet close to or in the positions where it is intended that the creases should be formed.

A plurality of reference marks are printed in transversely spaced positions with respect to the direction of advancement and aligned parallel to the straight crease lines which it is desired to form. A pair of transversely spaced optical detectors, in the embodiment illustrated photocells 51, 52, are mounted upstream of the or each creasing machine 30 (and 60 if a second creasing machine is provided). The two optical detectors detect passage of the two reference marks forming part of the same pair of transversely aligned reference marks and send two corresponding signals indicative of the instantaneous longitudinal position or advancement of the two reference marks to the processing unit. If transverse misalignment of the two reference marks is detected the processing unit consequently controls the rotation speed of one of the electric motors to cancel out the misalignment and cause the angularly orientated sheet to advance through the creasing machine with the pairs of notches aligned parallel to the blade of the creasing machine.

With reference to Figures 12 and 13, a still different embodiment of this method involves the use of a single creasing machine 30 that imparts both the first succession of crease lines
17, and thereafter, the second sequence of crease lines 18, perpendicular to the lines 17 of the first array. In a manner similar to that described for the embodiment of Figures 7 and 8, a pre-printed sheet 12 (Figure 12) is caused to advance along a predetermined path and go through the creasing machine 30, which imparts a first succession of straight crease lines 17 to the sheet.

Then, the motion of the transport system is reversed (Figure 12, arrow D), and the sheet that has received the first array of crease lines 17 is at first taken again upstream of the creasing machine 30, then it is rotated 90° in the horizontal plane (figure 13, arrow E) and, subsequently, it is caused to pass again through the creasing machine, thereby receiving a second sequence of crease lines 18 perpendicular to the first crease lines 17. Thus, a grid of crease lines in two perpendicular directions is obtained on each sheet. Also in this embodiment, the crease lines are imparted at predetermined distances with respect to the reference points located on the sheet, as for the other embodiments described above.

The rotation of the sheets in the horizontal plane may be preferably carried out by actuating the two motor-driven rollers 41, 42 in two opposite directions of rotation. In the phase of reverse (Figure 12), the sheet 12 may be moved backward until the optical readers 51 and 52 detect the passage of the new front edge of the sheet.

The reference marks may be located on the edges of the sheet so as to be subsequently removed by cutting machine 90, which trims off the edges.

In all the possible embodiments of the method, the reference points or reference marks may be printed on one or both of the opposite faces of the sheets, for example on the upper face and/or the bottom face. Consequently, the optical detection of the reference signs may be carried out from the side that has the reference marks, namely from above and/or from below.

As an alternative to two transversely spaced photocells or optical detectors, the optical detection device may comprise a single television camera or photographic camera capable of reading the positions of both the reference marks forming part of the same pair of
transversely spaced reference marks.

Programming of the processing unit is simplified by placing the reference marks in the positions intended for creasing, or close thereto. In order to know the position of the creasing lines with certainty it is not necessary to take into account any correction factors to evaluate shortening of the sheet as a consequence of the crease lines produced. In fact a minimum or zero distance between the reference marks and the crease lines eliminates uncertainty over the actual position of such lines.

Various aspects and embodiments of methods for the processing of sheet materials have been described. It is intended that each embodiment should be capable of being combined with any other embodiment. The invention is also not limited to the embodiments but may be varied within the scope defined by the appended claims.
CLAIMS

1. A method of processing sheet materials, comprising the steps of:
   - causing a pre-printed sheet (12) to advance along a predetermined path in a first, horizontal direction of advancement (A);
   - optically detecting the positions of at least a pair of first reference points (16a, 16b) on the sheet, wherein the two first reference points of a same pair are transversely spaced from one another in a direction substantially perpendicular to the first direction of advancement (A);
   - angularly orienting the sheet in a horizontal plane with respect to the first direction of advancement (A);
   - causing the angularly oriented sheet to advance in the first direction of advancement and forming in succession a first array of straight and parallel crease lines (17) spaced apart in the first direction of advancement (A), the crease lines (17) having an orientation and distances with respect to said at least one pair of first reference points;
   - optically detecting the positions of at least a second pair of second reference points (16c, 16d) on the sheet, wherein the two second reference points of a second pair of points are spaced from one another in a direction perpendicular to the direction in which the two first reference points of said at least a first pair of reference points are spaced apart;
   - angularly orientating the sheet (12) in a horizontal plane with respect to a second direction of advancement (B),
   - causing the angularly oriented sheet to advance in the second direction of advancement (B) and forming a second array of straight and parallel crease lines (18), wherein the lines of the second array of crease lines
     - have an orientation referred to the second pair of second reference points of the sheet (16c, 16d) and extend perpendicularly to the first array of crease lines,
     - are spaced apart with reference to the two second reference points (16c, 16d), and
     - define, together with the lines of the first array of crease lines, a pattern of perpendicular crease lines; and
   - feeding the sheet to a processing machine (90) to cut the sheet using as a reference at least two of the first (16a, 16b) or second (16c, 16d) reference points.
2. A method according to claim 1, wherein:
   the first (A) and the second (B) directions of advancement are consecutive directions of advancement, form an angle between them, and together define a substantially L-shaped path for the sheets;
   the first array of crease lines (17) is formed by a first creasing machine (30);
   the second array of crease lines (18) is produced by a second creasing machine (60);
   the sheets are angularly deviated from the first (A) to the second direction of advancement (B) at a deviation station arranged downstream of the first creasing machine (30) and upstream of the second creasing machine (60).

3. A method according to claim 2, wherein the sheets are deviated from the first (A) to the second (B) direction of advancement substantially without being rotated in a horizontal plane.

4. A method according to claim 2 or 3, wherein the sheets are deviated against a side abutment (23) extending in the second direction of advancement (B).

5. A method according to any one of claims 1 to 4, wherein the first (A) and the second (B) directions of advancement form an angle of about 90°.

6. A method according to claim 1, wherein
   the first (A) and the second (B) direction of advancement are consecutive and substantially aligned directions of advancement defining together a substantially straight path for the sheets;
   the first array of crease lines (17) is formed by a first creasing machine (30);
   the second array of crease lines (18) is formed by a second creasing machine (60); and
   the sheets (12) are rotated in a horizontal plane about 90° at an intermediate rotation station (85) arranged between the first creasing machine (30) and the second creasing machine (60).
7. A method according to claim 1, wherein

the first (A) and the second (B) direction of advancement are coincident and define
a single direction of advancement;

the first and the second arrays of crease lines (17, 18) are produced by the same,
single creasing machine (30);

the first array of crease lines (17) is formed by advancing the sheet a first time in
said single direction of advancement, and causing the sheet to pass a first time through the
creasing machine (30), with the sheet having a given angular orientation with respect to
said single direction of advancement;

the second array of crease lines (18) is formed by causing the sheet to advance a
second time in said single direction of advancement and causing the sheet to pass a second
time through the same creasing machine (30), with the sheet having an angular orientation
rotated 90° with respect to the angular orientation angle taken by the same sheet when
passing the first time through the creasing machine.

8. A method according to claim 1, wherein

the first (A) and the second (B) direction of advancement are coincident and define
a single direction of advancement;

the first and the second arrays of crease lines (17, 18) are produced by the same,
single creasing machine (30);

the first array of crease lines (17) is formed by advancing the sheet a first time in
said single direction of advancement, and causing the sheet to pass a first time through the
creasing machine (30), with the sheet having a given angular orientation with respect to
said single direction of advancement;

the second array of crease lines (18) is formed by causing the sheet to first move
backwards in an opposite direction with respect to the single direction of advancement, so
as to bring the sheet back upstream of the single creasing machine (30), then rotating the
sheet 90° in a horizontal plane, and subsequently causing the sheet to pass a second time
through the same creasing machine (30), with the sheet having an angular orientation
rotated 90° with respect to the angular orientation angle taken by the same sheet when
passing the first time through the single creasing machine (30).
9. A method according to any one of claims 2 to 8, wherein the first (30) and/or the second (60) creasing machines comprise either creasing machines or scoring machines configured to impart straight crease lines.

10. A method according to any one of the preceding claims, wherein the steps of optically detecting the positions of said pairs of reference points (16a, 16b; 16c, 16d) are performed
   - either by detecting the positions of two respective transversely spaced points on an edge (14, 19) of the sheet (12);
   - or by detecting the positions of at least one pair of reference marks (16a, 16b; 16c, 16d) transversely spaced and printed on the sheet (12).

11. A method according to any one of the preceding claims, wherein the steps of angularly orientating the sheet with respect to the first (A) or the second (B) directions of advancement are performed by controlling, on the basis of optically detected position data of said pairs of points, at least two electric motors which are driven independently of one another and actuate two respective rollers acting simultaneously on a same sheet (12), the two rollers being mutually spaced from one another in a transverse direction with respect to the first or the second directions of advancement, so as to cause a differential advancement between two transversely spaced parts of a same sheet (12), and, as a result, cause the sheet to rotate a desired angle in a horizontal plane.

12. A method according to claim 11, wherein the electric motors of the rollers are controlled on the basis of at least two signals of advancement related to transversely spaced zones of a sheet, said signals of advancement being provided by at least two encoders (49, 59) each associated with a respective rolling element (45, 46), the two rolling elements being configured to roll on the sheet in two respective zones transversely spaced apart on the sheet.

13. A method according to claim 12, wherein the two rolling elements (45, 46) are each arranged adjacent to the respective motor driven roller, preferably upstream thereof with respect to the direction of advancement of the sheet.
14. A method according to any one of claims 1 to 10, comprising optically detecting positions of a plurality of pairs of reference marks printed on a same sheet (12), wherein two reference marks of a same pair are arranged at positions transversely spaced with respect to the direction of advancement, and wherein the pairs of reference marks are spaced from each other in a direction of advancement perpendicular to the direction along which the reference marks of each pair are spaced from one another.

15. A method according to claim 11, wherein at least some of the pairs of reference marks are printed adjacent to opposite edges of a same sheet (12).
**INTERNATIONAL SEARCH REPORT**

**A. CLASSIFICATION OF SUBJECT MATTER**

INV. B26D5/00 B26D5/34 B31F1/08

ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

B26D B31B B31F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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Further documents are listed in the continuation of Box C. See patent family annex.

**Date of the actual completion of the international search**

10 October 2016

**Date of mailing of the international search report**

19/10/2016

**Name and mailing address of the ISA/V**

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**Authorized officer**

Wimmer, Martin
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<tr>
<td>A</td>
<td>EP 1 559 520 A2 (ESKO GRAPHICS AS [DK]) 3 August 2005 (2005-08-03) the whole document</td>
<td>1-15</td>
</tr>
<tr>
<td>A</td>
<td>WO 2011/027204 A1 (PETRATTO GIORGIO [IT]) 10 March 2011 (2011-03-10) figure 1</td>
<td>1-15</td>
</tr>
<tr>
<td>Patent document cited in search report</td>
<td>Publication date</td>
<td>Patent family member(s)</td>
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<td>NONE</td>
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<tr>
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<td>US 2005209075 A1</td>
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<td>US 2008108490 A1</td>
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<td></td>
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<td>WO 2005091982 A2</td>
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<td>US 2013267397 A1</td>
<td>10-10-2013</td>
<td>CN 103358586 A</td>
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<td>WO 2005108027 A1</td>
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<td>EP 1559520 A2</td>
<td>03-08-2005</td>
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<td>EP 1559520 A2</td>
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<td>EP 1380407 A2</td>
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