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THE DOUBLE–PENDULUM PIANO ACTION

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ABSTRACT

Free inertia synchronization of action members instead of forced kinematical one simplifies the construction, improves its reliability and makes the key more liberated for performance. The elements of inertia movement are used in the relative rotation of the members and their mutual rest during the free fall. The new type of the piano action has a number of versions with horizontal and vertical strings.

1. BALLISTIC DISENGAGEMENT

The traditional piano action includes three main levers: a key, a figure and a hammerstiel which can be pushed by a spieler in the form of the rod hinged to the figure and fixed there by the rest during the push. In almost three hundred years after Cristofori invented the first piano action (Italy, 1709) its construction has been improved. The removal of the spieler after the push was first carried out by Becker (England, 1770). The repetition spring facilitating the return of the spieler was introduced by Erard (France, 1823). There were many additional proposals. But some problems still exist.

The fixation of the spieler on the figure leads to the friction in its nonenvolute engagement with the hammer schulter. The disengagement of the hammer after the push is kinematical and occurs before the key comes to the end position. At the last quarter of the key shift the contact with the hammer is not reproducible enough which is perceptible at pianissimo. The short push from the starting key position is followed by the rigid fall of the hammer and is not favorable for repetition, e.g. when several fingers are used simultaneously with different force.

The new approach described here is an attempt to make the construction more simple and the control of the hammer movement more complete. For this object the principle of ballistic disengagement was proposed by the author earlier [1]: *the relative rotation of the spieler on the hammerstiel with inertia removal and gravity return*. Both the consecutive members, the hammerstiel and the spieler, form a special double pendulum. The second member prolongs by inertia the rotation of the first and returns after the return of the first. Here the new solutions are found on the base of this principle.

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2. REPETITION CYCLE WITH STEPWISE GRAVITY RETURN

The ballistic disengagement can be equally incorporated in a grand and an upright pianos. The action of the grand piano (figs. 1, 2) comprises a key 1 with a capstan 2 and a fanger 3, a figure 4 pivoted about a pin 5, a repetition spring 6 with a support 7, a repetition lever 8 pivoted about a pin 9 and having a cum 10, a hammerstiel 11 with a hammer 12 and plates 13, 14, a pin 15 of the hammerstiel, a holder 16, rails 17, 18, 19 and an auxiliary stop 20. The spieler 21 passes through the recess 22 in the hammerstiel and rotates on a pin 23 inserted into bearings 24. The upper end of the spieler has a cantilever 25 with a ballast 26 consisting of two nuts 27, 28 separated by a clearance 29 from the plate 14. The cantilever can be made flexible. A lower tip 30 of the spieler interacts with a tappet 31 of the figure. The tappet has two steps 32, 33, lower and upper, with elastic coating, a flat damper forming a vertical wall 34, a protecting fork 35.

The action comes in several modifications. Another version comprises the roller 36 on the cantilever spring 37 fastened to the holder 16 on the stationary rail 17 with possibility to shift a shoulder 38 of the spieler and drive the spieler into rotation against the gravity moment. This rotation can be forced to a positive stop on the hammerstiel with the subsequent free reverse movement of both the members falling together. A clearance 39 is adjusted by a screw 40 in a prop 41.

The total stroke of the key corresponds to the first angle part α of the hammer slew. At this stage the upper step of the tappet pushes the tip of the spieler (positions *A* and *B* in fig. 2). The clearance 29 between the ballast 26 and the plate 14 decreases to zero at the end of the key movement (in the action without the roller 36). In the second angle part β of the hammer slew it rotates as a unit with the spieler (position *C*). The collision of the hammer with strings separates the movements. The hammerstiel falls on the fanger; the spieler describes the additional angle γ (position *D*) and then descends by its tip into the space over the lower step of the tappet (positions *E*, *F*). The small lift of the key and the descent of the figure equalize the levels of the spieler tip and the upper step of the tappet (position *G*). Just after this the gravity of the ballast rotates the spieler into position over the upper step providing the reengagement which makes the action being ready for sound repetition or for reset. The rate of repetition 20 s^{-1} can be achieved.

The ballistic cycle *ABCDEFG* is shown for the central point of the spieler tip. The small way between the points *A* and *B* is an arc of the cycloid which is formed by the spieler tip revolving around the tappet near the point *P*. In such a movement the outer point *Q* of the tip recedes from the vertical wall of the tappet.

In the case of negligibly small friction the ballast–rod mass ratio μ and the time τ of reengagement satisfy the expressions:

$$\mu = (r_1/r_0)(\tau^2 g r_s \cos\theta_1 + 2br_1)/(\tau^2 g r_s \cos\theta_0 - 2br_0), \tag{1}$$

$$\tau > \sqrt{(r_0/r_s)(2b/g\cos\theta_0)}. \tag{2}$$

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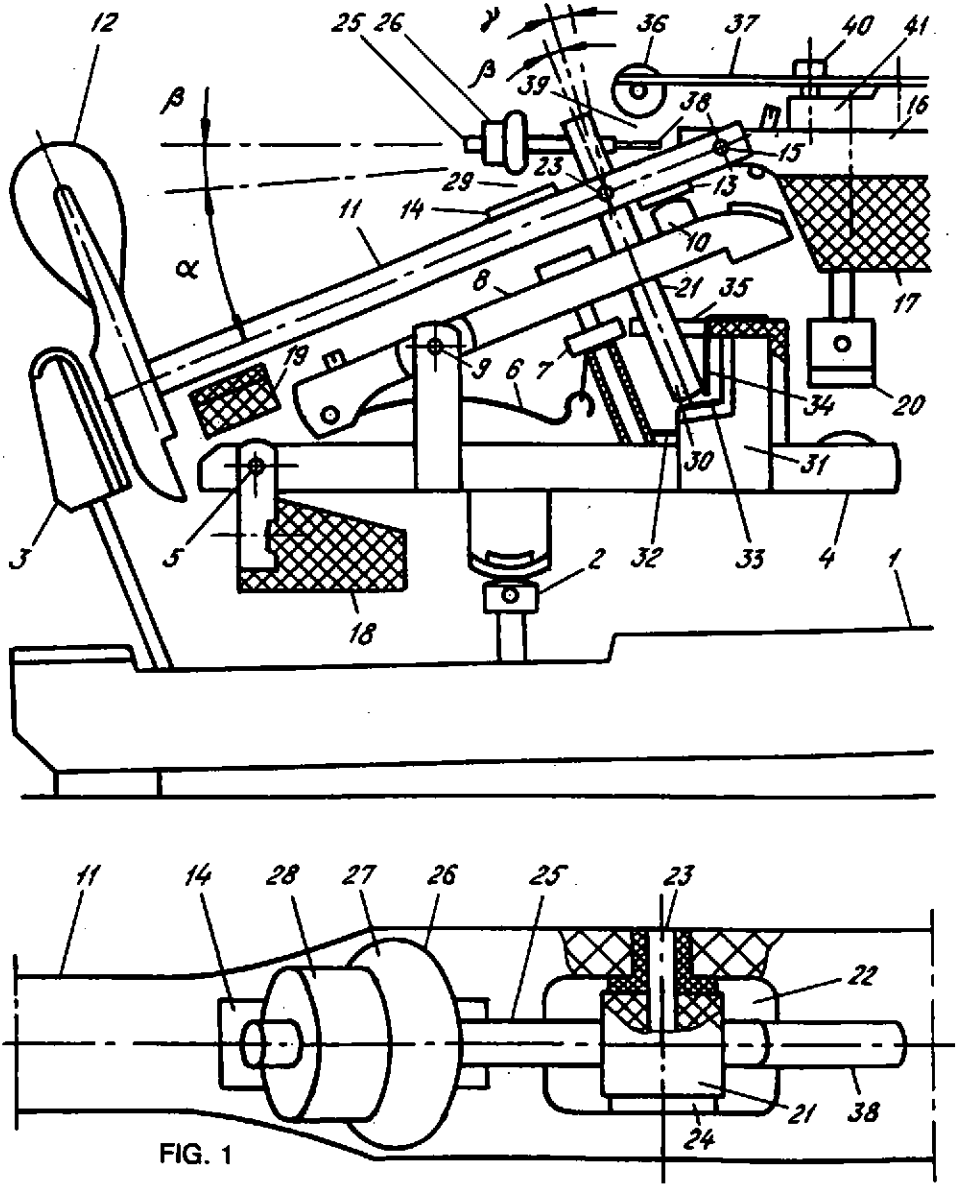
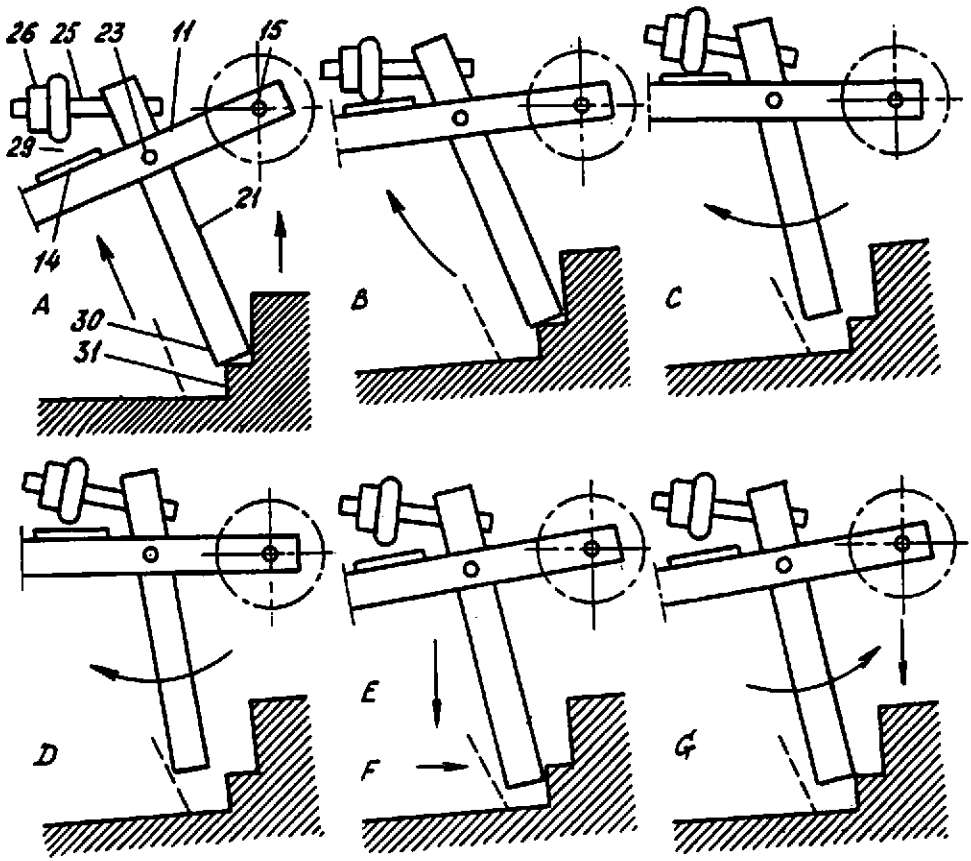


FIG. 1



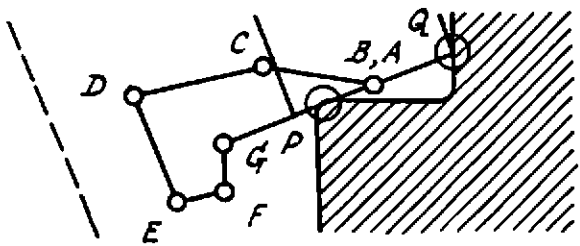
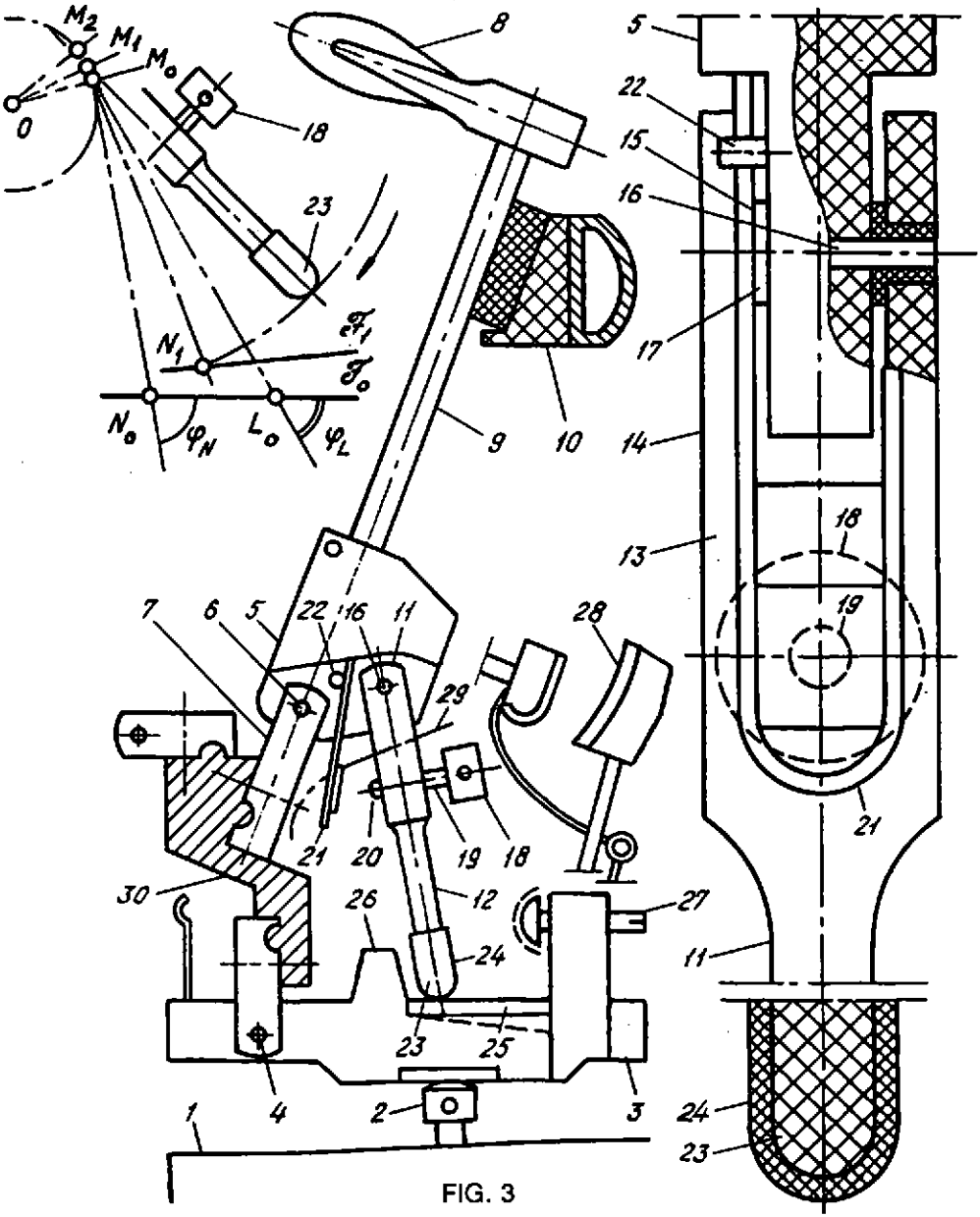


FIG. 2


M2
M1
M0
0
18
23
N1
N0
φN
L0
φL
8
9
10
5
22
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17
14
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11
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25
1
4
2
3
24
23

FIG. 3

where $\mu = m_0/m_1$, m_0 and m_1 are the masses of the ballast 26 and the spieler rod 21, $r_0 = |\mathbf{r}_0|$, $r_1 = |\mathbf{r}_1|$, $r_s = |\mathbf{r}_s|$, $\mathbf{r}_0$ and $\mathbf{r}_1$ are the radius vectors of the corresponding mass centres relative to the axis of the pin 23, θ_0 and θ_1 are the angles of these radius vectors to the horisontal, $\mathbf{r}_s$ is the radius vector of the spieler tip, b is the minimum overlapping which is necessary for the reengagement of the tip and the tappet, g is the acceleration due to gravity. For example, $\tau = 0.01$ s for $\theta_0 = 30°$, $\theta_1 = 68°$, $r_0 = 2$ cm, $r_1 = 1.4$ cm, $r_s = 5.0$ cm, $b = 0.1$ cm, $m_0 = 4$ g, $m_1 = 0.5$ g, $\mu = 8$.

3. CONTINUOUS SELF–ALIGNMENT

The upright piano action with the ballistic disengagement (fig. 3) is more simple compared with usual one. It includes a key 1 with a capstan 2, a figure 3 on a pin 4, a schulter 5 on a pin 6, a holder 7, a hammer 8 with a hammerstiel 9 and a rest 10. A spieler 11 has the form of a rod 12 with a jaw 13 at his upper end 14 which is connected to the schulter by a hinge 15 with a pin 16. Bearings 17 of the hinge minimize the friction. The spieler is supplied with a ballast 18 on a cantilever 19 in the form of a screw 20 which can interact with the Π–shaped spring 21 fastened to the schulter and having a prop 22. The lower tip 23 of the spieler is coated with a rubber cup 24 which leans against a friction plate 25 on the figure. The tip of the spieler can occupy any position on the plate between a threshold 26 and a checking screw 27. A fanger assembly 28 is not necessary but compatible with the new construction. The spring 22 can be replaced by a spring 29 (dotted line) for the interaction of the spieler with the holder 7 or another stationary member on a rail 30.

The forward way of the hammer consists of two parts and corresponds to the arc $M_0M_1M_2$ described by the pin 16 around the stationary centre 0. At the first part of the way the figure is rised by the key from position F_0 to position F_1 and pushes the tip of the spieler. The second part begins after the key reaches its limiting position. The schulter continues to rotate. The friction force between the spieler and the figure vanishes and the Π–shaped spring rejects the spieler. At forte the rejection can be done by the ballast only with returning the hammerstiel to the rest 10 (in the version without a fanger). Short time after the hammer strikes the strings the lower tip of the spieler falls on the friction plate forming the intermediate position M_1N_1 at some distance from the starting position M_0N_0. The next push can be transmitted by the spieler from this new position after lifting slightly the key. If the key is released completely the spieler returns to the starting position by continuous slipping along the friction plate. The condition $M_0N_0 < M_0L_0$ ($\varphi_N > \varphi_L$) must be fulfilled; $\pi/2 - \varphi_N < \psi_f$ where ψ_f is the friction angle. The spieler is able to select its working position at any state of the action. The rejection of the spieler can be bounded by the second spring or another stop attached to the schulter. The friction plate and the spieler tip can be stepped. The conjunction with a repetition spring is possible.

Some simple opportunities are found also for stabilizing the strings tension [2].

4. REFERENCES

[1] Patent of Russia (Invent. sertif.) No. 802991, 1981.
[2] Patent of Russia (Invent. sertif). No. 1267473, 1986.