Marco Tiella: Leonardo da Vinci's "Viola Organista"

In this paper I'm dealing with questions that arose in studying Leonardo's research of musical instruments. Every kind of instrument sketched by him can be identified with the class of folk instrument or instruments adapted to the needs of performing in the open air, battles, processions and tournaments whose ornamentation Leonardo was given charge of. Among a few dozen of sketches, mostly drawn in a few pages but also dispersed in other manuscripts, in the greater part of them the pictures related to a special hurdy-gurdy mechanization that can easily be recognized. The instrument was named by Leonardo 'viola organista', possibly drawing it from 'organistrum' (or 'performing organum'?).

This paper is chiefly concerned with the discussion of how so many details of mechanisms could have been arranged in a voluntary or self-acting bowing device.

The richness of the details designed by Leonardo enable us to give a precise description of what we see as to the matters they could have been the pictures in Leonardo's mind. Some parts, such as various devices for making the 'viola' automatically work—the so-called 'motors'—are casually depicted here and there in Leonardo's manuscripts as follows:

- Cod. Atlantico 93; 568
- Cod. B 50
- Cod. H 28 v; 45 r; 46 r.; 104 v
- Cod. M II 76 r

Fully written descriptions of the devices coming from Leonardo's hand aren't known, apart from a few rather obscure words scattered among some sketches. Therefore, it is at least unclear what Leonardo was expecting in order to play polyphonic music on the 'viola organista' and primarily to convert his imaginations into efficient machineries.

The historical succession of Leonardo's projects about the 'viola organista' hasn't been reconstructed yet.

A few lay-outs, not fully legible, show possible references to more usual hurdy-gurdy (C. Atl. 568 r.c.) or clavichord (C. Atl. 568 r.c.) structures. Such machineries, only superficial-

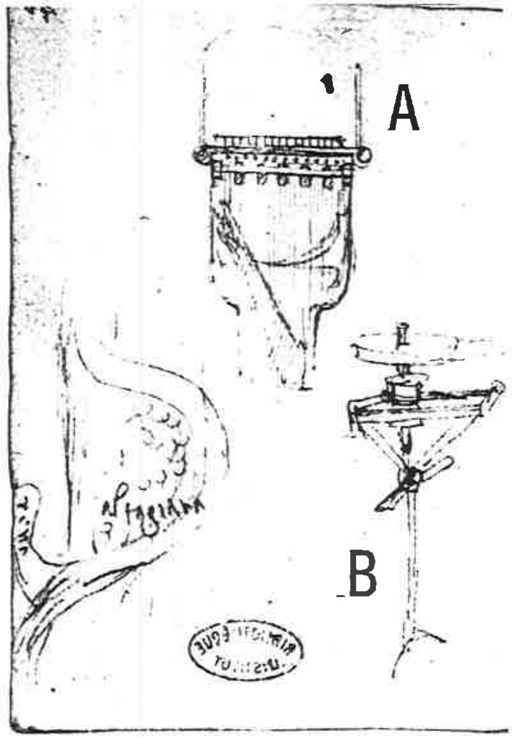


Fig. 1. C. H 46 r.—A: viola—B: 'Cord' motor

ly contrived by Leonardo, are beyond the content of this paper; owing to their evident unreliability it could be that they are just a matter of speculation, even if E. Winternitz, who claimed Leonardo to be 'the inventor' of 'viola organista', argued for a credible trust as to the reliability of these lay-outs (Raccolta Vinciana, XX).

Even if a few 'viola' body shapes were sketched in Leonardo's manuscripts (C. Atl. 93 and 568 r; Cod. H 28 v, 45 r, 45 v, 46 r and 104 v) further details of only one were effectively developed. The 'exagonal cross-section body' might have been designed to make the 'viola' suitable for a wider compass of tones; in the 'rectangular cross-section body' Leonardo was more explicative. Every mechanical detail of that seems to have been selected among these parts connected together; different geometrical projections show how Leonardo was thinking out 'keys' and their connections with the

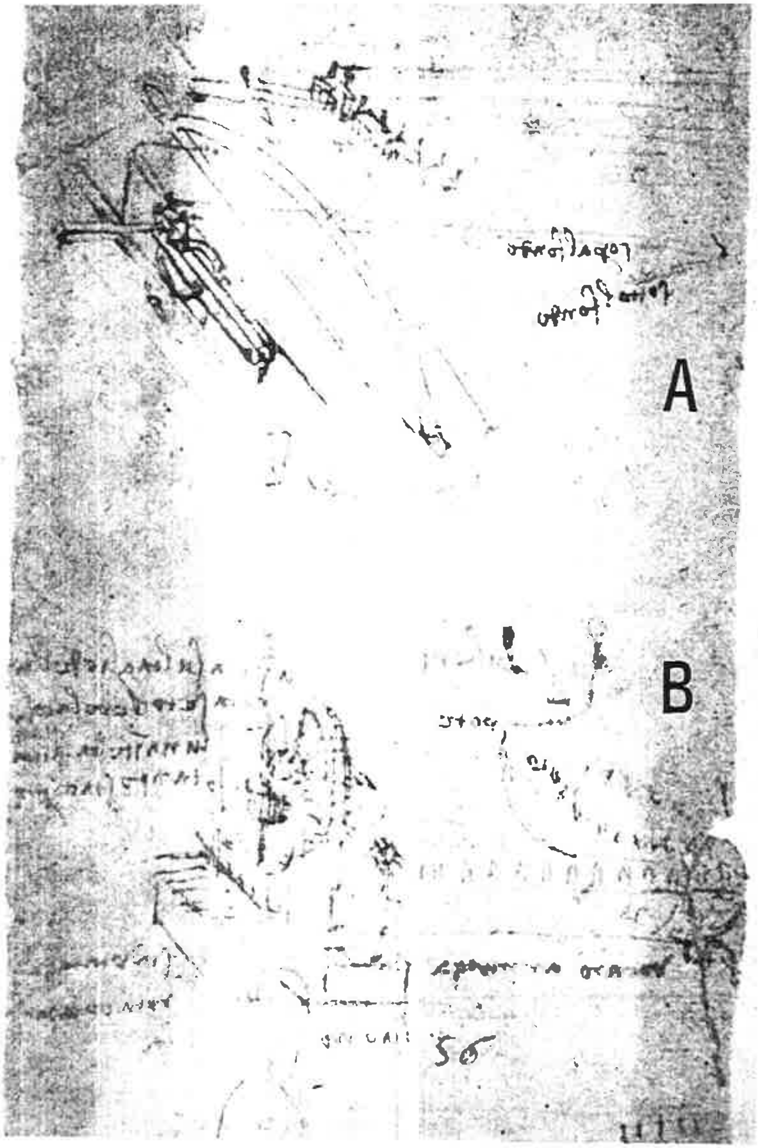


Fig. 2. C. ATL. 568—A: bow mechanism—B: 'Hurdy-gurdy' mechanism for viola organista

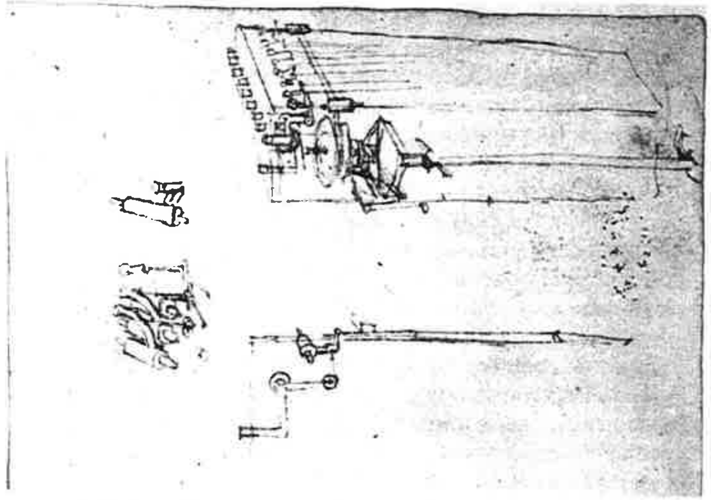


Fig. 3. C. H 45 r.—'Cord' motor and knob mechanism in a square cross-section viola body

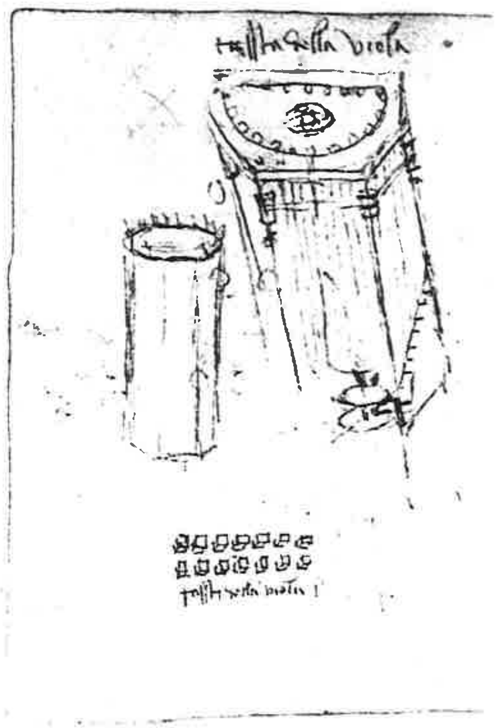


Fig. 4. C. H 28 v.—Octagonal and exagonal cross-section viola body

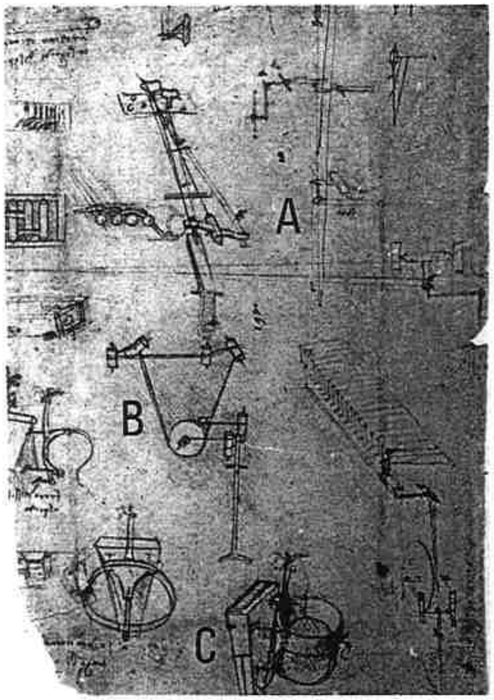


Fig. 5. C. ATL. 93—A: key mechanism—B: double cord motor—C: harness

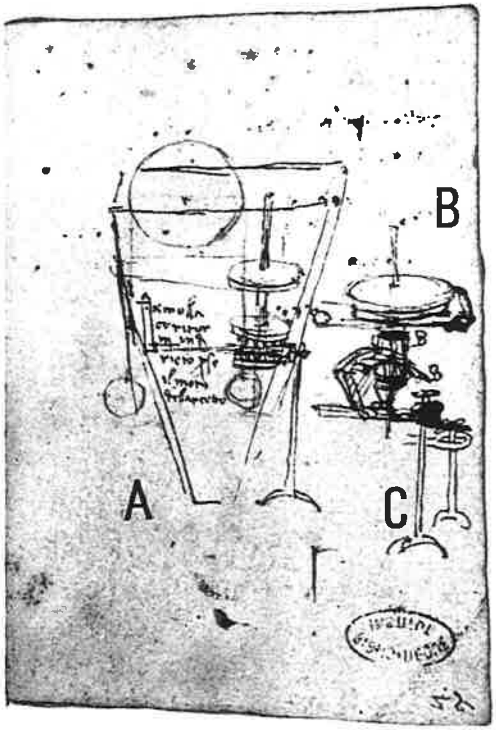


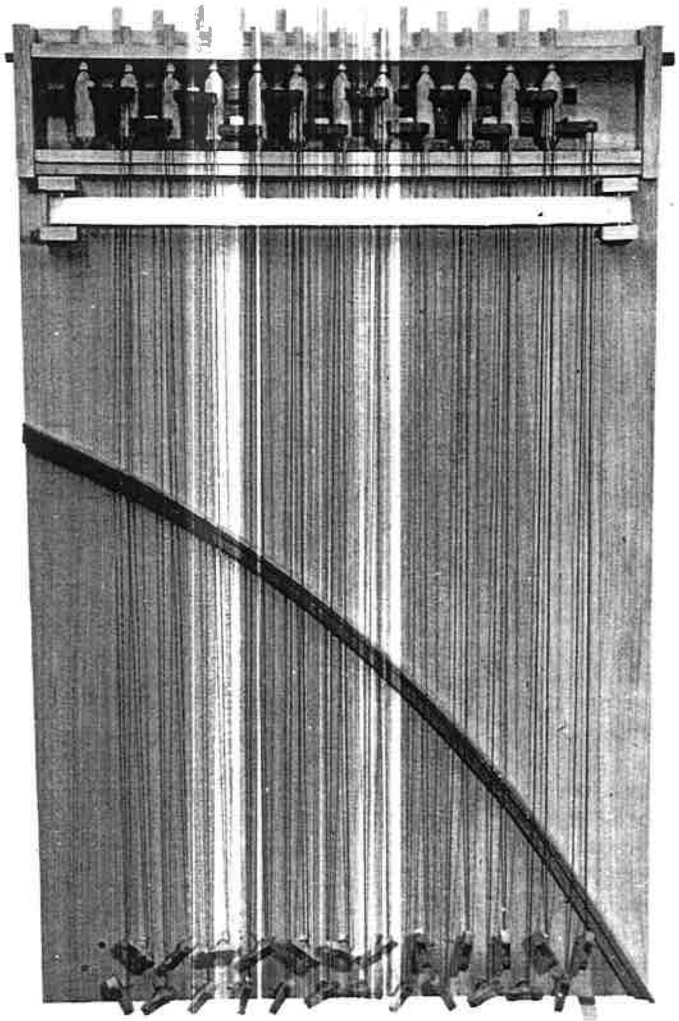
Fig. 6. C. H 28 r.—'Gear' motors—A: with double disk wheel—B: with disk wheel section gear—C: handle bar

levers driving the up-and-down motion of the 'pivots'. In most of the pictures of the 'rectangular cross-section body' Leonardo drew a case near to a parallelepyped and a somewhat convergent truncated pyramid, whose wider basis stood upright, showing the keys facing the players and a downwards protruding handle-bar. Generally, in the instrument case, the motors (of one or another kind) are also present.

In our reconstruction of how the 'viola' (Fig. 7 a, Fig. 8) could have been driven we based ourselves upon (i) some harnesses designed for putting the instrument on by the player, (ii) the details of mechanics in C. Atl. 93 r.b; H 45 r; H 46 r; H 104 v; M II 76 r. The player might have been allowed to drive the 'viola' not only with his hands but also by moving one arm joint, the fingers of both hands being restrained for pressing on the 'keyboard' knobs or levers. In such a case the cumbersomeness and the unwieldiness of the 'viola' would require a rather acrobatic dexterity by the player to be brought into action. Thus we are destined to assign the 'viola' to the popular shows done by 'jongleurs' rather than to the subtly learned profession at the end of the 15th century.

Fig. 7. C. B 50—Auxiliary mechanism for the viola organista—double escapement clock work moving the bow

Fig. 7 a. Viola organista reconstruction (C Atl. 93)



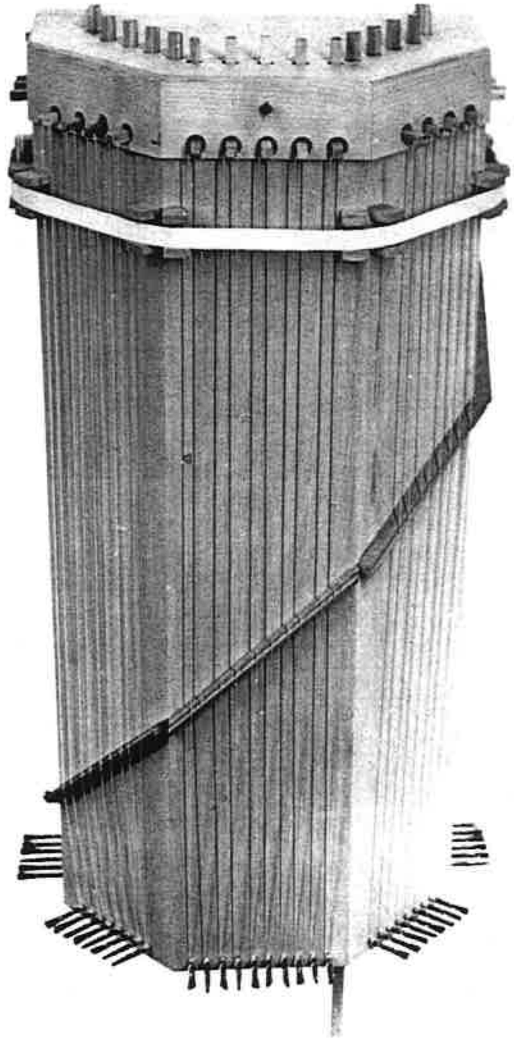
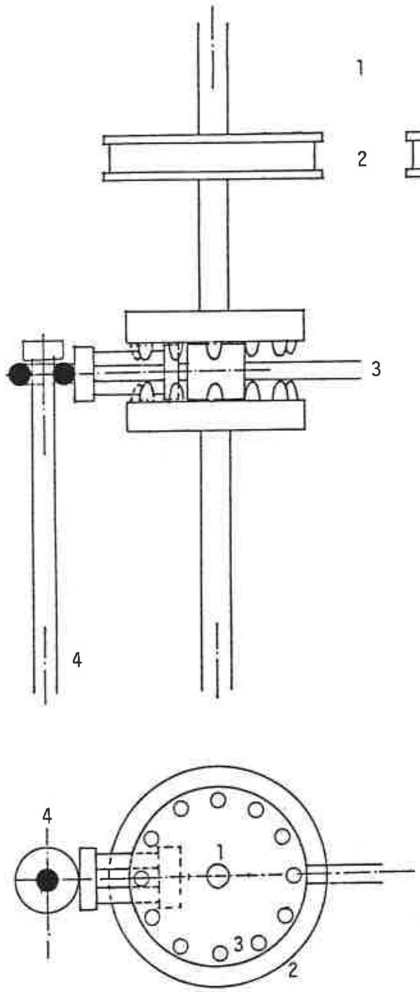


Fig. 8. Viola organista reconstruction (C. H 28 v.)

The 'motors' should have been fit so that the 'continuous bow' could be driven on two pulleys, one of them operating as a driving wheel, set on the 'motor' axle (Fig. 9 A; Fig. 9 B; Fig. 9 C). As regards the bowing (how the 'bow' must have been dragged) Leonardo stated that it rubs according to the way 'the player's right arm runs from key to key performing divisions' and he so calculated confusedly the amount of a bowing length in one arm's length ('braccio', or about two feet): 'the driving wheel will turn once what is one third of an arm's length and



'Gear' motor—C. H 28 r.
1 Motor shaft
2 Driving wheel
3 Double disk gear wheel
4 Handle bar

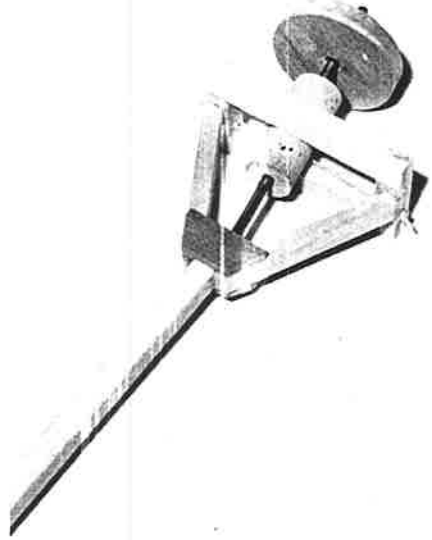


Fig. 9 b. C. H 46 r.—'Cord' motor

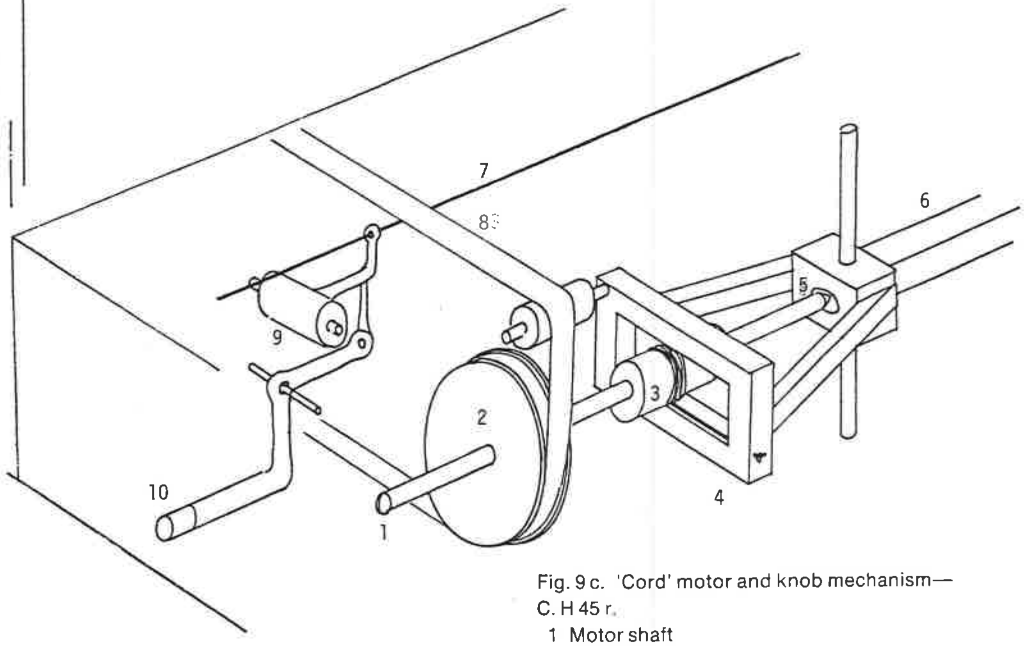


Fig. 9 c. 'Cord' motor and knob mechanism—C. H 45 r.
1 Motor shaft
2 Driving wheel
3 Reel
4 Frame
5 Seat
6 Handle bar
7 String
8 Continuous bow
9 Rocker arm
10 Knob

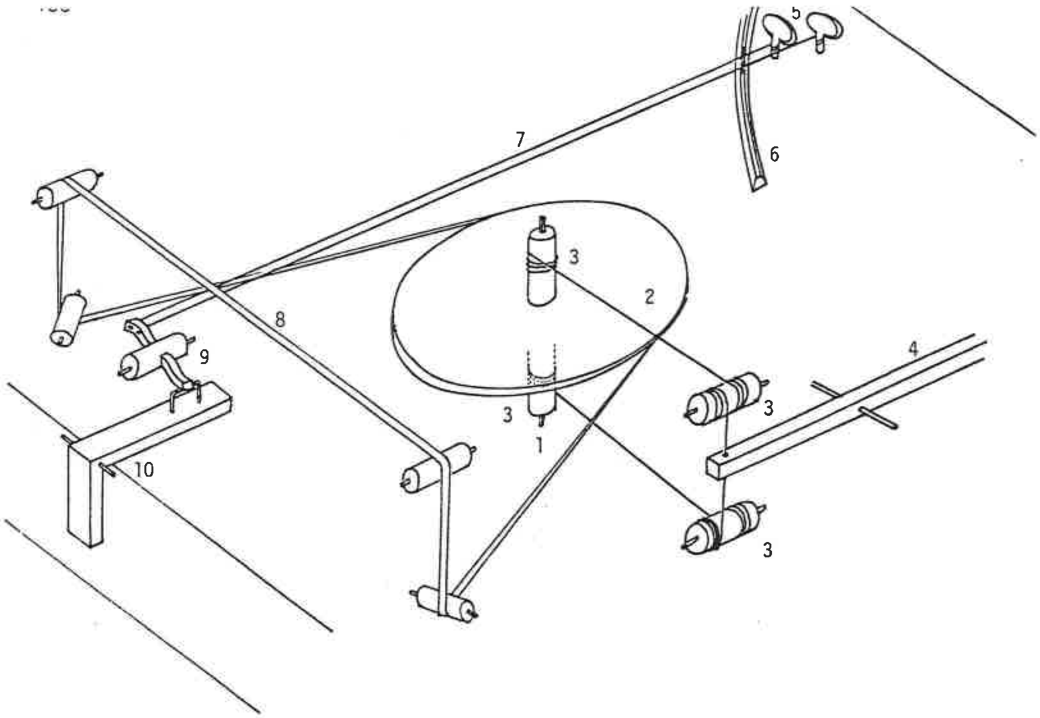


Fig. 10. Double cord motor and rocker arm mechanism—C. Atl. 93 r.b

1 Motor shaft
2 Driving wheel
3 Reel
4 Handle bar
5 Pegs
6 Bridge
7 Pair of string
8 Continuous bow
9 Rocker arm
10 Key lever

then will give one arm's length of bowing on the strings' (C. M II 76 r). From Leonardo's writings it seems that he was worried about how to solve two main mechanical problems (i) the bowing device (ii) how to make it automatically work in order to set the player's hands free from bowing and both suitable of pushing on the 'keyboard'. There were two mechanical working principles which Leonardo was thinking of (i) to make the instrument sound by a bow like those commonly in use (C. Atl. 568 r.c) (ii) to rub a 'continuous bow' on the strings by means of a wheel (C. Atl. 586 r.c) like the one of a hurdy-gurdy or a hair-thread loop (C. Atl. 93 r.b; H 45 r; H 46 r; H 104 v; M II 76 r). Presumably, Leonardo's aim was never fulfilled by the former mechanical alternative, no clear details of it having been yet recognized in the manuscripts. This way of bowing the 'viola' should have been entangled with an extraordinary mechanical complexity of any device designed for the voluntary rubbing of the bow against the strings by means of a 'drive'. Nothing is evident about how to finally arrange the motion work for a common bow mechanically operated. The latter mechanism took up Leonardo's mind more attentively and many of the details of the mechanisms were so precisely drawn that we were able to reconstruct a few of the simplest of them (C. Atl. 93 r.b), Fig. 10. Therefore one might assume that such a refinement in drawing them give us proof of Leonardo's acquaintance with something actually like 'vida organista' mechanisms—as E. Winternitz does believe. It must be remarked upon the 'prime motor' automation described by Winternitz that the reliability of Leonardo's designs is hardly tenable. In contrast with the mental linking of supposing to be in front of graphical fancies Leonardo was often caught up in, Winternitz credited his muddled sketches of 'prime motor' with the power of working. Like a 'clock work'

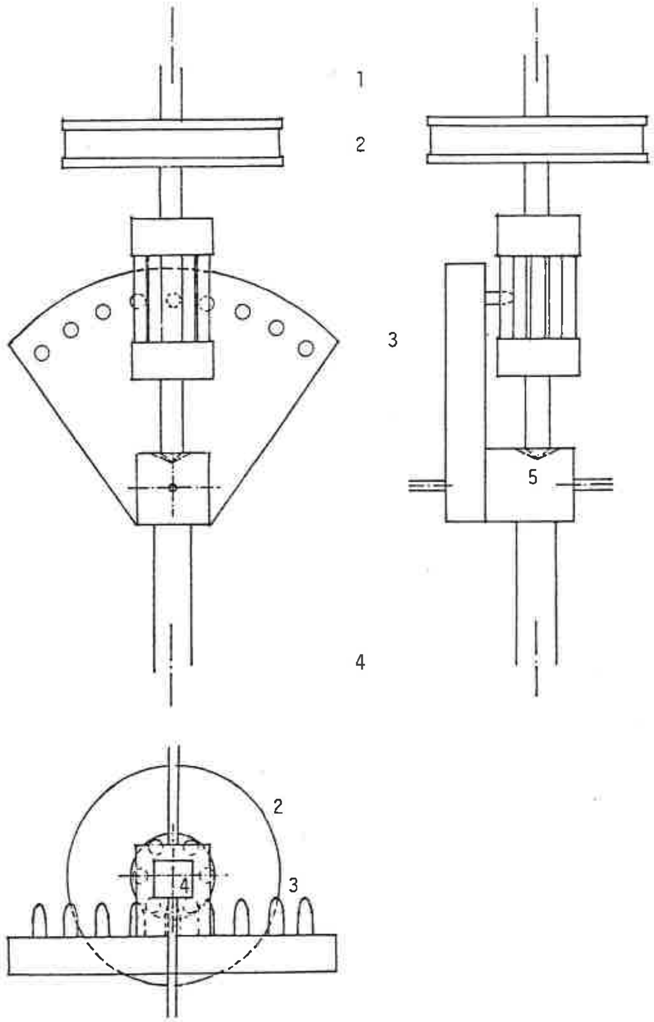
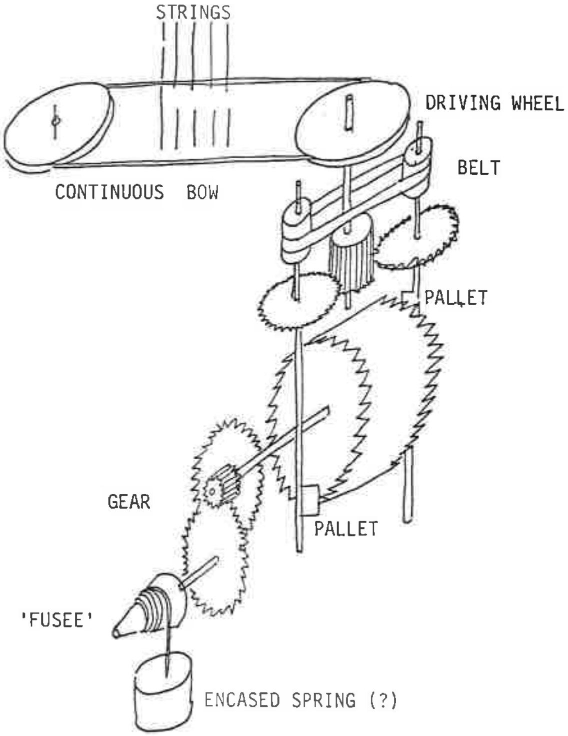


Fig. 11. Auxiliary mechanism for the viola organista—double escapement clock work moving the bow C. B 50
'Gear' motor—C. H 28 r.
1 Motor shaft
2 Driving wheel
3 Gear
4 Handle bar
5 Seat

(C. H 28 r) (Fig. 11) such a 'prime motor' would have caused to run 'in cascade' a few springs (encased in boxes) and then pulling the cords bound to them and wound around corresponding 'fusées'. In that way, the player would have been in the position of not taking care of moving the 'bow' and focusing on just his musical performance. That kind of 'clock work' would have been set in the primary axle of a gear, whose secondary axle would have also been set into a little 'cylinder' or a crown wheel. Toothlike projections on either side of its broad rim (shown in the drawing) and working a double as well as an opposite escape mechanism, would have imparted the constant slow motion that the 'unending bow' need rather than create a continuous swinging back and forth of the verges. Both the verges bearing a toothed wheel, which engaged a drum on its opposite sides, would have caused the driving wheel to drag the 'continuous bow' and also to rub the selected strings.

Other sketches (C. B 50; M II 76 r) deal with more factual ways of getting the mechanical transmission to work. To overcome the failure of the friction requested to avoid idle rods or wheels, Leonardo searches into interlocked gears, joined together in order to get a certain 'bow' section to rub back and forth. One gear is built of a toothed disk wheel section engaging a spur wheel (Fig. 12 A), whose larger disk coincides with one of the pulleys lifting the 'continuous bow' (C. M II 76 r); in another (C. H 28 r on the right) (Fig. 12 B) the disk wheel section is opeated by a handle-bar passing through the ring set on the extremity of the pinion locking into a double disk gear wheel (in this drawing, sketches of the two different versions are bound together with a figure of what Winternitz imagined to be a 'bow speed regulator'). On the border of page 'H 104 v' a sketch depicts a toothed wheel possibly moved by crank-connected arms; but close to that we see a 'viola' body furnished with an idle double-cord motor.

Undoubtely, the most reliable mechanisms for the 'viola' designed by Leonardo were those about how the strings could be selected and



Auxiliary mechanism for the viola organista—double escapement clock work moving the bow
C. B 50

Fig. 12 a. 'Gear' motor—C. H 28 r.
1 Motor shaft
2 Driving wheel
3 Gear
4 Handle bar
5 Seat

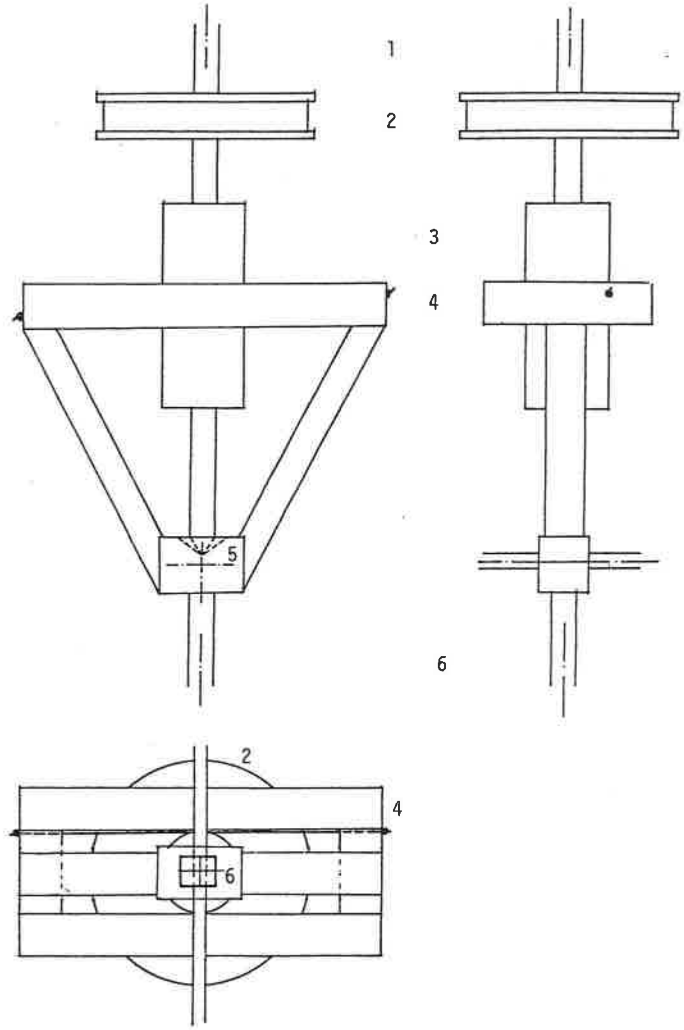


Fig. 12 b. 'Cord' motor—C. H 46 r.
1 Motor shaft
2 Driving wheel
3 Reel
4 Frame
5 Seat
6 Handle bar

pulled against the 'bow'. A rather odd but really effective clutch can be operated by key-levers, transferring by means of right-angular 'knee'-levers the motion to a 'turnable anchor' whose limbs are busy as 'pitch pins' for a couple of strings. String tension provides for the force to move back the 'anchor' to its rest position. Instead of using 'anchors', in a few other sketches Leonardo designed special 'capsules' bearing a short right-angular lever terminating in a little circular loop that should have grasped the string some little distance to the point where the 'bow' passed over the strings. In one of the most muddled drawings (C. Atl. 586 r. c) 'hitch pins' or fasteners in the shape of a 'u' are legible. These 'u's could operate like 'anchors' grasping the two strings at both their extreme ends. Pressing the front end of the key, the rear end will be lifted up and thereby the strings put against the 'bow'. Common pegs served for tuning the 'open' strings whose vibrating lengths were determined by a bridge like that of a harpsichord.

List of 'viola organista' representations among Leonardo's drawings of musical instruments:

Lyra viola	C. H.	46	r	Fig. 1
Bowed viola	C. Atl.	586	r.c	,, 2 A
Viola with wheel	C. Atl.	586	r.c	,, 2 B
Rectangular viola	C. Atl.	586	r.c	
Tapered viola	C. Atl.	93	r.b *	Fig. 5 C
Tapered viola	C. H.	104	v	
Hexagonal viola	C. H.	28	v	Fig. 4
Octagonal viola	C. H.	28	v	,, 4
Cord motor	C. H.	45	r	Fig. 3
Double cord motor	C. Atl.	93	r.b *	,, 5 B
Gear motor	C. M. II	76	r	
Gear motor	C. M. II	76	r	
Gear motor	C. B.	50		Fig. 7
Gear motor	C. B.	50		
Clock work motor	C. H.	28	r.	Fig. 6
Crank motor	C. Atl.	93	r.b	
Keyboard for viola	C. H.	28	v	
Capsule knob	C. H.	45	r *	Fig. 3
Anchor key	C. Atl.	93	r.b	Fig. 5 A

* some details are also present

As far as I know, only E. Winternitz wrote about Leonardo's musical instruments and attempted to explain what the drawings signify as to the actual ways of working the instruments. We have explanations for more than one of Winternitz' doubts in stating what the drawings really can supply, for instance, about how to connect the 'prime motor' with the 'continuous bow' and how to understand the 'viola organista' shape as to its suitability in playing mode. Having reconstructed the 'clock work' (C. H 28 r) we can state that Leonardo's words can not be referred to this mechanism; there is no means to avoid the 'swinging back' of each pallet after the tooth releases it. Of course, one cannot always reverse the function of a mechanism; the matter in this case is that the gear cannot regulate the motion of the verges bearing the pallets (which are connected with a 'continuous bow' driving wheel) but, on the contrary, this kind of clock escape mechanism (vz. the complete whole of 'continuous bow' gears) regulates the 'prime motor' revolving speed! The only definite effort done by the escape would have been that of getting a 'continuous bow' a back and forth swinging as wide as the teeth are apart and be scanned on crown wheel sides; that is, something like a very close bow trembling.

The 'motors' working principle that can be deduced from Leonardo's drawings are of two kinds: (i) how to put in motion the 'contiuous bow' pivot by means of a transmission belt (really a section of cord), (ii) or by means of gears.

The alternative motion of the 'motor' was generated by moving back and forth a 'handle-bar' protruding from the case—usually, through the side opposite to that on which 'keys' or 'knobs' are legible. The machinery transferring an alternative motion into an alternative rotation could have been materialized by a simple section of chord spirally wound around a section of a cylindrical rod (set on the axle of the 'motor') and hitched to both the lateral sections of the frame, this frame being firmly connected with the 'handle-bar'. If one end of the rod section axle has its seat (race) in the upper extremity of the 'handle-bar' and the other end is set in the wheel driving the 'continuous bow', the rod section—when rotating, being dragged by the spiral cord—puts the 'bow' in motion.

What makes the machinery work is the friction between cord and wood and hair thread and wood. Corresponding friction coefficients must be as great in the inverse ratio as the wheels and rod diameters are, otherwise only the larger wheel can transfer the motion to the smaller one (not vice versa). In fact we can sort out a set of drawn details to build up hypothetically Leonardo's mental attitude in looking through such a handicap. If we are correct in relating together a few sketched routes (vz. belt dispositions) where some pulleys are variously orientated, we are enabled to suppose that Leonardo was entangled in getting through the problem of how to effectively make the hair thread move. He also had to find actually by which means the hair thread route could go on two perpendicular plains. Unfortunately, in no case do the sketches give us proof of his awareness about friction consequences on driving belt devices as the hair thread passes firstly on a driving rod smaller than the wheels conducting the bowing section also. The old empiric misunderstanding between 'speed' and 'force' constrained Leonardo and made him believe in the possibility of transferring the 'handle-bar' swinging to a wheel so large, that the hair thread, driven by it, could rub the strings at the required bowing speed and by the usual hair section length. By the application of a gear to the 'motor' (instead of a cord transmission) only the first gap could be overridden. The same thing is valid for the other ingenious but scarcely efficient way of transferring the 'handle-bar' swinging into 'bow' rubbing through a doubled cord transmission. The hair thread is driven by a large wheel pivoted on a rod whose ends protrude from both wheel sides. The primary cord transmission should operate as that of a 'frame motor'. Both the cord ends being hitched on one of the opposite rod sections (protruding from the wheel) one end of the cord is wound clockwise on one rod section and the other cord end anticlockwise on the opposite rod section. In this first cord connection the 'handle-bar' makes one of the cord ends unwind on the corresponding rod section whereas the other cord end is being wound; therefore a reciprocating motion would have been transmitted to the wheel and thereby to the 'bow'. If the wheel could succeed in dragging the hair thread, such a way of winding and unwinding in the 'motor' enabled the 'handle-bar' operator to get a probable imitation of the usual type of bowing. Will the friction mechanics laws once again keep the machinery from operating? According to our attempts to put motor reconstructions into action, it does, unless the cord transmission will be replaced by a sprocket chain.

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