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(54) **DEVICE FOR THE CONTROLLED BRAKING OF PROJECTILES IN A PROJECTILE WEAVING LOOM**

(57) A device for the controlled braking of projectiles in a projectile weaving loom comprises two opposite braking elements (1, 2) parallel to the movement direction of the projectile (P). The braking element (2) is movable and operated by an electric drive, with a linear or rotary

motor, for tightening the projectile (P) between said braking elements (1, 2) with a braking force (F). Said braking force (F) is adjustable, with a feedback control, according to the stopping position of the projectile (P).

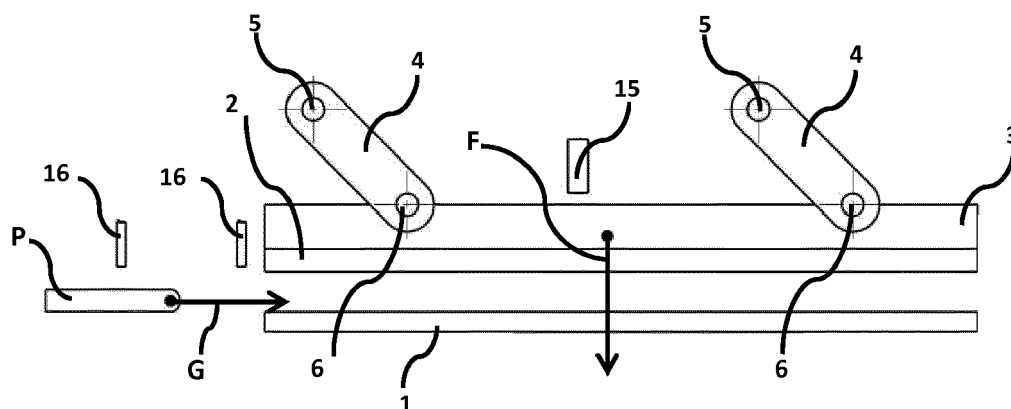


FIG. 1

Description

FIELD OF THE INVENTION

[0001] The present invention relates to a device for the controlled braking of projectiles in a projectile weaving loom. In particular, the invention relates to a braking device, which is controlled both in the braking intensity and in the position of the projectile, for optimally adjusting the braking action on the projectile to obtain stopping thereof, at the end of the weft insertion stroke, in a predetermined position.

STATE OF THE ART

[0002] As known, projectile weaving looms differ from the other types of looms in that the weft yarns are inserted into the shed through a projectile, i.e. a tapered metal body having a suitable mass and shape, along a guiding track. The projectile is loaded into a starting station of the guiding track, external to the shed, and then launched into the shed with any known device, after having gripped to the same the free end of a weft yarn. After the projectile has been launched, the projectile passes through the shed, dragging the weft yarn therewith and thus creating the desired weft insertion.

[0003] At the outlet of the shed (usually in correspondence of the right side of the loom, with reference to the weaver's position) the projectile is slowed down and stopped by a braking device positioned in an arrival station of the guiding track, external to the shed; after the projectile has been stopped, the weft yarn is released from the projectile. The projectile, free from the weft yarn, is then unloaded from the braking device and returned to the launching side of the loom (usually the left side) by means of a suitable removal and transfer system which returns the projectiles to the launching station, where they are again launched within the shed after having coupled them to a new desired weft yarn. Of course, a certain number of projectiles is operative at the same time on a specific loom, which number is determined substantially by the height of the loom and by the speed of the removal and transfer system which returns the projectiles from the arrival station to the starting station.

[0004] Currently the braking device used to stop the projectiles is a mechanical box device, containing an elastomeric material wherein the projectile stops. The elastomeric material comprises parallel upper and lower layers, placed at a mutual distance lower than the thickness of the projectile, between which the projectile is wedged, converting its kinetic energy into elastic compression deformation of the elastomeric material and heat. By modifying the distance between said layers of elastomeric material, a coarse adjustment of the braking intensity can be obtained, due to a quicker or slower wedging of the projectile.

[0005] Braking devices of this type have substantially two drawbacks: a substantial difficulty in accurately con-

trolling the final stopping position of the projectile and a very short service life due to the high fatigue and overheating wear and tear and to the high shear stresses borne by the elastomeric material of the braking device, as a result of the repeated impacts from the projectiles.

[0006] In relation to the first drawback, it should be noted that the final projectile stopping position is variable not only as a function of the degree of progressive wear and tear of the elastomeric material forming the braking device, but also as a function of the residual projectile energy at the beginning of the braking step, which energy can vary depending on the specific weaving conditions. In the projectile looms of the known type it is therefore always necessary to provide a device for repositioning the projectile after the end of the braking step. Such a device picks up the projectile from its actual, uncontrolled and then variable, stopping position, and moves it to a predetermined position suitable for carrying out the weft release and, successively, the projectile removal and transfer.

BRIEF DESCRIPTION OF THE INVENTION

[0007] The problem addressed by the present is therefore that of overcoming the above-described drawbacks of the current projectile braking devices in projectile looms, allowing, firstly, to adjust with sufficient precision the final stopping position of the projectile, regardless of the wear conditions of the braking device and of the level of residual energy with which the projectile enters said device and, secondly, to increase significantly the service life of the device.

[0008] A first object of the present invention is therefore to propose an active-type braking device for projectiles, wherein there is a braking element provided with adjustable position and force, to modulate the intensity of the braking action on the incoming projectile, to determine the stopping of the projectile in a predetermined desired position.

[0009] A second object of the present invention is then to propose a braking device for projectiles wherein the braking elements do not operate on the basis of their own elastic deformation, but on the basis of the frictional force alone. Moreover, said frictional force is developed during a braking stretch having a predetermined length determined to keep within a suitable range the stress and wear of the employed frictional material, by appropriately distributing the braking action throughout the whole length of said braking stretch. No harmful impact effects, upon contact between the projectile and the braking elements of the braking device, are therefore caused on the braking elements.

[0010] These objects are achieved by means of a device for the controlled braking of projectiles in a projectile loom having the features defined in the appended claim 1. Further preferred features of said braking device are defined in the dependent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Further features and advantages of the device for the controlled braking of projectiles according to the present invention will anyhow become more evident from the following detailed description of some preferred embodiments of the same, given by mere way of non-limiting example and illustrated in the accompanying drawings, wherein:

Fig. 1 is a schematic side elevational view of the device for the controlled braking of projectiles according to the present invention;

Fig. 2 is a perspective view of the movable braking element and relative support body of the braking device of Fig. 1 support body;

Fig. 3 is a view of the support body of Fig. 2 provided with a coil of a linear electric motor;

Fig. 4 is a view of the support body of Fig. 3 further provided with an inverted-w stator to form with said coil a linear motor of which the support body is the movable linear element;

Fig. 5 is a cross-sectional view of the assembly support body/linear motor of Fig. 4;

Fig. 6 is a perspective view of a second embodiment of the movable braking element of the braking device of fig. 1, and the relative drive consisting of a rotary electric motor; and

Fig. 7 is a sectional view of the assembly support body/linear motor of Fig. 4 comprising a preferred embodiment of the fixed braking element wherein several identical fixed braking elements are incorporated in a projectile withdrawal wheel.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0012] According to the present invention, in order to achieve the appointed objects and thus to solve the problem described above, an electrically operated braking device through which the speed of the projectile is progressively reduced until its complete stopping, by exploiting the frictional force arising from the contact between the projectile surfaces parallel to its moving direction and two opposite braking elements of the braking device, made with a suitable friction material, is provided.

[0013] As schematically illustrated in fig. 1, the braking device of the present invention preferably comprises a fixed braking element 1, aligned with the guiding track of the projectile P and an opposing movable braking element 2, mutually parallel and spaced apart to the extent necessary to allow the projectile P to enter between them, at the end of the weft insertion stroke, where the braking device of the invention is positioned. In the embodiments show in the drawing, the fixed braking element 1 is the lower braking element of the device and is securely fixed to the supporting structure of said device; on the other hand, the movable braking element 2 is fixed to the lower

portion of a movable support body 3. Preferably, support body 3 can perform two different movements according to two degrees of freedom, i.e. both a movement in the moving direction G of the projectile P entering the braking device and a movement in the direction F, orthogonal to moving direction G, to apply the braking force and to compensate the progressive wear of the friction material of the braking elements 1 and 2. Furthermore, the two above said movements are mutually connected in such a way that a movement of the support body 3 in the direction G causes a simultaneous movement of the same support body 3, and therefore of the braking element 2, in an opposite direction in respect of the braking direction F.

[0014] In the illustrated preferred embodiment, said mutual connection of the two degrees of freedom of the support body 3, in the directions F and G, is obtained thanks to an articulated parallelogram connection between the support body 3 and the supporting structure of the braking device. In this way, the friction force exerted by the projectile P on the opposing braking element 1 and 2, which tends to move the upper braking element 2 in the direction of the arrow G, also moves the braking element 2 in a opposite direction in respect of the arrow F and therefore tends to "open" the braking device in opposition to the "closing" braking action on the same better discussed below. This makes the braking action more gradual and avoids any possible risk of "jamming" the projectile P between the braking elements 1 and 2, which would block the braking device.

[0015] Said articulated parallelogram connection is preferably obtained by a pair of connecting rods 4 of equal length, hinged at one end thereof (5) to the supporting structure of the braking device (not shown) and at the other end (6) to the support body 3. The angular displacement of the two connecting rods 4 is therefore the same, and involves a translation, and the simultaneous raising/lowering of the support body 3, which however always remains parallel to itself and to the sliding path of the projectile P. The movable support body 3 performs several functions, namely:

- it supports the movable braking element 2;
- it has a shape suitably designed to optimize the dissipation of heat generated during the braking step;
- it is the parallelly translating element of the articulated parallelogram comprising also the connecting rods 4, whose displacement is detected and processed to control the braking operation;
- it optionally allows a direct application of the braking force, in the embodiment where the braking device drive is a linear actuator integral with said support body 3.

[0016] The braking device of the invention can in fact be driven either by means of a linear electric motor, the movable part of which is integral with the support body 3, or by means of a rotary electric motor which, by means

of any suitable kinematic mechanism, per se known, applies a mechanic moment to one of the connecting rods 4 of the support body 3. In the following paragraphs, merits and limits of these two types of drives of the braking device will be discussed.

[0017] A possible embodiment of a linear electric motor applied to the support body is shown in figs. 3 to 5, where this motor is composed of an annular coil 7 having a substantially rectangular shape, wound on a spool 8 which provides its mechanical firmness and allows it to be steadily fixed on the support body 3. The coil 7, suitably sized and mechanically integral with the support body 3, thus is the movable element of the linear electric motor. The fixed element or stator 9 of said linear electric motor is instead formed by a ferromagnetic core having an up-turned ω cross-section shape, as shown in fig. 5. On the internal sides of the two external leg of stator 9, permanent magnets 10 are fixed, while the central leg of the stator 9 is inserted inside the coil 7. The stator 9 is obviously integral with the supporting structure of the braking device, whereas between the stator 9 and the coil 7 there is a longitudinal clearance which is sufficient to allow the longitudinal movement due to the articulation of the support body 3. Since this movement has in any case a very limited extent, the rectangular structure of the coil 7 can be kept inside the magnetic field generated by the magnets 10 in every working condition, so maintaining the efficiency of the linear motor almost constant while the position of the support body 3 changes.

[0018] The main advantage of the above said linear drive of the support body 3 is that the braking force provided by the linear electric motor is directly charged onto the projectile P underlying the movable braking element 2, said braking force being also well-balanced and evenly distributed both crosswise and lengthwise with respect to the support body 3. The drawback of the linear drive is that the Joule effect heat developed by the coil 7 during its operation is partly transferred by conduction directly to the support body 3. This impairs the ability of support body 3 of dissipating heat developed by the braking action on the projectile P and ultimately increases the temperature of said projectile. It may therefore be useful to resort to a forced cooling of the support body 3, by providing a circulation of cooling fluid in suitable internal channels of the same.

[0019] A second type of drive of the braking device of the invention, as already said, consists of a position-controlled rotary electric motor M. The torque provided by motor M can be directly applied to the rotation fulcrum of one of the connecting rods 4, thus obtaining a transmission ratio $T=1$ between motor angle and connecting rod angle. The main limitation of such a system would however be to require very high torque values for developing the necessary braking forces. For high weaving speeds it would therefore be necessary to use large motors, characterized by high rotor inertias, which would impair the operational rapidity of the braking device. Another limit of such a direct drive would be the precision in the position

control of the support body 3, due to the unitary transmission ratio which makes necessary to resort to very short connecting rods 4.

[0020] Fig. 6 shows a preferred embodiment of the mechanical connection between rotary electric motor M and one of the connecting rods 4, which allows said mechanical moment to be applied to the connecting rod 4 of the parallelogram as a result of a driving torque on a crank 11 of an articulated quadrilateral comprising connecting rods 12 and 13, wherein the connecting rod 13 is integral with the connecting rod 4, having a common centre of rotation 6 on the support body 3. The lever ratio obtained through the crank 11 and the articulated quadrilateral formed by the connecting rods 12 and 13 allows to have a transmission ratio $T < 1$ between motor angle and connecting rod angle, thus reducing the driving torque of motor M for obtaining a desired braking force. Moreover, the above said lower transmission ratio allows a better angular resolution of the support body 3 movement.

[0021] The above illustrated drive solution then has the significant advantage that any overheating of the motor M does not affect the thermal condition of the support body 3 and, consequently, the temperature of the braking element 2 depends only on the room temperature and on the heat produced by friction during the braking action on the projectile P. Moreover, the geometric shape of the support body 3 in this case can be modified, by adding cooling fins as shown in fig. 6 to obtain a deeper cooling action of the support body 3 and of the braking element 2, as an alternative or an additional cooling means with respect to the forced cooling obtained by internal circulation of a cooling fluid as above disclosed in relation to the linear motor embodiment.

[0022] Among the drawbacks of the rotary drive, it should be noted that, unlike the linear drive, the braking force applied to the support body 3 is not evenly distributed on the support body itself but is applied in one definite point, i.e. at the connecting rod 13. The correct spreading of this braking force over the whole support body 3 is therefore conditioned by the rigidity of the same support body 3 and by the clearances in the articulated joints of the mechanism.

[0023] Finally, another advantage of the rotary drive, in respect of the linear drive, is a lighter mass of the movable portion of the mechanism - i.e. the support body, 3 devoid of the coil 7 forming the movable element of the linear motor - which improves the dynamic performance of the system. The driving shaft of motor M preferably comprise an intermediate elastic coupling 14 for damping the impulsive torques on the driving shaft generated by the contact between braking element 2 and the projectile P entering the braking device.

[0024] The braking device according to the invention is operated by an electronic controller, according to a special program providing two different, alternately operating modes. In a first operating mode, a force-control is implemented, based on the assumption that the force applied by the support body 3 in an orthogonal direction

to the projectile P is equal to the force provided by the linear drive, or directly proportional to the torque provided by the rotary drive. Since this force or torque are both directly proportional to the electric current supplied to the respective motors, the electronic controller, by adjusting the intensity of the electric current, can accurately and continuously modify the braking force orthogonally applied to the projectile P. In a second operating mode, a position-control is instead implemented, based on a position sensor 15 (Fig. 1) which detects the height of the support body 3 in respect of a fixed reference frame and then adjusting, for example by means of a PID regulator, the force/torque provided by the motor, to maintain the height of the support body 3 to a desired set value.

[0025] During the free flight step of the projectile P within and across the shed, the movable support body 3 is position-controlled, and its height is adjusted to a waiting position higher than the thickness of the projectile P, thus ensuring that when the projectile P enters the braking device there is no interference between projectile P and the upper braking element 2 of the braking device. Upon arrival of the projectile P in front of the braking device of the invention, two successive sensors 16, positioned at the entry of the braking device, activate the braking device and at the same time allow to calculate the speed of projectile P. In an alternative embodiment, when speed of the projectile P is already known from other devices, a single sensor 16 is sufficient to determine the time when the projectile P enters the braking device.

[0026] As soon as the braking device is activated, the distance between the upper support body 3 and the projectile P is gradually reduced through a controlled movement of support body 3, bringing these two elements into mutual contact only when the projectile P is completely onboard of the braking device. Based on the estimated friction coefficient and the speed of the incoming projectile P, the orthogonal force F to be applied to the latter to obtain a braking stretch having the desired length is calculated and the electric current necessary to provide this force is then supplied to the electric motor of the device. Since the braking element 2 is already in contact with the projectile P, the force F is instantly applied to the same and the projectile P is readily slowed down until a complete stop thereof. The projectile P is then kept compressed between the two braking elements 1 and 2 also when the projectile P is completely stationary - preferably with a reduced force compared to the force used during the braking step - to make the most of the available times to dissipate the heat, transferring it from the projectile P to the braking device.

[0027] In this step there is also a new reading of the position sensor 15 of the support body, which will be subsequently used to determine the expected height of the next projectile P, thus compensating each time the progressive wear of the braking elements 1 and 2. Subsequently, the electronic controller goes back to the position-control mode, bringing the support body 3 to a position suitable for unloading the projectile P from the brak-

ing device. Once the projectile P has been unloaded from the braking device, the position-control mode of the support body 3 remains active and the height of the support body 3 is brought to the above said expected height of the next incoming projectile P.

[0028] Previously it has been stated that the braking force F is calculated at each new projectile P entering the braking device, based on the speed of projectile P and the coefficient of friction of the braking elements 1 and 2. However, the coefficient of friction is not constant, but it varies over time due to temperature, wear, and possible foreign material on the braking elements, such as oil and dirt residues. In view of this, the coefficient of friction is preferably obtained dynamically from the electronic controller. This is achieved by implementing an integral regulator aimed at maintaining the length of the braking stretch at the set value, and acting precisely on this coefficient of friction, by means of a feedback control based on the stopping position of the projectile P.

[0029] In practice, at each incoming projectile the actual braking stretch is detected by means of a suitable sensor and the error in respect of the set stopping position is calculated. Through a suitably weighed constant (K_i of the integral regulator) the estimated coefficient of friction is modified up to obtain in a running condition, on average, the desired set braking stretch. The so obtained constant K_i of the integral regulator is then increased to $K_i + \Delta$ during any restart step of the weaving machine, to have a quick adjustment of the braking device to the coefficient of friction of the braking elements not yet in thermal stationary conditions.

[0030] The braking device according to the invention can be effectively associated with a wheel unloading device as disclosed in the patent publication EP-3037575 in the name of the same Applicant. As a matter of fact, in a wheel unloading device of this type, an exemplary schematic representation of which is shown in fig. 7, the fixed braking element 1 can advantageously be made in multiple form, i.e. by providing a plurality of braking elements 1 secured in several circumferential positions of an unloading wheel Rs. The axis of rotation of the unloading wheel Rs is parallel to the travelling direction of the projectile P, so that its rotation brings the different fixed braking elements 1, from time to time, first in correspondence with the loading station 17, where the braking elements 1 are located exactly in correspondence with the mobile braking element 2 of the above-disclosed braking device, and subsequently, in correspondence with the discharge station 18, from which the projectiles P are returned to the initial launching station. As a matter of fact, in correspondence with each fixed braking element 1, suitable magnetic or mechanical fastening means are provided for temporarily keeping said projectiles P associated with a correspondent fixed braking element 1 during their movement between the loading station 17 and the unloading station 18. In fig. 7 the unloading station 18 has been indicated, merely by a way of example, in a position at 180° with respect to the loading station

19; however, the position of the unloading station 18 is in no way angularly limited and can be positioned in any useful position different from the loading station 17, depending on the particular arrangement of parts of the single loom where the braking device of the invention is set up.

[0031] The use of a plurality of fixed braking elements 1 provided on the unloading wheel Rs shows, in addition to the apparent advantage of combining in a single device the projectile braking function as well as the projectile removal and transfer function, also another not less essential advantage, i.e. to allow a good natural dissipation of the braking heat from the projectiles P, during their movement from the loading station 17 to the unloading station 18, and to considerably lengthen the service life of each single braking element 1.

[0032] Naturally, when adopting an unloading wheel Rs comprising a plurality of fixed braking elements 1, the height information read by the position sensor 15 at the end of the braking step and then used to determine the expected height of the next projectile P, also takes into consideration the specific features of the fixed braking element 1 on which one is actually working, to consider any variation in quality, wear or initial positioning thereof.

[0033] It is understood, however, that the invention is not to be considered as limited by the specific embodiments illustrated above, which represent only exemplary implementations of the same, but different variants are possible, all within the reach of a person skilled in the art, without departing from the scope of the invention itself, which is exclusively defined by the following claims.

Claims

1. Device for the controlled braking of projectiles in a projectile weaving loom **characterised in that** said device comprises two opposite braking elements (1, 2) parallel to the movement direction of the projectile (P), wherein at least one braking element (2) is movable and is operated by an electric drive for tightening the projectile (P) between said braking elements (1, 2) with a braking force (F), **and in that** said braking force (F) is adjustable, with a feedback control, depending on the stopping position of the projectile (P).
2. Device for the controlled braking of projectiles as in claim 1, wherein said movable braking element (2) is housed in a support body (3), which support body moves parallel to itself through a pair of connecting rods (4) of equal length pivoted (5) to the supporting structure of the braking device and (6) to the support body (3), the movement of the support body (3) away from the other braking element (1) implying a simultaneous movement of said support body (3) in the same progress direction of the projectile (P).
3. Device for the controlled braking of projectiles as in

claim 2, wherein said electric drive is a position-controlled rotary electric motor (M).

4. Device for the controlled braking of projectiles as in claim 3, wherein the rotary shaft of said electric motor (M) is connected to at least one of said connecting rods (4) through a kinematic mechanism apt to transfer a mechanic moment to said connecting rod (4).
5. Device for the controlled braking of projectiles as in claim 4, wherein said kinematic mechanism is an articulated parallelogram leverage comprising a crank (11) and a first and a second connecting rod (12, 13).
6. Device for the controlled braking of projectiles as in claim 5, wherein said second connecting rod (13) is integral with said connecting rod (4) and has the same centre of rotation (6) thereof on the support body (3).
7. Device for the controlled braking of projectiles as in claim 2, wherein said electric control is a position-controlled linear electric motor.
8. Device for the controlled braking of projectiles as in claim 7, wherein said linear electric motor comprises a coil (7) integral with said support body (3) and a stator (9) integral with the supporting structure of the braking device.
9. Device for the controlled braking of projectiles as in claim 8, wherein said coil (7) has a substantially rectangular annular shape and said stator has an up-turned ω section shape, comprising a central element inserted in the annular cavity of the coil (7) and two peripheral elements on the inner sides of which permanent magnets (10) are fastened.
10. Device for the controlled braking of projectiles as in any one of the preceding claims, wherein said support body (3) is provided with inner channels with circulation of cooling fluid.
11. Device for the controlled braking of projectiles as in any one of the preceding claims, wherein said support body (3) is provided with cooling fins for heat dissipation.
12. Device for the controlled braking of projectiles as in any one of the preceding claims, wherein said feedback control comprises at least one entry sensor (16) for determining the time the projectile (P) enters the braking device and a stopping sensor for determining the stopping position of the projectile (P).
13. Device for the controlled braking of projectiles as in claim 10, wherein said feedback control is based on

the arrival speed of the projectile (P) and on a constant (K_i) representative of the estimated coefficient of friction of said braking elements (1, 2) with the projectile (P), the value of which is updated at each incoming projectile, to obtain on average the set stopping position of the projectile (P) .

movement of said fixed braking element (1) from said loading station (17) to said unloading station (18).

14. Device for the controlled braking of projectiles as in any one of the preceding claims, wherein a position sensor (15) of said support body (3) is further provided, for adjusting the distance between said movable braking element (2) and said fixed braking element (1) in the approaching, entering and stopping steps of said projectile (P) .
15. Device for the controlled braking of projectiles as in claim 14, wherein when approaching of the projectile (P) to the braking device is detected, the position of said support body (3) is adjusted at a height wherein the distance between the movable braking element (2) and the fixed braking element (1) is larger than the thickness of said projectile (P) .
16. Device for the controlled braking of projectiles as in claim 14, wherein when the entry of the projectile (P) in the braking device is detected, the position of said support body (3) is adjusted at a height wherein the distance between the movable braking element (2) and said projectile (P) is adjusted to zero and said braking force (F) is hence imparted.
17. Device for the controlled braking of projectiles as in claim 14, wherein when the stopping of the projectile (P) in the braking device is detected, firstly a new height value of the support body (3) is detected, said height value taking into account the occurred wear of the fixed braking element (1) and of the movable braking element (2), and hence the position of said support body (3) is brought to a height apt to allow unloading of the projectile (P) from the braking device.
18. Device for the controlled braking of projectiles as in any one of the preceding claims, comprising a plurality of fixed braking elements (1) fastened in multiple circumferential positions of an unloading wheel (Rs), which unloading wheel (Rs) displaces said fixed braking elements (1) in succession from a loading station (17), where the braking elements (1) are in correspondence of the movable braking element (2) to an unloading station (18), from which the projectiles (P) are caused to return to the initial launching station.
19. Device for the controlled braking of projectiles as in claim 18, further comprising fastening means for maintaining said projectiles (P) temporarily associated with said fixed braking elements (1) during the

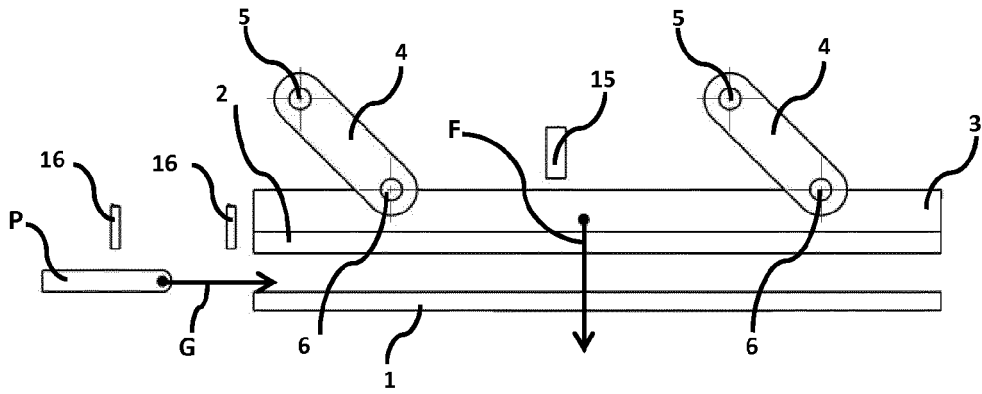


FIG. 1

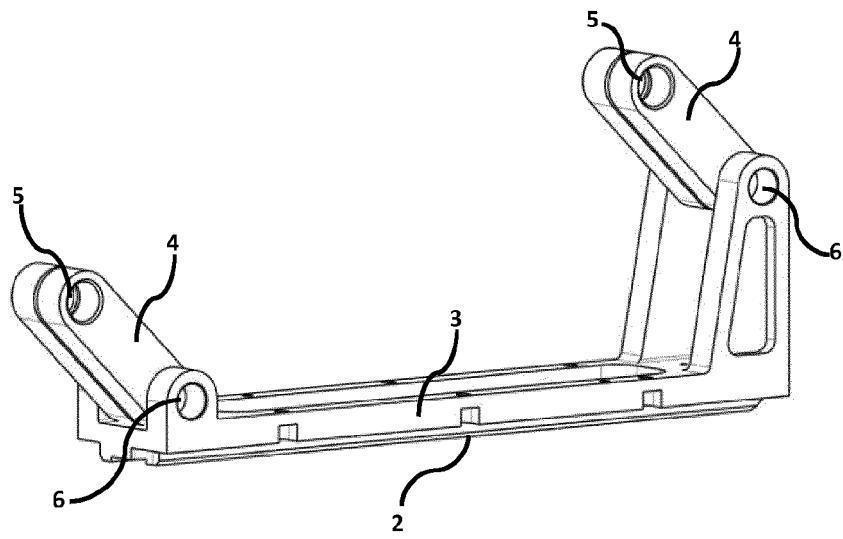


FIG. 2

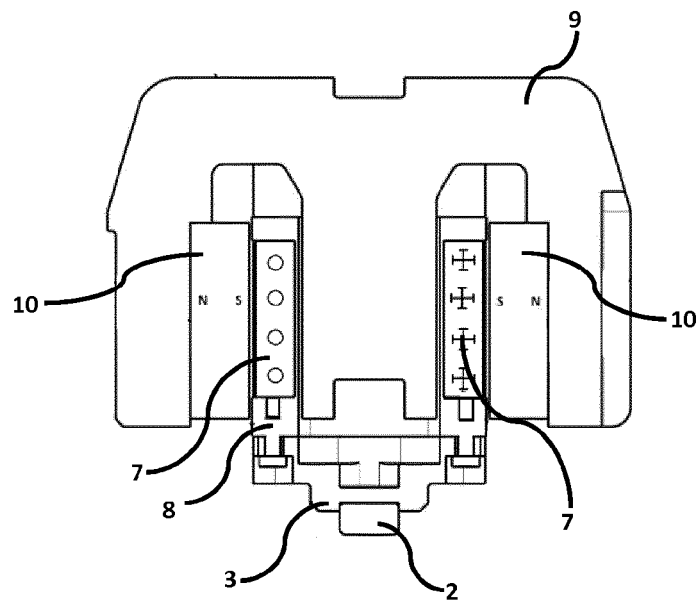


FIG. 5

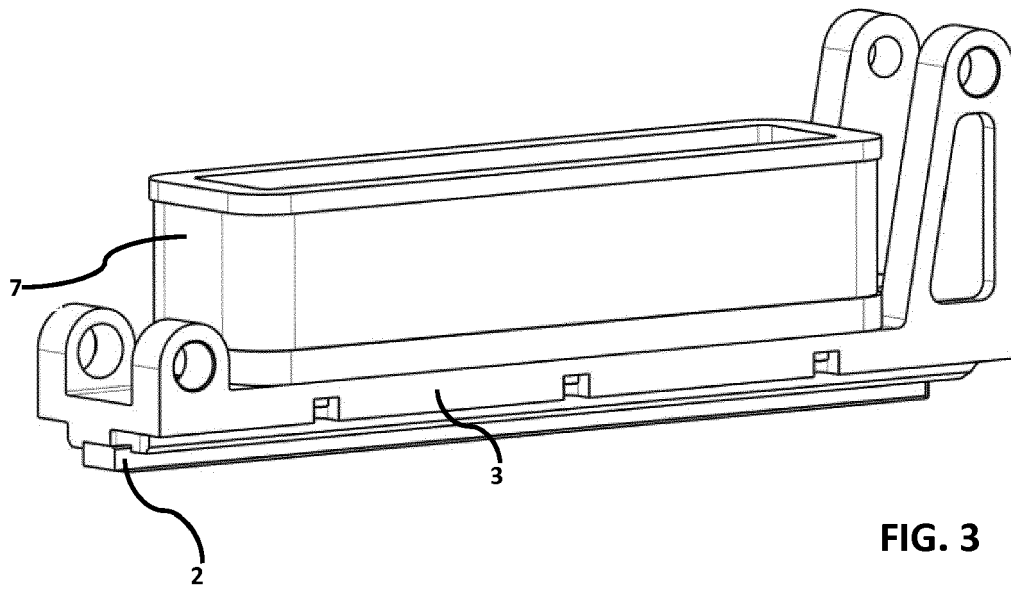


FIG. 3

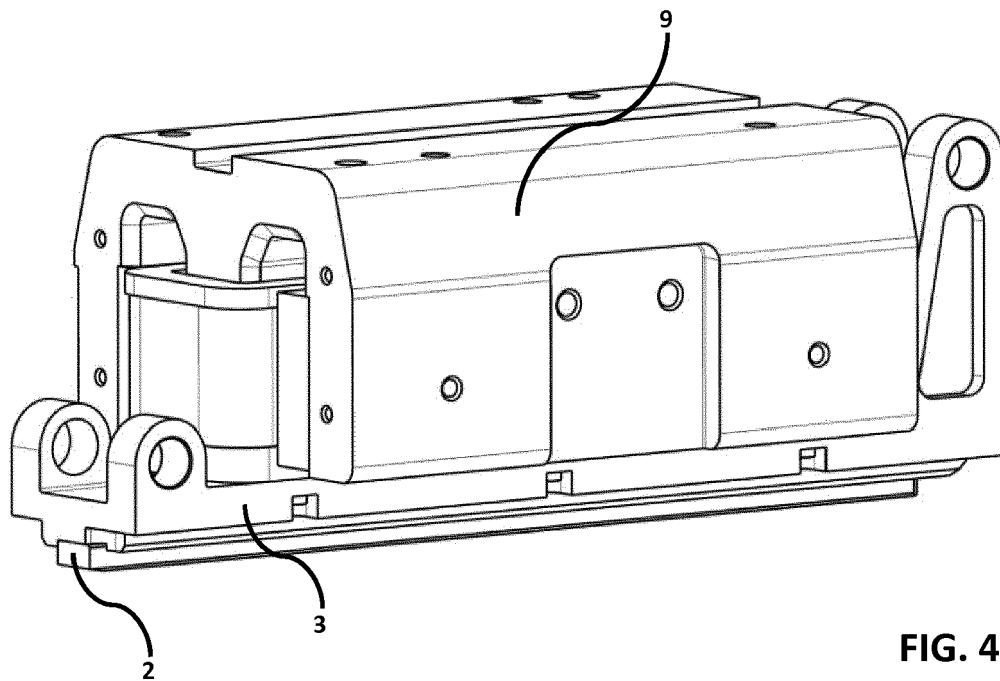


FIG. 4

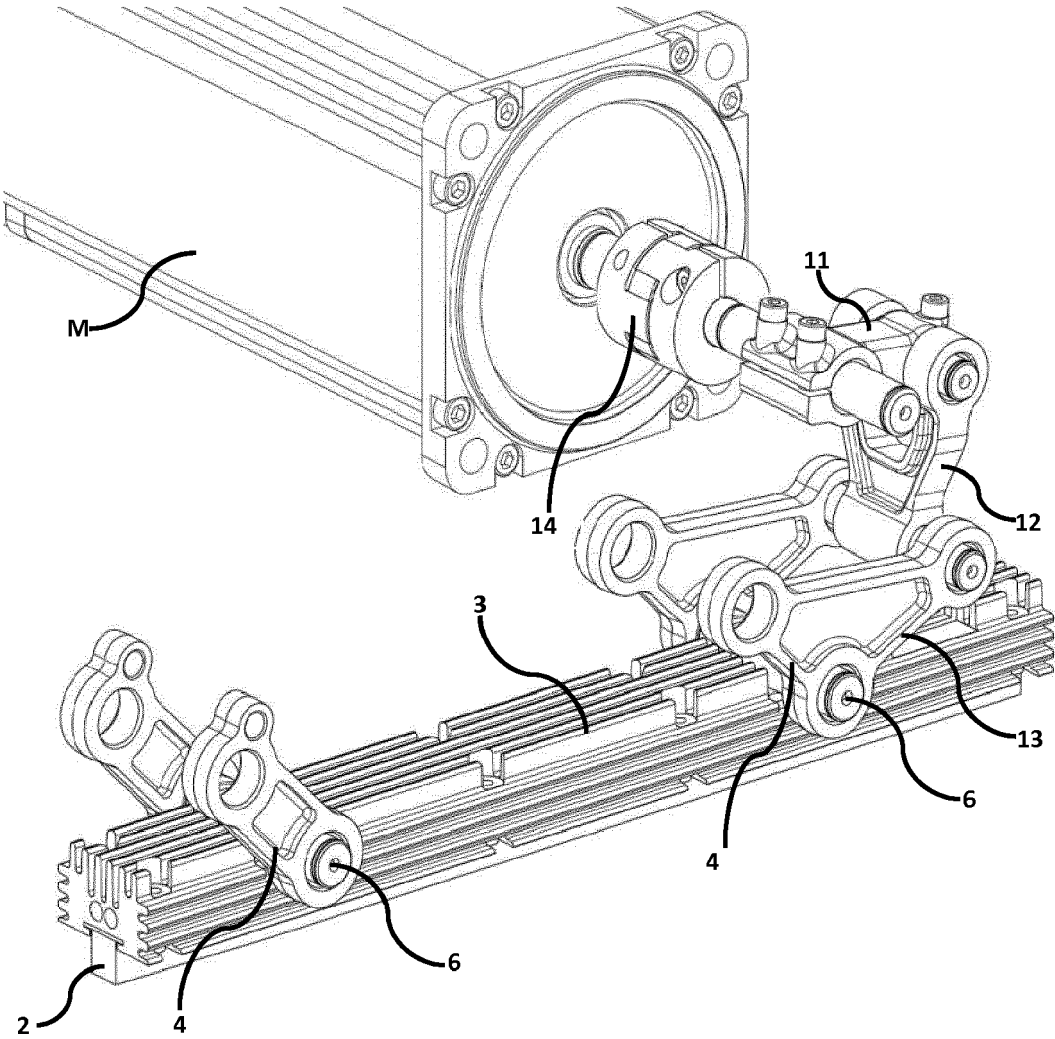


FIG. 6

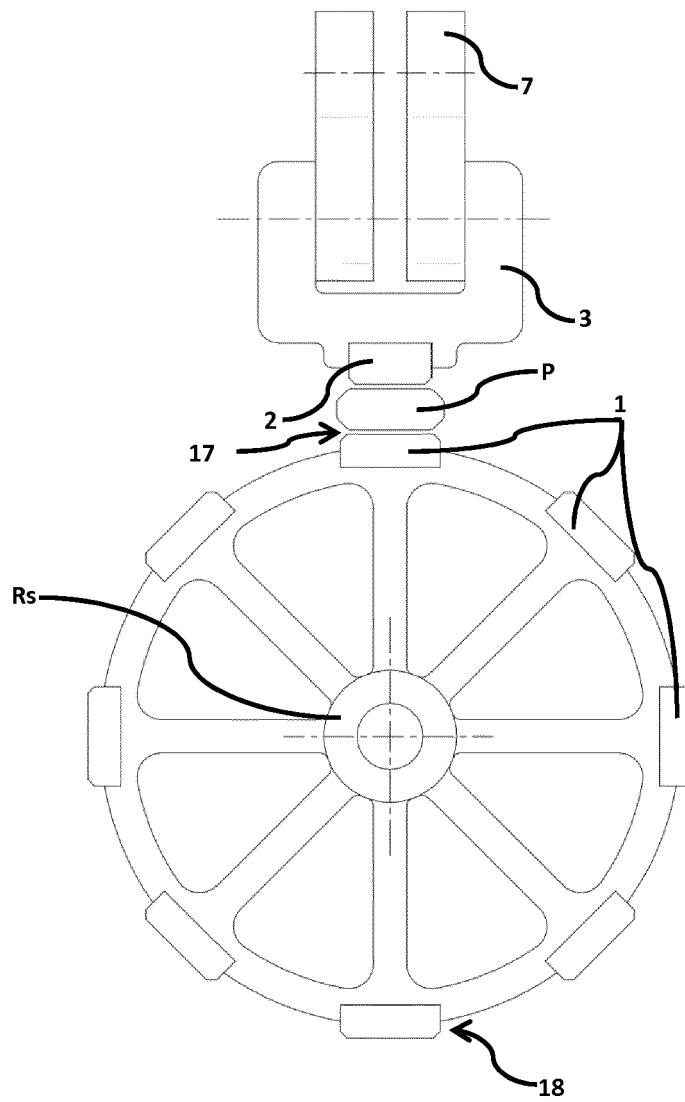


FIG. 7



EUROPEAN SEARCH REPORT

Application Number
EP 18 18 2543

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	EP 0 189 495 A1 (SULZER AG [CH]) 6 August 1986 (1986-08-06)	1,12, 14-17	INV. D03D47/24
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	* figures 2-4 *		
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