A method of producing springs involves feeding a wire to a forming device. The machine feeds the wire using a controllable axis. This axis positions the forming device during the forming operation. The wire is wound around a mandrel, which has a mandrel axis perpendicular to the feed direction. The machine adjusts the position and orientation of the feed device to complete the forming process.
METHOD FOR PRODUCING SPRINGS AND SPRING MACHINE FOR CARRYING OUT THE METHOD

TECHNICAL FIELD

[0001] This disclosure relates to a method of manufacturing springs by a numerically controlled spring machine and to a spring machine that carries out the method.

BACKGROUND

[0002] Springs are machine elements required in numerous fields of application in high numbers and in different forms. Springs of the type concerned in this instance are normally manufactured from spring wire or spring strip by cold forming. There are many different types of springs. Coil springs, which are also referred to as wound torsion springs, are loaded predominantly in the direction of their spring axis in their intended use and can be designed as tension springs or compression springs depending on the load present during use. In the case of cylindrical coil springs, the spring diameter is constant over the length of the springs, but may also vary over the length, such as in the case of conical or barrel-shaped coil springs. Coil springs designed to be loaded by torsion about their spring axis during use are referred to as leg springs. Spiral springs are flat, wound flexible springs.

[0003] Spring machines are forming machines which, with the aid of suitable tools, can produce relatively small to very large series of springs, sometimes of complex spring geometry, from semi-finished products such as wire, strip or the like, predominantly by forming in an automatic fabrication process. In this application, the term “wire” is used as a synonym for wire, strip and similar workpieces. A spring machine can be designed to manufacture compression springs, tension springs, leg springs, spiral springs or other spring-like molded parts. In particular, spring winding machines and spring coiling machines are spring machines.

[0004] A multitask spring machine controlled by computer numerical control has a plurality of controllable machine axes, a drive system with a plurality of drives that drive the machine axes, and a control device for the coordinated control of movements of the machine axes during a fabrication process according to a computer-readable control program specific for the fabrication process. The term “machine axis” denotes generally a movable device which can be moved in at least one mechanical degree of freedom by at least one drive, for example, an electromechanical, electrohydraulic or electrohydraulic drive. It may be a translator machine axis, which moves a linearly movable sliding carriage, for example, or a rotary machine axis, for example, a spindle. A machine axis can move either a tool or the workpiece.

[0005] Nowadays, coil springs are often manufactured by spring winding with the aid of numerically controlled spring winding machines. A wire (spring wire) is fed in a feed direction to a forming device of the spring winding machine by a feed device under the control of a control program and is formed into a coil spring with the aid of tools of the forming device. These tools generally include one or more winding pins, the position of which can be adjusted mechanically or in a motor-driven manner to define and possibly change the diameter of spring windings. One or more pitch tools are often additionally provided, with which the local pitch of the spring windings can be determined in each phase of the fabrication process.

[0006] A cutting unit having a movable cutting tool is used to separate the finished spring from the starting material. A mandrel (trimming mandrel) located inside the developing spring and having a cutting edge which cooperates with the cutting tool during the separation process is used as a counter element for the cutting tool.

[0007] The trimming mandrel is a key tool during the trimming process. It is subjected to a high impact load during the trimming process. In known spring winding machines, it is received in a “mandrel casing.” The mandrel casing is supported by a linearly movable mandrel carriage which carries the movable cutting tools and the drives thereof. The mandrel casing may possibly be displaced within the mandrel carriage, parallel to the longitudinal axis of the spring. This possibility for axial displacement can be utilized in the manufacturing process for the axial displacement of the trimming mandrel. This is also referred to as “mandrel displacement” and can optionally be driven by a servomotor. The “mandrel displacement” function is used, for example, in the manufacture of springs when the wire would collide with the trimming mandrel during the manufacturing process. In this case, the trimming mandrel is moved away from the collision area of the spring by the axial movement of the mandrel casing. Once the spring has been formed, the trimming mandrel is moved back into the cutting position with the mandrel casing to trim the spring. This design allows a high level of versatility for the manufacturing process. The design may be complex to ensure sufficient stability in view of the forces which are exerted during the trimming process.

[0008] DE 101 34 826 B4 discloses a spring winding machine having a feed device equipped with a pair of feed rolls each mounted on a table together with a wire guide and with respective associated drive devices, the table being movable in a rising and lowering direction relative to the tool units. The feed rolls are mounted to be changeable in terms of their position relative to the tool units. The mutually opposed position between the feed device and the tool units can thus be adjusted easily. This is supposed to be advantageous in particular in the case of thin wires because a protrusion of a wire, which is unfavorable for machining accuracy, can be prevented since wire can be formed directly in the region in front of the distal end portion of the wire guide.

[0009] Spring winding machines have a winding mandrel as a key element, the winding mandrel being driven rotatably about its axis of rotation by a rotary machine axis during manufacture of a wound spring. EP 0 804 978 B1 discloses a spring winding machine which has a feed device which can feed the spring wire in a feed direction extending at right angles to the axis of rotation of the winding mandrel. In relation to the winding mandrel, the feed device can be driven in a controlled manner both parallel to the feed device and transverse to the axis of rotation of the winding mandrel to change the point of contact of the wire and of the winding mandrel. It is thus possible to manufacture springs having opposed winding directions without replacing the winding mandrel.

[0010] It could therefore be helpful to provide a method of manufacturing springs by a numerically controlled spring machine, the method simplifying the manufacture of springs of different and possibly complicated spring geometry. It could further be helpful to provide a spring machine designed to carry out the method, the machine offering a high level of fabrication quality and versatility at favorable manufacturing cost.
SUMMARY

[0011] We provide a method of manufacturing springs by a numerically controlled spring machine including feeding a wire in a feed direction to a forming device of the spring winding machine by a feed device under control of a control program forming the wire into a spring with the aid of tools of the forming device in a forming operation, the forming device having a mandrel with a mandrel axis oriented at right angles to the feed direction, and windings of the spring surrounding the mandrel during the forming operation, and adjusting a position and/or orientation of the feed device with the aid of a controllable machine axis during the forming.

[0012] We also provide a spring machine that manufactures springs by spring winding or spring coiling under control of a control program including a plurality of controllable machine axes, a control device that coordinates control of axial movements of the machine axes of the spring machine on the basis of a control program, a feed device that feeds wire (DR) in a feed direction (DZ) in a region of a forming device of the spring machine, and a mandrel with a mandrel axis oriented at right angles to the feed direction, the mandrel being positioned or positionable such that windings of the spring surround the mandrel during the forming operation, wherein the feed device is an adjustable feed device in which the position and/or orientation of the feed device is/are adjustable with the aid of one or more controllable machine axes during production of a spring.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIG. 1 shows an overall schematic view in FIG. 1A of a spring winding machine for manufacturing spiral springs having some components of a system for programming the control of the machine, and in FIG. 1B shows a detail merely with electrical and mechanical components.

[0014] FIG. 2 shows a schematic view of the operating principle of the spring winding machine from FIG. 1 having a feed device which can be adjusted during spring manufacture.

[0015] FIG. 3 shows an oblique perspective view (3A) and a front view (3B) of a conventional spring winding machine.

[0016] FIG. 4 shows an example of a spring winding machine having a pivotable feed device and a movable mandrel.

[0017] FIG. 5 shows an example of a spring winding machine having a pivotable feed device and a machine-fixed mandrel.

[0018] FIG. 6 shows an example of a spring winding machine having a vertically displaceable feed device and a machine-fixed mandrel.

[0019] FIG. 7 shows a further example of a spring winding machine having a vertically movable feed device and a machine-fixed mandrel.

[0020] FIGS. 8 and 9 show schematic movements of machine axes during the manufacture of springs of different or varying diameter for right-hand springs (8A to 8D) and left-hand springs (9A to 9D).

DETAILED DESCRIPTION

[0021] The method can be implemented in spring machines in which the feed device is not mounted rigidly on the machine body, but has at least one degree of freedom of movement transverse to the feed direction and can be adjusted selectively in terms of its position and/or orientation with the aid of a respective controllable machine axis under the control of the control system of the spring machine during a forming operation. Different manufacturing processes for springs can thus be improved. At the same time, it is possible in some cases to simplify the spring machine at other points in terms of design and to thus reduce the manufacturing costs with at least a constant quality of the manufactured springs.

[0022] A spring having windings of different winding diameter is preferably produced during the forming operation and the mandrel preferably does not move at right angles to the mandrel axis during the forming operation. The mandrel can remain at the same point up to the separation of the finished spring from the fed wire, although linear movements parallel to the mandrel axis can be provided if needed. A “fixed” arrangement of the mandrel with regard to transverse movements can bring considerable advantages in terms of design and function, which will be explained in greater detail below.

[0023] In some cases, the feed device is movable at right angles to the feed direction in a linear manner by a possibly controlled, transatory machine axis. The feed direction of the wire is thus displaced in parallel, this possibly being carried out during the forming operation. In other cases, the feed device is controlled pivotably as a whole about a pivot axis extending parallel to the mandrel axis by a corresponding machine axis, for example, a rotary machine axis. This movement can also be carried out as needed during the forming operation.

[0024] One class of spring machines is characterized by the fact that the spring machine is designed as a spring winding machine and that the mandrel is a winding mandrel which can be rotated about the mandrel axis at a definable speed or with a predefinable speed profile by a rotary machine axis. The winding mandrel can preferably additionally be moved parallel to the mandrel axis by a transatory machine axis.

[0025] For example, such a spring winding machine can be used to produce a spiral spring during the forming operation. To this end, preferably, the position and/or orientation of the feed device is/are first set such that, before manufacture of a new spiral spring is begun, the free front wire end can be introduced into a transverse slit in the winding mandrel. The wire is then introduced into the transverse slit by the feed device. The further forming operation then takes place, in which the wire is fed as the winding mandrel is rotated. The winding mandrel can act as a draw-in element and the action of the feed device on the wire can be released. It is also possible to feed or to convey the wire further by the feed device so that the winding mandrel may only need to perform the function of winding the spring windings.

[0026] During the winding process, the position and/or orientation of the feed device is/are then changed such that the feed direction defined by the feed device always extends substantially tangentially to a winding of the spring just being produced. In the case of aplanar spiral spring, the winding diameter always increases further. If, at any phase of the winding process, the feed direction extends substantially tangentially to the outer periphery of the developing spiral spring, the wire may be hardly bent between the exit from the feed device or a guide device of the feed device and the winding at the periphery of the spiral spring and, therefore, plastic deformation can be avoided in this region. Spiral springs of high quality and good reproducibility can thus be manufactured. In addition, a space-saving compact design is
possible since the exit of the feed device can be brought very close to the region of the winding mandrel.

[0027] In another class of spring machines, the spring machine is designed as a spring winding machine for the manufacture of coil springs by spring winding. The forming device has at least one winding tool which basically determines the local diameter of a developing coil spring at a predefined position. At least one pitch tool is generally further provided, the action of which on a developing coil spring determines the local pitch of the coil spring. However, this is not compulsory. Spring winding machines of the type considered in this instance also have a cutting unit provided to separate from the feed wire a finished, manufactured spring with the aid of a cutting tool which is movable via a suitable machine axis. In these machines the mandrel is used as a counter element for the cutting tool during the cutting process and is therefore also referred to as a “trimming mandrel.”

[0028] The mandrel (trimming mandrel) is preferably received in a “mandrel casing” and can be displaced linearly by moving or displacing the mandrel casing parallel to the mandrel axis. In some cases, a separate controlled machine axis is provided for this purpose.

[0029] The trimming mandrel is a key tool during the trimming process. It is subjected to a high impact load during the trimming process. To minimize downtimes of the spring winding machine, it is desirable if the trimming mandrel can be removed and re-installed quickly. On the other hand, the trimming mandrel must be securely fixed in the mandrel casing during operation to be capable of withstanding the high and sudden cutting forces. The design in the region of the mandrel casing and of the trimming mandrel may thus be relatively complex.

[0030] For the trimming process, it should be ensured that the trimming mandrel rests against the inner face of the spring winding at which the cut is to be made with the aid of the movable cutting tool to avoid deformations of the finished spring as a result of the cutting process. Furthermore, it should also be possible to manufacture both right-hand and left-hand springs using a single spring winding machine. Lastly, there are numerous types of spring which have varying spring diameters, for example, conical or barrel-shaped coil springs. To ensure the versatility of the spring winding machine required for this, the trimming mandrel or the mandrel casing is housed in conventional, highly versatile spring winding machines in a mandrel carriage which is movable at right angles to the mandrel axis, for example, vertically, and which can be set in different (vertical) positions in relation to the feed device via a translatory machine axis.

[0031] In spring winding machines in which the position and/or orientation of the draw-in device can be adjusted with the aid of a controllable machine axis, a substantially more simple and more robust design in the region of the trimming mandrel is enabled, and in particular in this instance it is not necessary for the trimming mandrel to have degrees of freedom of movement for controlled movements at right angles to the mandrel axis. Preferably, the mandrel (trimming mandrel) or the mandrel casing supporting the mandrel is therefore attached fixedly to the machine body of the spring winding machine, the term “fixedly” meaning that, in this instance, no degrees of freedom of movement at right angles to the mandrel axis and no corresponding machine axes are provided. In accordance with this example, a mandrel carriage movable at right angles to the mandrel axis is no longer necessary or provided and the corresponding components of the mandrel carriage and the drive thereof can be omitted.

[0032] As a result of this design, a much greater rigidity of the overall system can be achieved. A direct, closed and more compact flow of forces is produced between the components involved in the trimming process. The flow of forces extends merely over the trimming blade, the wire, the trimming mandrel acting as a counter blade, the devices with which the trimming mandrel is received in the main body, the movable elements of the cutting unit, and the point of support of the trimming blade. In addition, relatively simple assembly for the trimming mandrel is provided. Furthermore, longer service lives of the trimming tools can be provided as a result of smaller relative movements of the involved components caused by the cutting load due to the greater rigidity. Due to the simple design, advantages in terms of assembly and thus lower manufacturing costs of the spring winding machine are also provided.

[0033] Advantages during operation are provided, inter alia, when springs with windings of different winding diameter are produced. More specifically, the position and/or orientation of the feed device can be changed during the forming operation so that the trimming mandrel rests against the inner face of the spring during each phase of the forming operation or is arranged at such a short distance from the inner face of the wire that, during a cutting operation, the counter element (the trimming mandrel) can immediately support the wire against the action of the cutting blade, and plastic deformation of the finished spring as a result of the cutting process is thus prevented.

[0034] Further advantages of the method will be explained in detail in conjunction with the figures on the basis of examples.

[0035] These and further features are clear from the appended claims and also from the description and from the drawings, wherein the individual features are implemented alone or together in the form of sub-combinations and in other fields, and may constitute examples which are advantageous and which can be protected separately. Examples are illustrated in the drawings and will be explained in greater detail hereinafter.

[0036] On the right-hand side, the schematic overview in FIG. 1A shows some mechanical and electromechanical components of a spring winding machine 100 designed for the manufacture of spiral springs from wire-like, flat wire-like or strip-like semi-finished product and is accordingly also referred to as a spiral spring machine 100. FIG. 1B shows these components again in detail for reasons of clarity. The spring winding machine controlled by computer numerical control has a plurality of controllable machine axes, a drive system with a plurality of electric drives that drive the machine axes and a control device 180 for the coordinated control of movements of the machine axes during operation.

[0037] The fabrication process for a spiral spring having a specific geometry and spring properties is controlled by a computer-readable control program specific for the fabrication process, the movements of the machine axes provided for manufacture of the molded part and the sequence thereof being stored in the control program in the form of NC sets and/or in the form of path/time tables or corresponding data sets.

[0038] The system for programming the spring winding machine and the movements of the machine axes has an operator unit 190, shown schematically on the left-hand side
in FIG. 1A, which serves as an interface to the machine operator. The operator unit has a display unit 192 in the form of a graphics screen controlled by a computer unit (not illustrated). One or more input units can be connected to the computer unit, for example, a keyboard 194 and a mouse 196. If the display device is formed as a touchscreen, some or all separate input units can also be omitted.

[0039] The operator unit 190 connects to the control device 180 via a bidirectional data line path 185 so that information can be transferred from the computer unit of the operator unit to the control device and information from the control device can be displayed on the display unit 192, after processing if necessary.

[0040] The spring winding machine has a feed device 110 having two pairs of feed rolls or draw-in rolls 112A, 112B and 114A, 114B arranged one above the other, successive portions of a wire, flat wire or strip coming from a material store (not shown) and guided by a straightening unit (likewise not shown) being fed with a numerically controlled advanced speed profile into the region of the forming device 120 as a result of the paired rotation of the pairs of feed or draw-in rolls in opposite directions. The flat wire or the strip is a wire-like material having a relatively large width compared to its thickness. This material will be referred to generally hereinafter as “wire.” The feed device is occasionally also referred to as a draw-in device, and the terms “draw-in roll” and “feed roll” are accordingly also used synonymously. A feed device or draw-in device equipped with rolls can have one pair or a number of pairs of rolls (draw-in rolls or feed rolls).

[0041] In the example the spring winding machine has a right-angled machine coordinate system MK denoted by the lowercase letters x, y and z and having a vertical z-axis and horizontal x- and y-axes. In the example, the x-axis runs parallel to the direction of feed or feed direction, defined by the feed device 110, of the as yet unbent wire. A distinction is to be made between the machine-fixed coordinate axes and the machine axes driven in a controlled manner and yet to be explained hereinafter and denoted by capital letters in each case. For example, the C-axis is responsible for the advance or feed of the as yet unbent wire in the direction of the forming device 120.

[0042] The wire fed into the operating range of the forming device 120 is formed with the aid of numerically controlled tools of the forming device in a planar spiral spring. The following tools and corresponding machine axes are provided in the configuration shown:

[0043] A winding mandrel 130 illustrated particularly clearly in FIG. 2 is rotatable about a horizontal axis of rotation 135 extending parallel to the y-axis and is axially displaceable relative to this axis. The machine axis responsible for the rotation of the winding mandrel is the Y-axis, and the axial displacement of the winding mandrel is achieved by the Z-axis. The winding mandrel has a transverse slit 132, into which a starting portion of the fed wire 115 is introduced before a spiral spring is wound, and fixed by rotating the winding mandrel and thus held in place during the further rotation.

[0044] A threading tool 140 having a wedge-shaped tip is slid into the slit of the winding mandrel with the aid of a first slide 145 in the region directly in front of the winding mandrel to assist the threading of the start of the wire. The respective translatory axis running substantially radially to the Y-axis is the W-axis.

[0045] A fixing tool 150 having a concave cylindrical pressing contour is displaced, with the aid of a second slide 155, in the direction of the spring wound about the winding mandrel. The fixing tool is used in the end phase of the winding process to press together and fix the wound spiral spring so that it does not uncoil suddenly when the spring is separated from the fed wire. The translatory machine axis running substantially radially to the axis of rotation of the winding mandrel is the P-axis.

[0046] In the example, a terminal portion bent a number of times is provided at the outer end of the spiral spring to be produced and is produced with the aid of two further machine axes. A first bending tool 160 is used as a female mold and advanced vertically from below approximately radially to the axis of rotation of the winding mandrel in the direction of the wire. The respective translatory axis is the O-axis.

[0047] At the same time, a second bending tool 170 formed as a male mold is displaced downwardly from the opposite side with the aid of a further translatory axis (B-axis) to form the bent end portion. At the same time, the B-axis moves a cutting tool 186 mounted beside the second bending tool and used to separate the spiral spring from the fed wire.

[0048] The rolls of each draw-in roll pair may be brought towards one another or moved away from one another selectively. If the rolls are brought towards one another, the winding process continues in the following manner: The feed direction of the wire is reversed and is passed through the slit in the winding mandrel and the mandrel is rotated until it securely fixes the start of the wire, the pairs of draw-in rolls can be opened so that the wire is advanced further since the rotating winding mandrel pulls the wire in the direction of the winding mandrel. The axis for the roll weighting is called the CO-axis and causes a linear movement of the upper draw-in rolls 112B, 114B at right angles to the feed direction of the wire or parallel to the z-direction.

[0049] In the example shown, the entire feed device can also be moved vertically, that is to say parallel to the z-direction or at right angles to the feed direction of the wire, in a controlled manner. The respective translatory machine axis is the CQ-axis. One possibility for use is explained in conjunction with FIG. 2.

[0050] With this configuration, the course of movement of the machine axes during a movement cycle for fabrication of a spiral spring can be controlled as follows, for example.

[0051] With the aid of the rotating draw-in rolls (C-axis) rotating pairwise in opposite directions and located in their position of engagement, the wire is first conveyed in the direction of the winding mandrel until a wire start portion is slid into the transverse slit in the winding mandrel. This threading movement can be assisted by the threading tool 140. If the axis (W-axis) of the threading tool is programmed, the tool can be moved by the drive of the W-axis so close to the winding mandrel in the phase before feeding of the start of the wire into the slit that a swerving of the advanced start of the wire is mechanically prevented and the start of the wire is therefore fed in any case into the transverse slit in the winding mandrel. This insertion aid may also be omitted in other processes.

[0052] As soon as the rotating winding mandrel has securely grasped the wire, the upper draw-in rollers 112B, 114B can be raised at the same time by the CO-axis and,
therefore, the wire is advanced further merely by the rotating winding mandrel. It is also possible to leave the draw-in rolls in engagement with the wire and to rotate them further in accordance with the desired advance profile.

[0053] If the winding process is completed after a pre-defined number of rotations of the winding mandrel, the winding mandrel is wound back slightly to relieve the wire material of pressure. In addition, the fixing tool 150 is placed against the outer periphery of the spring by an advancing movement of the P-axis and secures the spring against a sudden uncoiling during the subsequent processing steps.

[0054] In the end phase of the movement cycle, the two bending tools 160, 170 shaped complementarily move towards one another simultaneously from opposite directions with the aid of the O-axis and the B-axis. The finished, wound spiral spring is first separated from the wire by being cut by the cutting tool 180. The bending tools 160, 170 then shape the intricately bent end portion of the spiral spring in a forming process, either directly after the cutting operation or with a temporal overlap. The winding mandrel is then withdrawn by the Z-axis, whereby the finished spring is slid off.

[0055] An identical, next movement cycle can then be started, by which the next spiral spring is produced.

[0056] A possibility for use of the adjustable feed device 110 which can be moved linearly in a controlled manner with the aid of the controlled translatory CQ-axis at right angles to the draw-in direction or feed direction is explained on the basis of FIG. 2. To the right, FIGS. 2A and 2B each show the outlet-side draw-in rolls 112A, 112B of the feed device 110. These are mounted on a support 116 which can be moved vertically with the aid of the CQ-axis. A guide device 118 having two parallel guide rails is also attached to the support 116 after the draw-in rolls in the direction of conveyance, the guide rails guiding the conveyed wire in a straight line as it is advanced in the direction of the forming device 120.

[0057] In each case, the winding mandrel 130 provided with a transverse slit 132 is shown to the left and can be rotated about the axis of rotation 135 of the winding mandrel in a predefinable rotational direction with the aid of the Y-axis and can additionally be displaced parallel to the axis of rotation 135 with the aid of the Z-axis, for example, to slide off the finished spring by withdrawing the winding mandrel.

[0058] FIG. 2A shows the feed device 110 in a basic position, in which the feed direction 125 defined by the vertical position of the draw-in rolls and the guide rails extends exactly radially to the axis of rotation 135 of the winding mandrel. This basic position is approached, for example, for the threading of the leading end of the wire into the transverse slit 132, for which purpose the winding mandrel is rotated such that the transverse slit 132 extends substantially parallel to the feed direction (or parallel to the z-axis of the machine coordinate system MK).

[0059] When, after completion of the threading process, windings of the spiral spring start to be produced by rotation of the winding mandrel, the outer diameter of the spiral spring changes gradually with continuous wire feed and an increasing number of windings. If, in this case, the feed device 110 were to remain in its basic position, the wire, after exiting the guide device 118, would be subjected to an ever-increasing bending load with increasing diameter of the spiral spring, before it came to rest against the outer region of the previous winding.

[0060] To avoid plastic deformation of the wire in this region, it is possible to keep the distance between the feed device/guide rails and the winding mandrel at such a level in relation to the maximum diameter of the spiral spring, that only a slight elastic bending of the wire occurs at all diameters, without plastic deformation.

[0061] With the aid of the draw-in assembly which can be displaced during creation of the spiral spring, it is possible for the wire to remain practically unbent between the exit from the guide device 118 and the resting against the outer face of the developing spiral spring. In the example the advancing movement of the CQ-axis during the winding of the spiral spring is programmed such that the feed direction 125 of the wire defined by the feed device 110 extends substantially tangentially to the outer periphery of the developing spiral spring during all phases of the winding process. As can be seen in FIG. 2B, the wire is thus hardly bent between the exit from the guide device 118 and the winding at the periphery of the spiral spring and, therefore, plastic deformation is reliably avoided in this region.

[0062] An advantage of this example is that springs of high quality can be produced. Another advantage is that a very space-saving and compact design is possible, since the exit of the feed system (in this case the exit from the guide rails 118) can be brought very close to the region of the winding mandrel.

[0063] In other examples not illustrated, the feed device can be pivoted as a whole in a controlled manner by a corresponding machine axis about a pivot axis extending parallel to the axis of rotation 135 of the winding mandrel 130. As a result, the feed wire can also be guided substantially tangentially to the winding of the spiral spring, which is becoming increasingly larger in terms of diameter.

[0064] The spiral spring machine is an example of a spring machine having a feed device that draws an elongate workpiece (in this case a wire) into the region of the forming device, wherein the position and/or orientation of the feed device define(s) a feed direction and the feed device can be adjusted with the aid of a controlled machine axis (in this case the CQ-axis). The draw-in assembly, which can be adjusted by the control device with the aid of a machine axis, can be used when setting up the machine for a forming process to orient the feed direction favorably in relation to the tools of the forming device. Specific advantages emerge from the fact that the machine can be controlled such that the draw-in assembly is adjusted during production of the spring, for example, to adapt the feed device to a winding diameter which is ever-changing during production of the spring. The adaptation may be carried out in particular such that the feed device always extends substantially tangentially to the winding just being produced.

[0065] Some advantages have been explained on the basis of FIG. 2 with reference to the example of production of a planar spiral spring. An adjustable draw-in assembly can also be provided in other spring machines, however, for example, in a spring machine that produces coil springs by spring winding, that is to say in a spring winding machine. In this case, an adjustable feed device can be used, for example, if coil springs having a winding diameter which varies along the axial direction of the spring are to be produced, for example, conical coil springs or barrel-shaped coil springs. In this case, too, the feed direction defined by the feed device can be changed gradually, by displacing the feed direction in a direction of displacement extending at right angles to the feed direction or by pivoting the feed device about a pivot axis extending parallel to the spring axis, for example, such that
the feed direction always extends substantially tangentially to the winding just being produced, even if the winding diameter changes during manufacture of the spring.

Various examples of spring winding machines equipped with a draw-in device which can be adjusted in a program-controlled manner during spring manufacture will be explained hereinafter. To facilitate comprehension of the key differences from conventional spring winding machines, the design of a conventional spring winding machine characterized by high versatility and which allows manufacture of left-hand and right-hand coil compression springs having many different spring geometries will first be explained on the basis of FIG. 3. For illustrative purposes, the same machine is shown in perspective view in FIG. 3A and in front view in FIG. 3B and will also be used later for the examples.

The spring winding machine has a main body with a right-angled machine wall on which many components of the winding machine are mounted. A feed device has one or more, in this example two, pairs of feed rolls arranged one above the other, can be driven in pairs in opposite directions, and which feed successive wire portions of a wire coming from a wire store and guided by a straightening unit (not shown) into the region of a forming device with a numerically controlled feed speed profile. The wire is cold formed into a coil spring with the aid of numerically controlled tools of the forming device during a forming operation (spring winding operation). The feed device installed fixedly on the machine wall has wire guides to prevent a deflection of the wire caused by the winding process.

A “mandrel carriage” is attached to the machine wall and constitutes a key element of a cutting unit, the purpose of which is to separate a finished spring from the feed wire and act as a shearing edge or as a corresponding element for the cutting tool during the cutting process. The mandrel is attached to a mandrel casing (not illustrated in greater detail) or is received by the mandrel casing. The mandrel casing is received in the mandrel carriage in an opening formed with a positive fit, generally in a rectangular opening. The mandrel carriage can be displaced within the opening in the axial direction, parallel to the longitudinal axis of the spring or the y-axis of the machine coordinate system. The possibility of axial displacement can be utilized in the manufacturing process for the axial displacement of the trimming mandrel. This is also referred to as “axial mandrel displacement” and optionally driven by a servomotor.

The cutting unit is movable in the vertical direction (parallel to the z-direction of the machine coordinate system) with the aid of a crank mechanism attached to the mandrel carriage such that, when cut, the wire is separated between the mandrel and the cutting tool. When manufacturing right-hand springs, the cutting tool is attached to an upper cutting unit, as illustrated, and a lower cutting unit attached below the mandrel is used when manufacturing left-hand springs.

The mandrel carriage is displaceable as a whole in the vertical direction with the aid of a translatory machine axis. To be able to manufacture different spring diameters and to change from left-hand to right-hand springs, the entire mandrel carriage is moved in the vertical direction, together with the cutting devices and the mandrel attached thereto so that the respective correct mandrel position can be reached (see FIGS. 8A and 9A).

To manufacture spring windings, two winding tools are provided in the example shown, namely an upper winding pin and a lower winding pin. The terms “winding tool” and “winding pin” are used synonymously in this instance. The upper winding pin is retained by an upper winding unit mounted on an upper winding plate which is displaceable via a translatory machine axis (HO-axis) horizontally or parallel to the feed direction of the wire (X-direction of the machine coordinate system). The upper winding unit is displaceable in a linear manner on the upper winding plate at an angle of 65° to the horizontal via a controlled machine axis (YO-axis). The lower winding pin is retained by a lower winding unit mounted on a lower winding plate which is displaceable in a horizontal manner via a translatory machine axis (HU-axis). The lower winding unit can move the lower winding pin in a linear manner by a translatory machine axis (YU-axis) in a direction of movement 65° to the horizontal. In the example, the winding units are movable independently of one another along their linear axes of movement via their own crank mechanisms. Each of the winding pins is positioned at 20° to the direction of movement of the respective winding units so that they engage with the spring at an angle of 45° to the horizontal or to the feed direction of the wire. There are also spring winding machines having only a single winding pin, which then engages substantially horizontally, that is to say parallel to the feed direction.

In other examples, the orientations of the axes of movement, for example, the YO-axis and the YU-axis, and/or of the winding tools in relation to the parts of the winding units receiving them can deviate from the values mentioned.

By controlling the individual drives of the machine axes accordingly, springs having very different geometries, in particular cylindrical coil springs, conical springs, double conical springs, springs with turned grooves at the ends, springs of varying pitch, springs with curved spring axes, springs with tangentially protruding spring ends and the like, can be manufactured using this machine design.

To change the machine from right-hand winding to left-hand winding, the mandrel carriage is moved vertically. It is rotated if a mechanical coupling is provided between the winding plates. If there is still no cutting tool at the lower cutting unit, one is attached.

A spring winding machine according to an example is illustrated schematically in FIG. 4. Like or functionally like or corresponding components and assemblies compared to FIG. 3 are denoted by like reference signs compared to those used with the spring winding machine of FIG. 3, increased by 100. Compared to the prior art (FIG. 3), the spring winding machine is characterized by a more simple construction in the region of the winding units. Full versatility for the manufacture of different spring geometries is retained.

A particular feature of this example lies in the fact that the feed device is pivotable relative to the machine wall about a pivot axis extending parallel to the mandrel axis of the mandrel. The pivot axis extends in the y-direction of the machine coordinate system. The component of the feed device supporting the rolls sits in a recess in the machine wall for this purpose. The mechanism for carrying out the pivoting movement is not illustrated in detail. For
example, the pivoting movement can be achieved via a cam, via a cylinder, via a spindle, or the like. A corresponding machine axis (SQ-axis) for the pivoting movement is connected to the control device such that the pivoting movement can be carried out under the control of the NC control program, even during a forming operation for the manufacture of a coil spring. A further modification with respect to the conventional spring winding machine from FIG. 3 lies in the fact that the upper winding unit 440 and the lower winding unit 450 are mounted commonly on a single rigid winding plate 442, that is to say a winding plate mounted in an immobile manner. The corresponding machine axes (HO-axis and HU-axis) in FIG. 3B) can thus be omitted. The linear axes of movement of the two winding units run, for example, at 45° to the horizontal, and therefore the respective winding tools 444 (upper winding tool) and 454 (lower winding tool) are each aligned with the direction of movement of the respective winding unit.

[0077] In this arrangement, only the linear movement along the direction of movement of the winding units located, for example, at 45° to the horizontal is necessary as the only degree of freedom for the movement of the winding units. The design with regard to the winding units is thus less complex than in the prior art and can be implemented in a more stable manner. Further degrees of freedom of movement of the winding units can be omitted, since the spring axis or spring center FZ can adopt the same fixed position in the case of right-hand and left-hand springs and the winding units can thus always move over the same trajectory BK, irrespective of which spring diameter or which winding direction has to be manufactured (see FIGS. 8B and 9B).

[0078] Similarly to the example of FIG. 4, the spring winding machine 500 according to the example of FIG. 5 has a pivotable draw-in device 510 pivotable about a horizontal pivot axis 512 with the aid of a suitable machine axis (SQ-axis), wherein the pivot axis 512 is oriented parallel to the mandrel axis of the mandrel 535. In this example, the mandrel 535 or the mandrel casing 536 supporting the mandrel is mounted rigidly on the machine wall 502, however, since mandrel displacement in the vertical direction (when converting from left-hand to right-hand springs and/or when winding springs of varying diameter during the spring winding operation) can be omitted. There is accordingly also no linearly placeable mandrel carriage and the drive components of the respective machine axis (V-axis in FIG. 3) can be omitted.

[0079] Similarly to the example of FIG. 4, the two winding units (upper winding unit 540, lower winding unit 550) are mounted on a common winding plate 542 and, in the example, can be moved in a linear manner at 45° to the horizontal direction via the respective machine axes. The winding plate as whole is mounted on the machine wall to be vertically placeable via suitable guides and can be placed in the vertical direction with the aid of a translatory machine axis (VW-axis).

[0080] With this design, spring manufacture is controlled such that the current spring winding (that is to say the spring winding which is currently in contact with the winding pins and is thus produced by forming) always runs directly along the mandrel 535 so that the wire or the spring is at all times located in a cutting position, in which separation by the cutting tool 534 of the respective cutting unit 530 is possible. A favorable cutting position of the mandrel is characterized in that the mandrel is either in slight contact with the inner face of the wire (tangential contact of the trimming mandrel against the inner face of the spring) or is located merely at a short gap or at a very short distance therefrom. For example, the finite distance between wire and mandrel may be the same as the wire diameter or less. Plastic deformations of the wire caused by the cutting process are thus avoided.

[0081] The spring F can be positioned relative to the mandrel 535 via the pivoting movement of the feed device 510. The different positions for different diameters and for right-hand and left-hand springs can be deduced from FIGS. 8 and 9 and from the respective parts of the description.

[0082] The examples of FIGS. 4 and 5 show, by way of example, that when using a pivotable feed device, merely one vertical linear relative displacement between the mandrel and the two winding units has to be enabled to obtain full versatility for the manufacture of left-hand and right-hand springs. This possibility for adjustment of different relative positions between the mandrel and the winding units is achieved by the vertically placeable mandrel carriage in the example of FIG. 4 and, therefore, the winding plate 442 can be mounted fixedly. By contrast, in the example of FIG. 5, the two winding units 540, 550 are vertically placeable together by vertical movement of the winding plate 542 supporting them, whereas the mandrel 535 or the mandrel casing does not require a degree of freedom of movement in the vertical direction and is accordingly mounted rigidly in this direction.

[0083] Tests we carried out have shown that the omission of a movable mandrel carriage or the measure of installing the mandrel or the mandrel casing with the mandrel incorporated therein directly in the front wall (machine wall) of the main body of the spring machine results in considerable advantages for the design of the spring winding machine and also for the function thereof and the quality of the springs manufactured thereby. For comprehension, it is to be considered that, in the case of conventional machines of the type shown in FIG. 3, the main body of the spring machine is divided by the mandrel carriage into a left and right half, wherein, in the examples shown, the feed device is mounted on the left half and the winding units are mounted on the right half. Design measures should ensure that the overall rigidity of the system is not impaired by this division of the main body into two halves. If the overall rigidity of the system is not sufficient, this can sometimes become evident in the wear behavior of the tools involved in the cutting process.

[0084] Due to the fixed arrangement of the mandrel or of the mandrel casing, not only can the complexity of the design of the spring winding machine be reduced, but a considerable increase in the overall rigidity in the cutting system (cutting mandrel, cutting blade, cutting slide or the like) can also be increased considerably. The trimming plane is shifted by the program-controlled movability of the feed device. The requirement of tangential contact of the mandrel against the inner face of the spring can thus be met and achieved for different springs. The omission of a movable mandrel carriage may also offer the following advantages, inter alia: simpler design, lower manufacturing costs, greater rigidity of the overall system, possibility of direct attachment of the trimming tools to the main body of the spring winding machine, longer service lives of the trimming tools, simpler fastening of the trimming tools, no division of the main body into a left and right half, and simpler assembly of the different components.

[0085] With reference to the spring winding machine 600 according to the example in FIG. 6, another possibility is explained to achieve full versatility when manufacturing a
wide range of coil springs with the omission of a movable mandrel carriage. In the example of Fig. 6 also, the mandrel 635 or the mandrel casing 636 supporting the mandrel is mounted fixedly (not to be displaceable in the vertical direction) on the front machine wall 602 of the spring winding machine. Components of the cutting devices also do not have to be movable in a vertical manner above and below the mandrel, but can be mounted fixedly on the front wall. The upper winding unit 640 and the lower winding unit 650 are mounted on a common winding plate 642 which is movable vertically in a program-controlled manner via a translatory machine axis.

[0086] Versatility in terms of wire feed is achieved in this case since the feed device 610 is movable in a program-controlled manner along a vertical translatory movement direction parallel to the z-direction of the machine coordinate system. It is thus possible for the feed direction of the wire to be extended horizontally or in the x-direction or at 45° (or another angle) to the winding tools at all times. At the same time, however, the wire feed can be adapted to different winding diameters, wherein the mandrel can rest against the inner face of the front machine wall at all times. With the vertically displaceable feed device, the requirement of tangential contact of the trimming mandrel against the inner edge of the spring can thus also be met and achieved for a wide range of springs. In addition, it is possible to achieve a fixed spring center at all times during spring manufacture (see Figs. 8D and 9D and the respective parts of the description).

[0087] The vertical relative movability between the mandrel and the winding fingers is achieved in the example of Fig. 6 since the winding units can be vertically adjusted together and synchronously with one another by moving the winding plate 642 supporting them.

[0088] Alternatively, it would also be possible to install the two winding units on a fixedly mounted winding plate and design the mandrel or the mandrel casing comprising the mandrel to be movable in a linear manner with the aid of a vertically displaceable mandrel carriage. This is also possible in combination with a feed device which is likewise movable in a vertical manner.

[0089] Similarly to the example in Fig. 6, the spring winding machine 700 in Fig. 7 has a program-controlled, vertically displaceable draw-in device 710 and a mandrel casing 736 which comprises a mandrel 735 and is mounted fixedly on the front wall of the machine. A mandrel carriage is not provided and, therefore, the design is less complex and highly rigid. In contrast to the example of Fig. 6, the upper and the lower winding unit 740 and 750 are mounted on separately controllable winding plates 742 and 752, similarly to the conventional machine in Fig. 3, and can therefore be moved horizontally independently of one another.

[0090] In each of the examples of Figs. 4 to 7, the mandrel is received in a mandrel casing (not illustrated in greater detail). The mandrel casing can be displaced parallel to the longitudinal axis of the spring (parallel to the y-direction of the machine coordinate system). This possibility for axial displacement can be utilized in the manufacturing process for the axial displacement of the mandrel mandrel ("axial mandrel displacement"), which may possibly be driven by a servomotor. The "axial mandrel displacement" function is used, for example, in the manufacture of springs when the wire would collide with the trimming mandrel during the manufacturing process. In this case, the trimming mandrel is moved away from the collision area of the spring by the axial movement of the mandrel casing. Once the spring has been formed, the trimming mandrel is moved back into the cutting position with the mandrel casing to trim the spring.

[0091] With reference to Figs. 8 and 9, different positions of the winding tools or winding pins for different spring diameters are illustrated together with the respective position of the mandrel and the respective position of the spring axis to explain the coordinated movements of the respective machine axes during spring manufacture. In all sub-figures of Figs. 8 and 9, the wire DR is fed from the left by a feed device (not shown), parallel to a feed direction DZ with a definable advance speed profile of the forming device. The forming device has an upper winding unit WEU comprising the upper winding tool (winding pin) WZO and a lower winding unit WEU comprising the lower winding tool WZU. The mandrel DO, which is semi-circular in cross section, forms the vertical cutting edge SK, which cooperates with the vertically movable cutting tool SW during the separation process. Each winding of the spring defines the position of the spring center FZ as a center point of the circle which is defined by the spring winding. In each case, reference sign BK denotes the trajectory of the position in which the contact point between the winding tool and the wire moves when the spring diameter changes. These references apply to all sub-figures in Figs. 8 and 9. Fig. 8 shows the relative positions during manufacture of right-hand springs, whereas Fig. 9 shows corresponding positions during manufacture of left-hand springs.

[0092] Fig. 8A shows the relative machine axis movements during manufacture of a right-hand spring with a conventional spring winding machine, in which the mandrel DO is movable in a vertical manner by the vertically movable mandrel carriage and the winding units can be moved independently of one another (see Fig. 3). Since the feed device is mounted in a fixed manner, that is to say to be immobile, the feed direction DZ of the wire remains unchanged in terms of position and orientation with all spring diameters and, therefore, the wire DR is fed horizontally at a specific height and always parallel to the x-direction of the machine coordinate system. It can be seen that, during manufacture of spring windings, the mandrel DO has to be moved increasingly further upwards with increasing diameters so that the mandrel rests against the inner face of the developing spring winding at all times. The position of the spring center FZ shifts with increasing winding diameter, likewise in an upwards direction. The upper winding unit and the lower winding unit require a few degrees of freedom to always ensure the radial support of the spring winding with the aid of the winding tools. When manufacturing springs having different winding diameters in the axial direction, the movements of the corresponding machine axes are to be coordinated in a phase-correct manner via the control unit. When the spring machine is changed to fabrication of springs with cylindrical spring diameter, the movements are likewise to be carried out, but temporal coordination can be omitted.

[0093] Corresponding situations emerge with the manufacture of left-hand springs according to Fig. 9A.

[0094] In Figs. 8B and 9B, machine axis movements are shown for the eventuality of a spring winding machine which has a feed device pivotable about a horizontal pivot axis and in which the mandrel DO is also attached to a vertically movable mandrel carriage (see Fig. 4). It can be seen that, by pivoting the feed device according to the diameter of the spring winding to be produced, the feed direction DZ of the wire can be set such that the feed direction of the wire extends
tangentially to the current spring winding. For larger diameters, the feed device is thus pivoted further downwards than with smaller diameters. To ensure that the mandrel DO rests against the inner face of a spring winding at all times, irrespective of winding diameter, the mandrel carriage is moved vertically with the mandrel DO attached thereto. With this approach, the position of the spring center FZ in relation to the machine coordinate system remains constant, irrespective of the winding diameter. At the same time, the winding units WEO and WEU each require only a translatory degree of freedom, namely the linear movement in the movement direction inclined, for example, by 45° to the horizontal. Since the spring axis FZ adopts a fixed position (FIG. 8B in the case of a right-hand spring and FIG. 9B in the case of a left-hand spring) and the winding units thus always move over the same trajectory BK, no additional degree of freedom of the forming tools is necessary, irrespective of which spring diameter or which winding direction is to be manufactured (see example in FIG. 4).

FGS. 8C and 9C illustrate movements of machine axes in an example according to FIG. 5, in which the mandrel DO is attached rigidly to the machine body and in which a feed device is also provided pivotally about a horizontal pivot axis. In this example, which does not require a movable mandrel carriage, the adaptations to different spring winding diameters are achieved by additional degrees of freedom of the winding units WEO and WEU by mounting the winding units commonly on a single winding plate which allows a program-controlled vertical movement relative to the fixed mandrel DO. With this design, spring manufacture is spring-controlled independently of the current spring diameter so that the current spring winding runs directly along the mandrel and is thus located in the cutting position at all times. The relative positioning of the wire to the rigid mandrel is enabled by the pivoting movement of the feed device.

FGS. 8D and 9D illustrate the movements of the winding units and of the feed device in an example according to FIG. 6, in which the feed device is vertically linearly movable in a program-controlled manner so that the feed direction DZ of the wire always extends horizontally (parallel to the x-direction of the machine coordinate system), but can be located at different heights. In this case, when manufacturing springs of different diameter, the vertical position of the feed device is always controlled such that the fed wire extends in the direction tangential to the current spring winding. The mandrel is always in contact with the current spring winding. To produce spring windings of different diameters, the feed device is accordingly moved vertically and the winding units are also moved synchronously and vertically, which is achieved in the example of FIG. 6 by mounting both winding units on a common, vertically movable winding plate.

It is also possible, with the aid of a vertically movable draw-in assembly, to achieve a fixed spring center. To this end, the movable draw-in assembly can be combined with a mandrel which is likewise movable and which is supported by a mandrel carriage.

1. A method of manufacturing springs by a numerically controlled spring machine comprising feeding a wire in a feed direction to a forming device of the spring winding machine by a feed device under control of a control program:

forming the wire into a spring with the aid of tools of the forming device in a forming operation;

the forming device having a mandrel with a mandrel axis oriented at right angles to the feed direction, and windings of the spring surrounding the mandrel during the forming operation; and

adjusting a position and/or orientation of the feed device with the aid of a controllable machine axis during the forming.

2. The method according to claim 1, wherein a spring having windings of different winding diameter is produced during the forming operation, and wherein the position and/or orientation of the feed device is/are changed during the forming operation such that the feed direction defined by the feed device always extends substantially tangentially to a winding of the spring just being produced.

3. The method according to claim 1, wherein a spring having windings of different winding diameter is produced during the forming operation, and wherein the mandrel does not move at right angles to the mandrel axis during the forming operation.

4. The method according to claim 1, wherein the spring machine is a spring winding machine and the mandrel is a winding mandrel rotateable about the mandrel axis by a rotary machine axis and rotated about the mandrel axis during the forming operation.

5. The method according to claim 4, wherein a spiral spring is produced during the forming operation.

6. The method according to claim 4, wherein, before manufacture of a spiral spring is begun, the position and/or orientation of the feed device is/are set such that a front wire end can be introduced into a transverse slit in the winding mandrel, after which the wire is then introduced into the transverse slit by the feed device, and after which the further forming operation then takes place, in which the wire is wound as the winding mandrel is rotated, the position and/or orientation of the feed device preferably being changed during the winding process such that the feed direction defined by the feed device always extends substantially tangentially to a winding of the spring just being produced.

7. The method according to claim 1, wherein the spring machine is designed as a spring winding machine and has a cutting unit with a movable cutting tool that separates the finished spring from the fed wire, the mandrel being located inside the spring during the separation process and having a cutting edge which cooperates with the cutting tool during the separation process.

8. The method according to claim 7, wherein, when a spring having windings of different winding diameter is manufactured, the position and/or orientation of the feed device is/are changed during the forming operation so that the mandrel rests against the inner face of the wire during each phase of the forming operation or is arranged at such a short distance from the inner face of the wire that, during a cutting operation, the mandrel immediately supports the wire against the action of the cutting blade.

9. A spring machine that manufactures springs by spring winding or spring coiling under control of a control program comprising:

a plurality of controllable machine axes;
a control device that coordinates control of axial movements of the machine axes of the spring machine on the basis of a control program;
a feed device that feeds wire (DR) in a feed direction (DZ) in a region of a forming device of the spring machine; and

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a mandrel with a mandrel axis oriented at right angles to the feed direction, the mandrel being positioned or positionable such that windings of the spring surround the mandrel during the forming operation, wherein the feed device is an adjustable feed device in which the position and/or orientation of the feed device is/are adjustable with the aid of one of the controllable machine axes during production of a spring.

10. The spring machine according to claim 9, wherein the machine axis associated with the feed device is controllable such that, during a forming operation for a spring having windings of different winding diameters, a feed direction (DZ) defined by the feed device always extends substantially tangentially to a winding of the spring just being produced.

11. The spring machine according to claim 9, wherein the spring machine is a spring winding machine and the mandrel is a winding mandrel rotatable about the mandrel axis by a rotary machine axis, the winding mandrel additionally being movable parallel to the mandrel axis by a translatory machine axis.

12. The spring machine according to claim 9, designed to carry out the method of manufacturing springs by a numerically controlled spring machine comprising feeding a wire in a feed direction to a forming device of the spring winding machine by a feed device under control of a control program: forming the wire into a spring with the aid of tools of the forming device in a forming operation; the forming device having a mandrel with a mandrel axis oriented at right angles to the feed direction, and windings of the spring surrounding the mandrel during the forming operation; and adjusting a position and/or orientation of the feed device with the aid of a controllable machine axis during the forming operation.

13. The spring machine according to claim 9, wherein the spring machine is a spring winding machine, the forming device has at least one winding tool which basically determines the diameter of the coil spring in a predefinable position, a cutting unit with a movable cutting tool that separates the finished spring from the fed wire is provided, and the mandrel is located inside the spring during the separation of the spring and has a cutting edge (SK) which cooperates with the cutting tool (SW) during the separation process.

14. The spring machine according to claim 13, wherein the mandrel is received in a mandrel casing and the mandrel casing is displaceable in a linear manner parallel to the mandrel axis, a controlled machine axis being provided for this displacement.

15. The spring machine according to claim 13, wherein the mandrel and/or a mandrel casing supporting the mandrel is/are attached rigidly to the machine body of the spring winding machine such that the mandrel has no degrees of freedom of movement for controlled movements at right angles to the mandrel axis.

16. The spring machine according to claim 9, wherein the feed device is movable by a translatory machine axis in a linear manner at right angles to the feed direction.

17. The spring machine according to claim 9, wherein the feed device is pivotable in a controlled manner by a machine axis about a pivot axis extending parallel to the mandrel axis of the mandrel.

18. The spring machine which is the spring winding machine that manufactures springs by spring winding or spring coiling under control of a control program comprising: a plurality of controllable machine axes; a control device that coordinates control of axial movements of the machine axes of the spring machine on the basis of a control program; a feed device that feeds wire (DR) in a feed direction (DZ) in a region of a forming device of the spring machine; and a mandrel with a mandrel axis oriented at right angles to the feed direction, the mandrel being positioned or positionable such that windings of the spring surround the mandrel during the forming operation, wherein the feed device is an adjustable feed device in which the position and/or orientation of the feed device is/are adjustable with the aid of one of the controllable machine axes during production of a spring carries out the method according to claim 1.

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