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(54) **GRAND PIANO COMPOSITE PIANO ACTION**

(75) Inventors: **Bruce Clark**, Nottingkam, NH (US); **Kevin Burke**, Haverhill, MA (US); **Kurk Burgett**, Sacramento, CA (US)

(73) Assignee: **Wessell, Nickel & Gross**

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(22) Filed: **Jun. 14, 2007**

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G10C 3/18 (2006.01)
(52) **U.S. Cl.** **84/239**; 84/243
(58) **Field of Classification Search** 84/239, 84/243, 236
See application file for complete search history.

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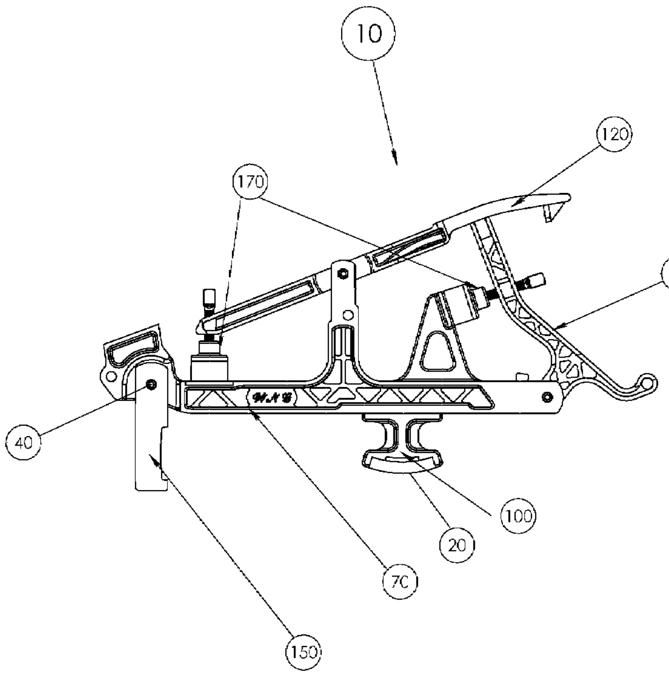
Primary Examiner—Jianchun Qin
(74) *Attorney, Agent, or Firm*—Craig A. Simmerman

(57) **ABSTRACT**

Composite or plastic molded articles used in a grand piano action. A piano action actuates in response to depression on a piano key to swing a hammer into a piano string. The articles are assembled to form a piano action with significantly less dynamic mass which is much more responsive to the touch. In addition, the new action provides the valuable collateral benefits of increased efficiency of manufacture and maintenance. The invention also provides the capability to achieve true half stroke design in both the sharp and white keys. Additionally, the application discloses a universal composite grand piano action that is capable of being installed into any brand of grand piano.

4 Claims, 16 Drawing Sheets



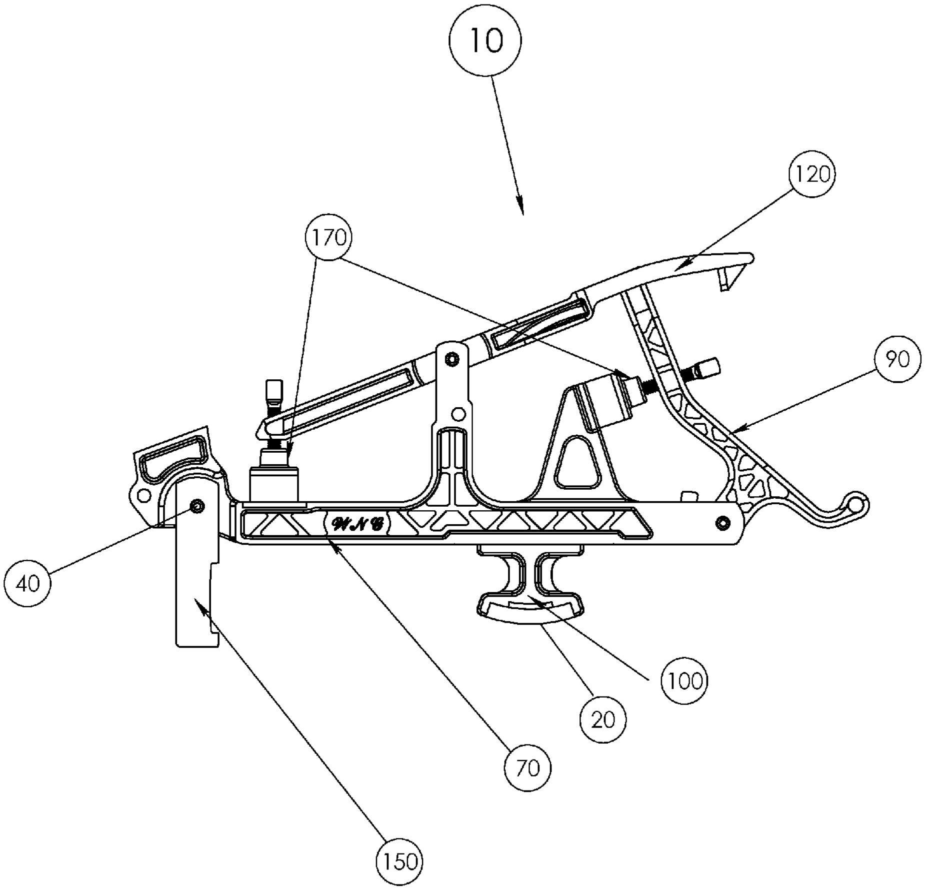
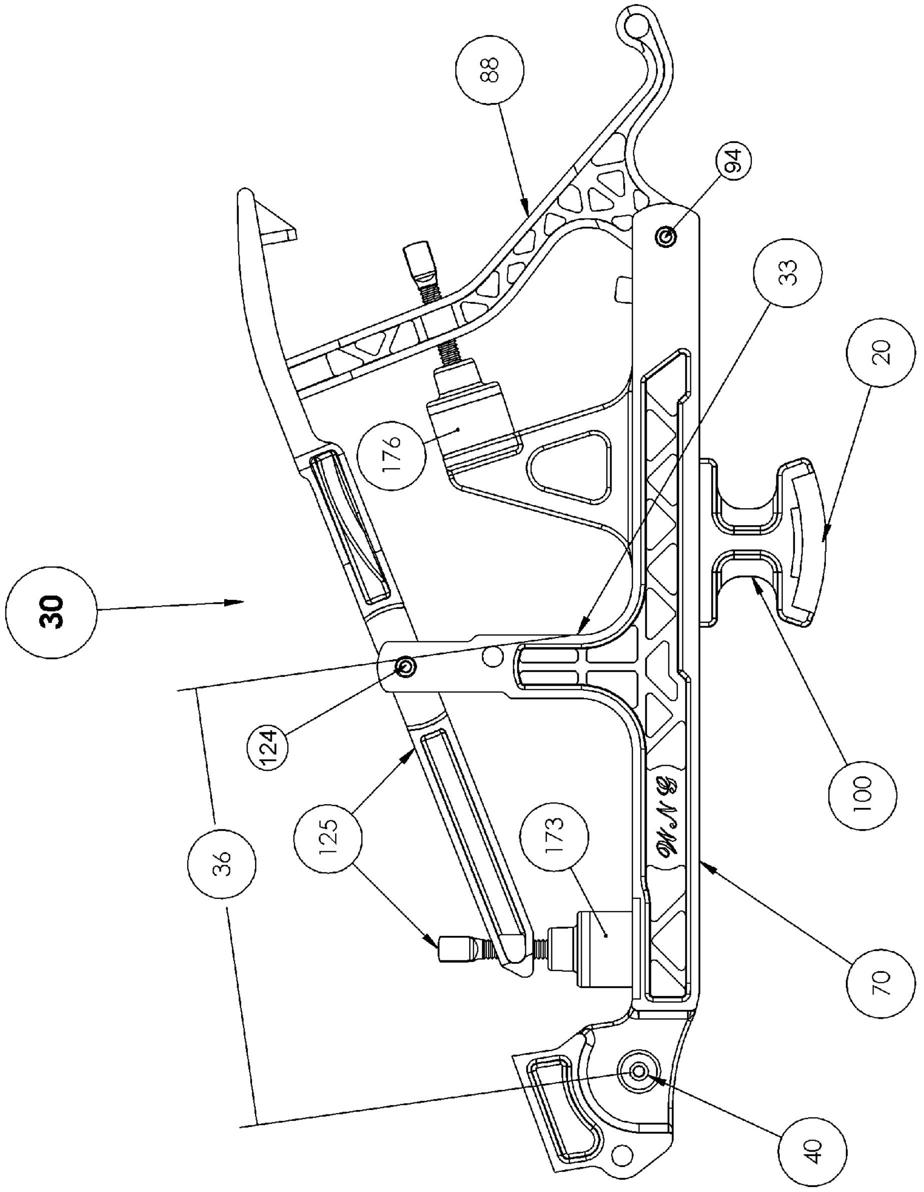


FIG. 1



45599 grams mm^2

FIG. 2

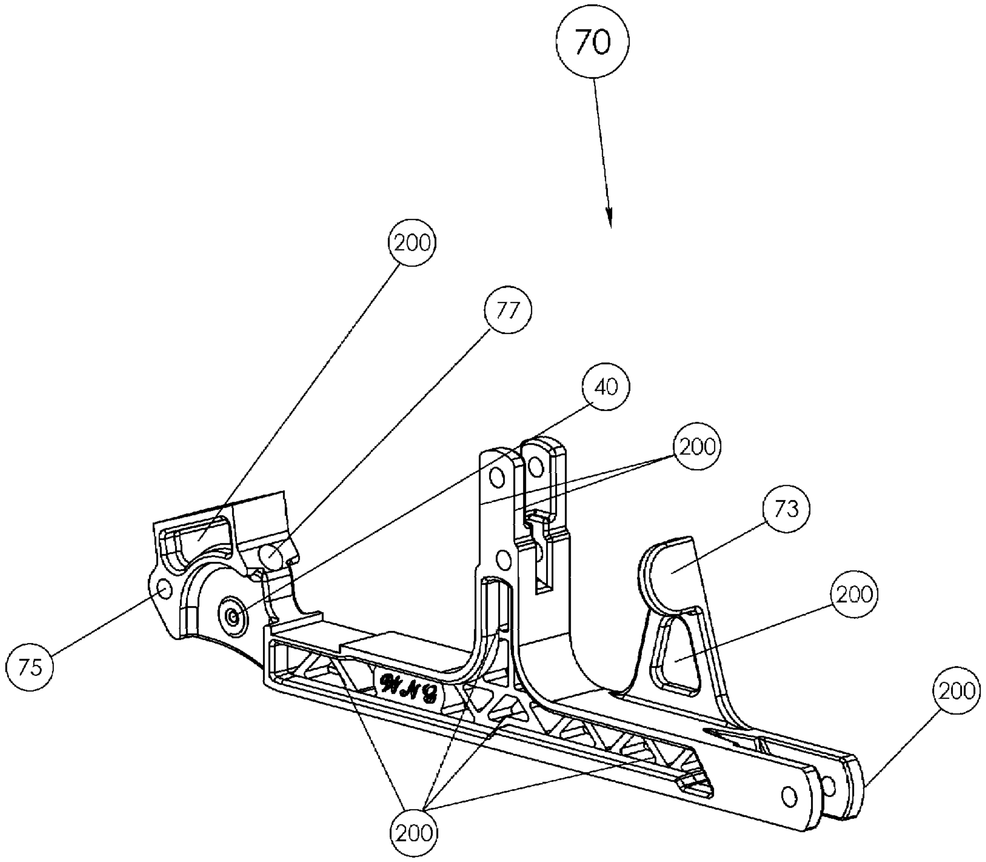


FIG. 3

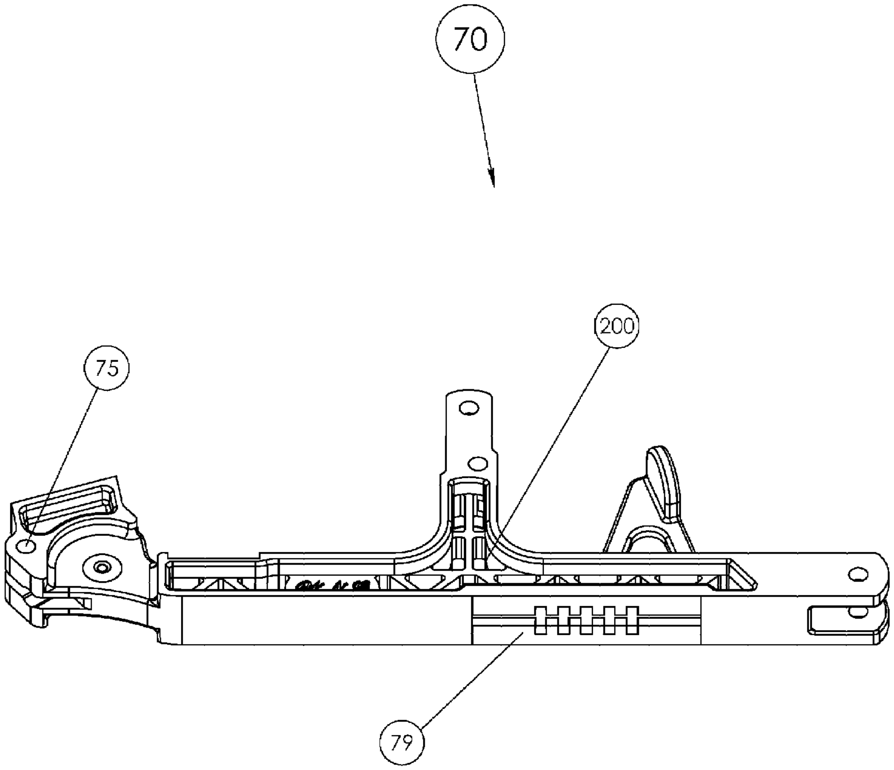
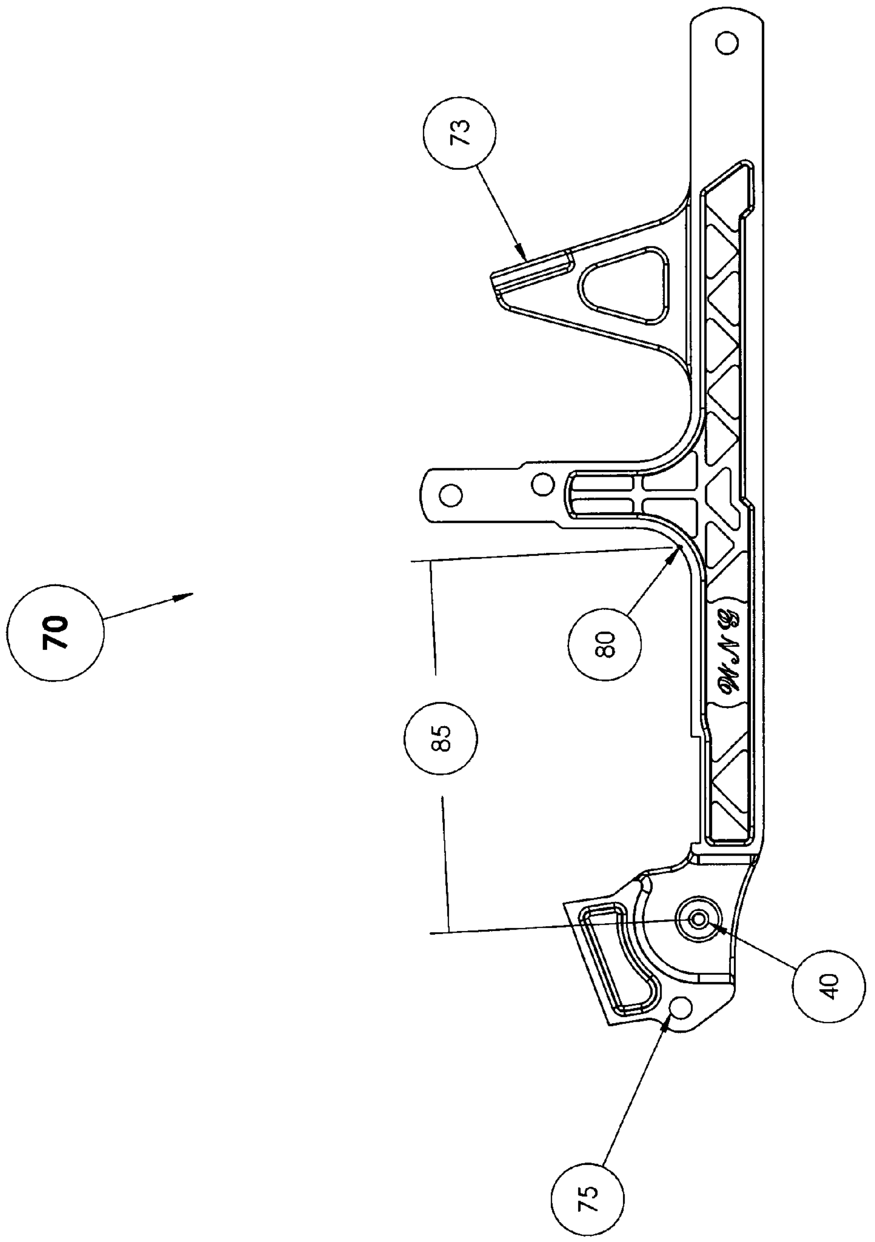


FIG. 4



15605 grams mm^2

FIG. 5

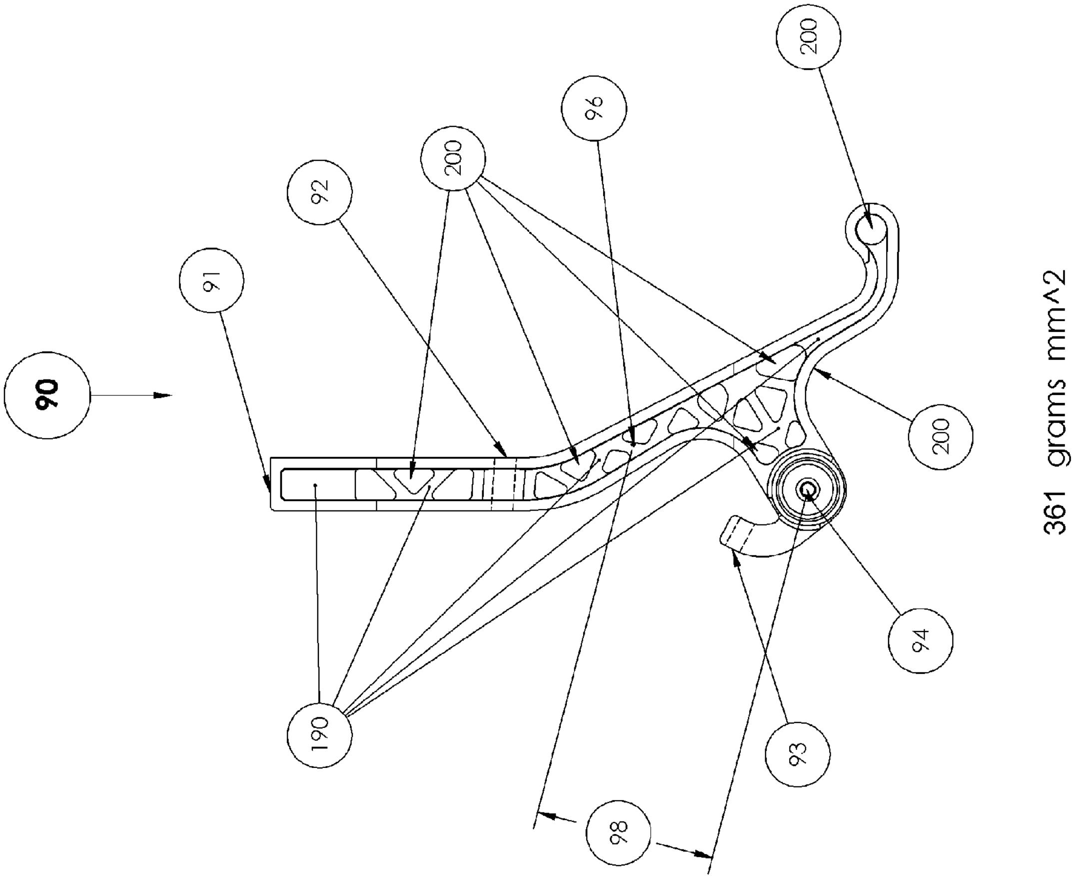


FIG. 6

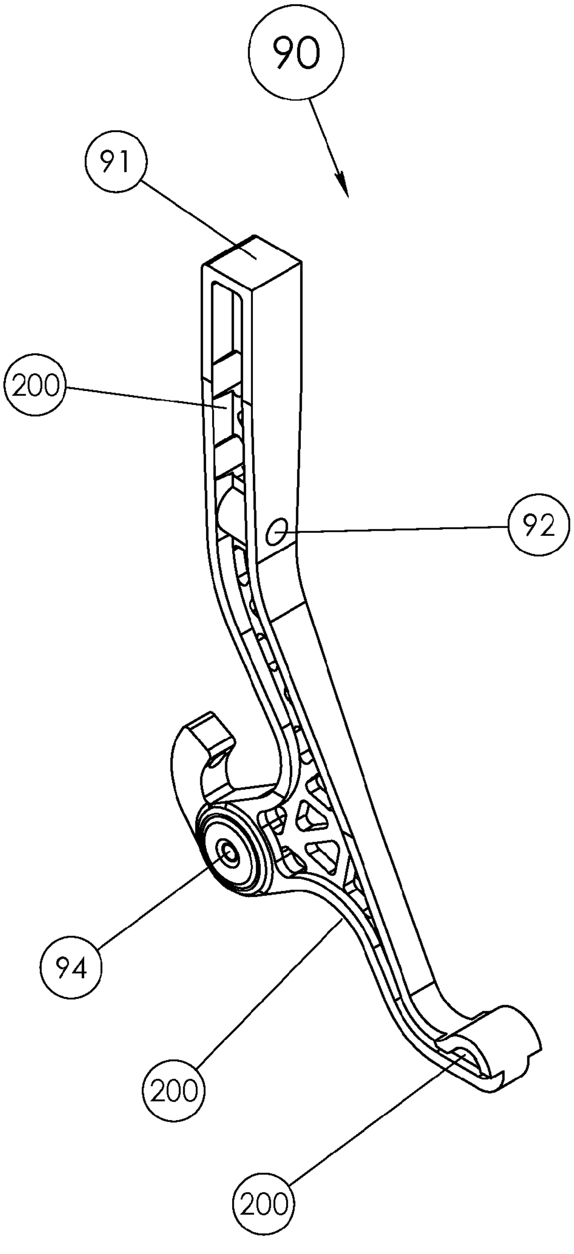


FIG. 7

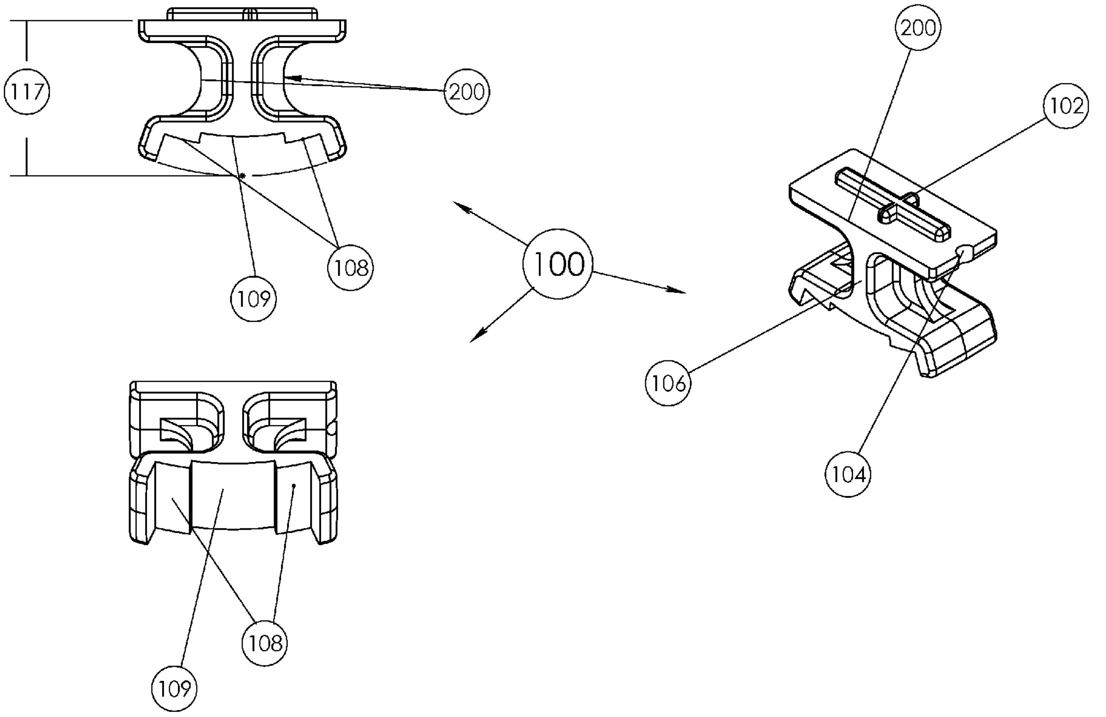


FIG. 8

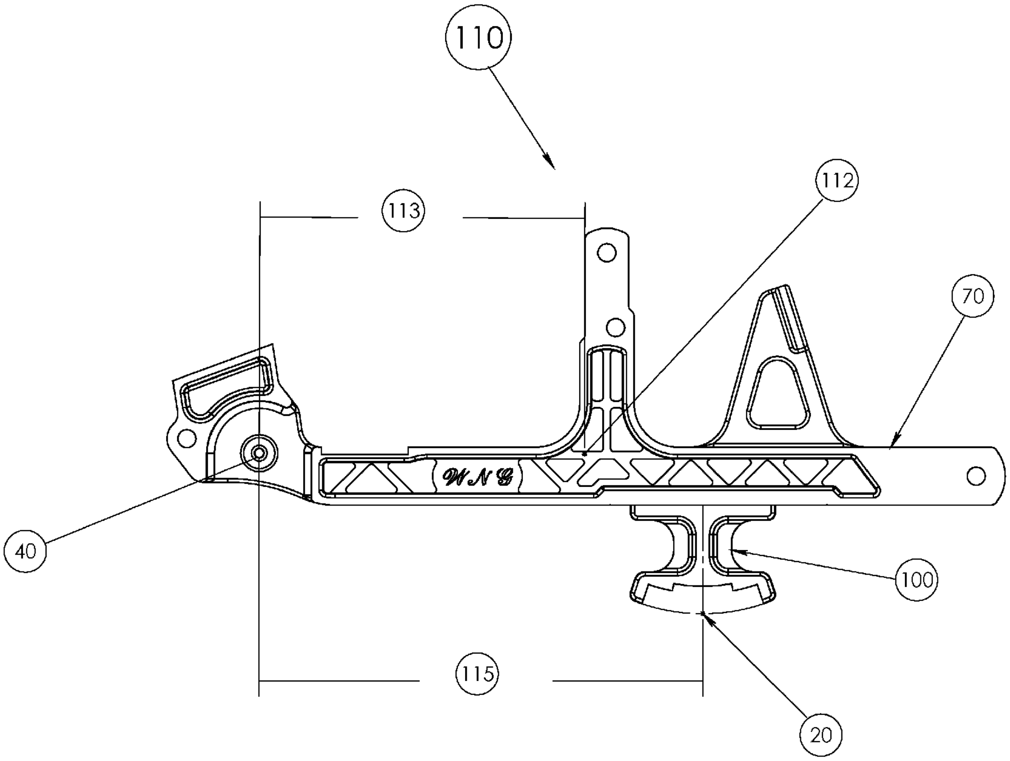


FIG. 9

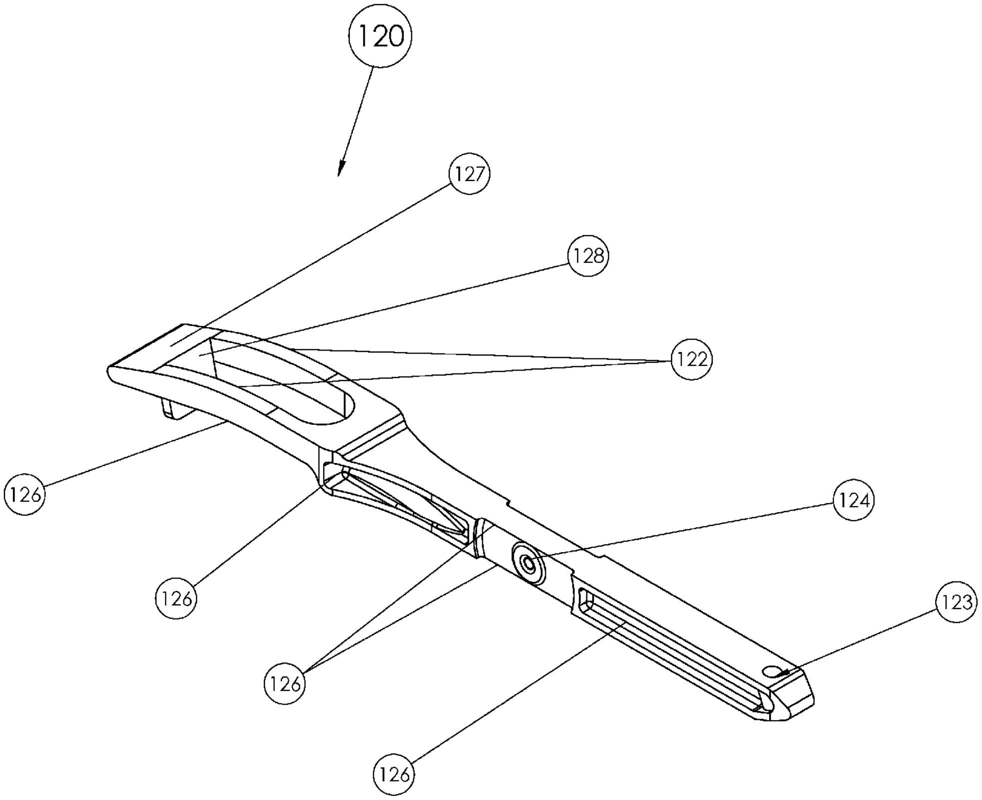


FIG. 10

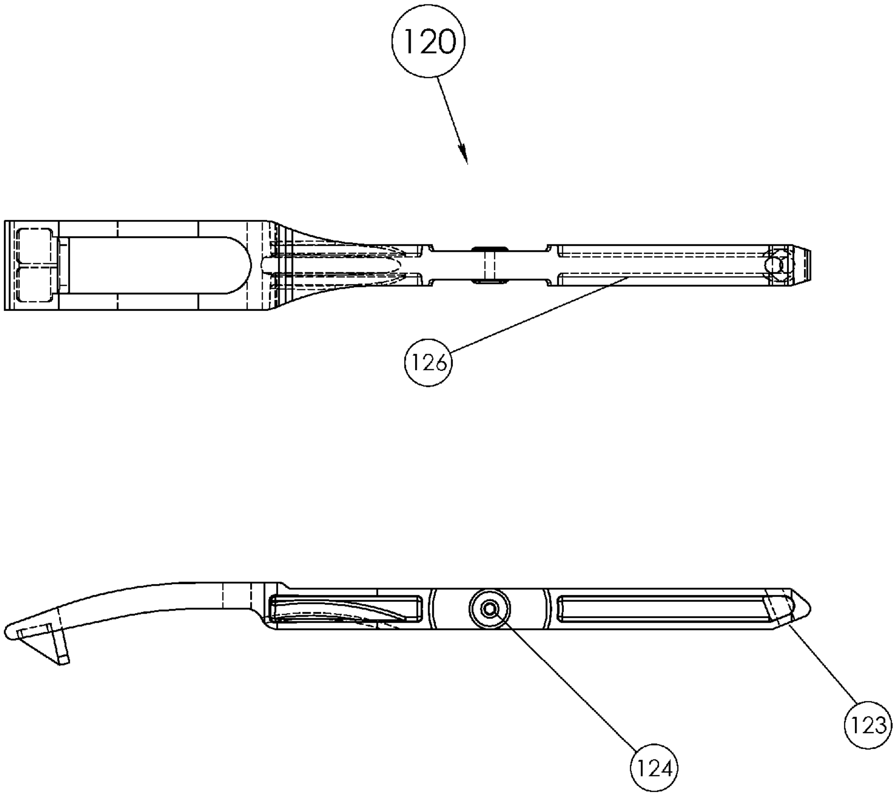


FIG. 11

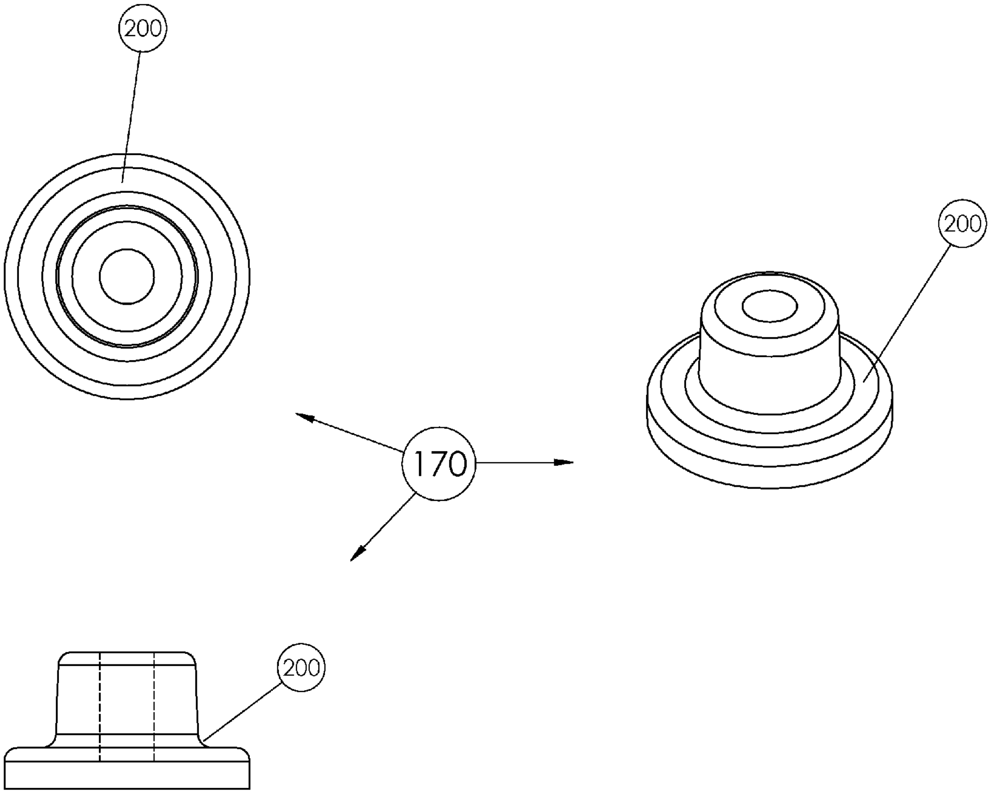


FIG. 12

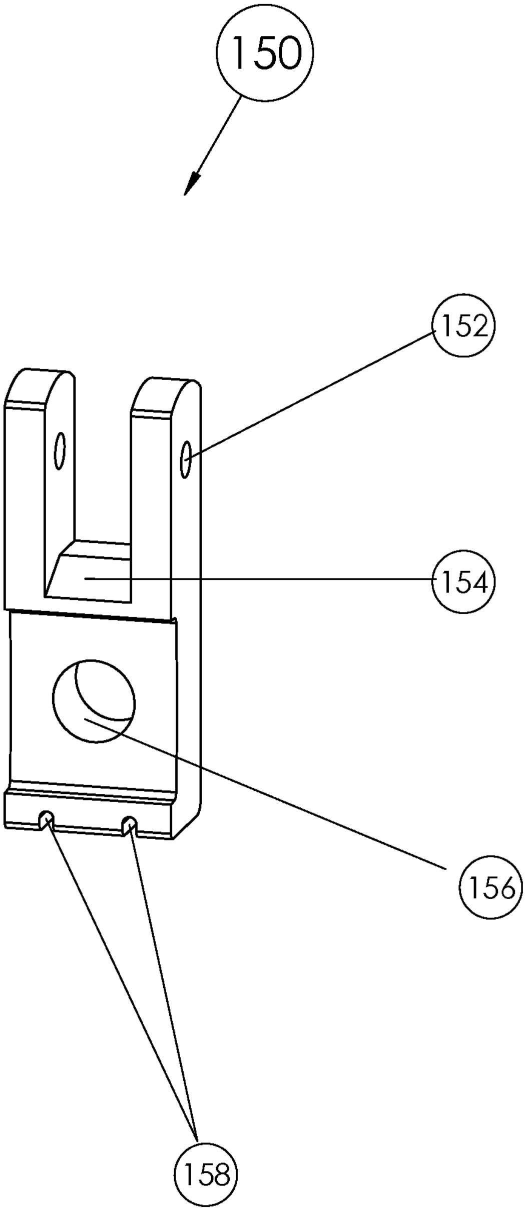


FIG. 13

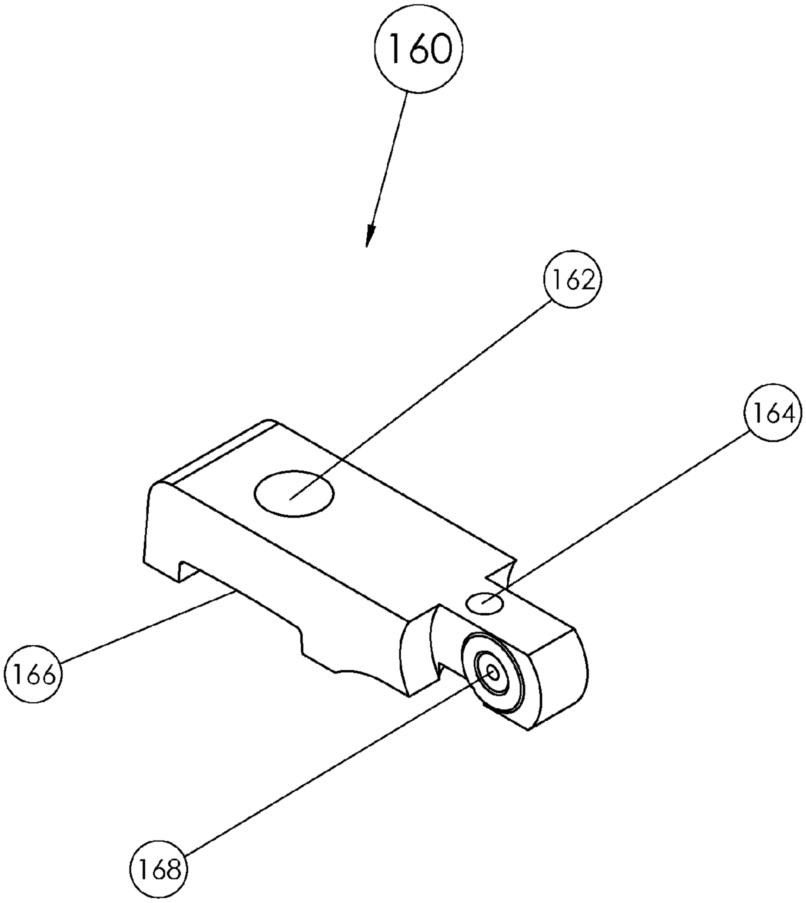


FIG. 14

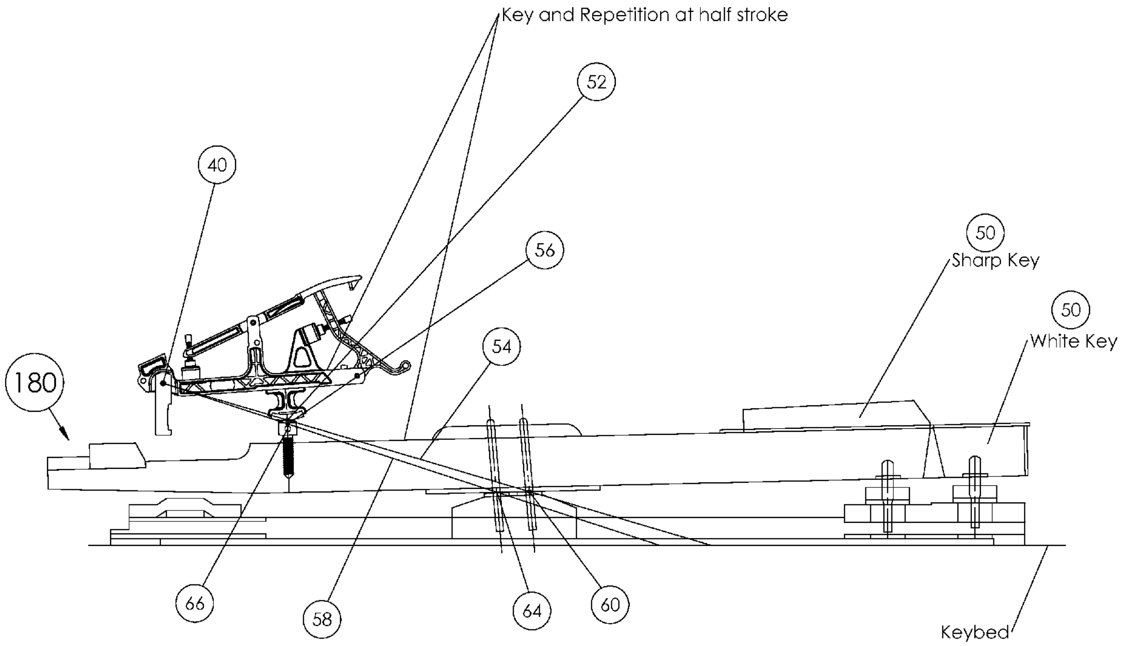

Key and Repetition at half stroke
52
40
56
50
Sharp Key
50
White Key
54
180
66
58
64
60
Keybed

FIG. 15

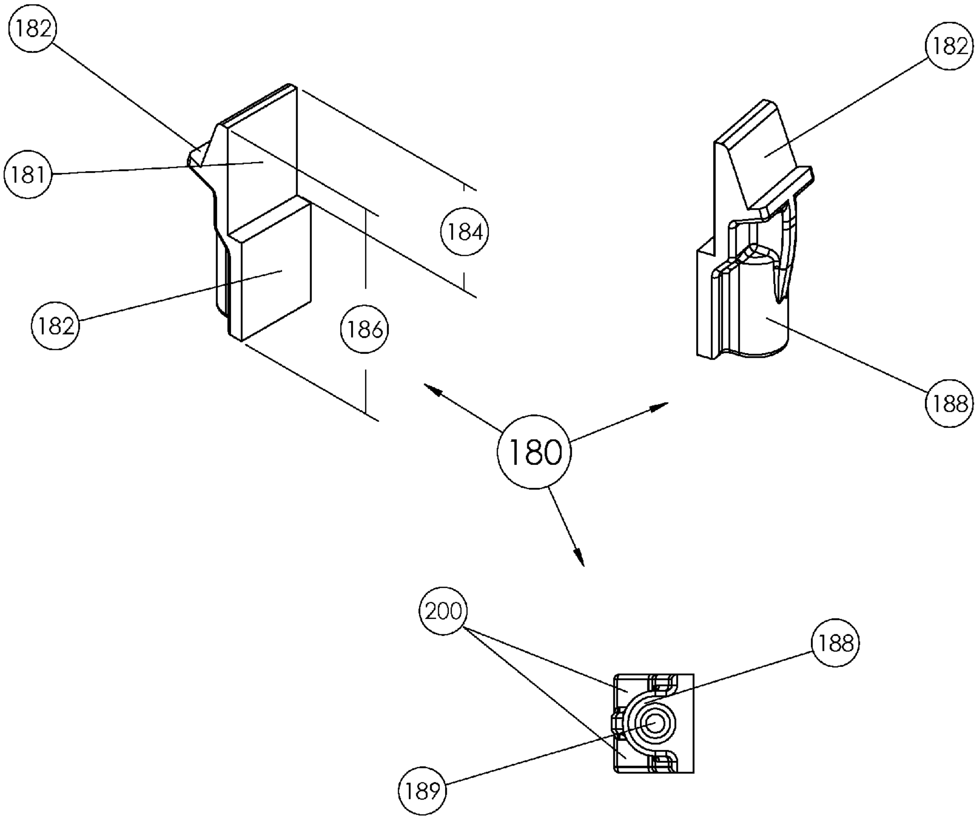


FIG. 16

GRAND PIANO COMPOSITE PIANO ACTION

BACKGROUND OF INVENTION

This invention relates to key operated percussion devices such as grand pianos and, more specifically, to the "actions" of such devices. A piano action transmits motion from the pianist's fingers to the piano strings.

The grand piano is a mature product that has remained relatively unchanged for nearly 100 years. Pianists, in general, must spend many years playing a piano in order to develop their technique. As a result, pianists, generally, prefer traditional piano actions because they learned to play on traditional piano actions which have remained unchanged. Traditional piano actions are made of wood. Typically, hornbeam or maple is used.

Relative to more modern materials, such as composites or plastics, wood is an inefficient raw material from which to manufacture piano action components. Wood action pieces must be drilled to produce the holes required for pivotal connections and assembly with other action components. The hole-drilling process is a laborious and costly process as compared to the production of molded piano action pieces with holes accurately formed therein during the initial molding process.

Wood is hydroscopic, i.e. wood swells or shrinks as its moisture content changes in response to the environment. This can cause binding in the action. Additionally, after repeated occurrences, this causes compression of the wood leading to failure of the piano action component. For instance, wood flanges often crack due to expansion from a rise in moisture content, as the screw crushes the wood in the flange where it is fastened to the rail. Moreover, wood has different strengths in different directions, complicating manufacturing processes, also resulting in reduced manufacturing efficiencies. Additionally, the production of any finished wood piece necessarily involves relatively large quantities of wasted material in the form of saw dust, which is inherent in any wood-working process. Finally, the lifespan of wood piano action components is limited as compared to that of other materials such as composites or plastics because wood eventually crumbles into dust after a certain amount of environmental cycles. On the other hand, composite piano action components would eliminated all the preceding drawbacks and result in more efficient manufacture and maintenance of a piano. Composite is defined as an engineered material made from two or more constituent materials with significantly different physical or chemical properties and which remain separate and distinct on a macroscopic level within the finished structure.

Thus far, all but one attempt to use composite piano action components has met with less than satisfactory market acceptance. This is because composite material is heavier than wood. Thus far, manufacturers have simply replaced traditional wood components with similarly designed and shaped composite components, resulting in heavier or, at best, equivalent mass composite action members. Our experimentation shows that, in all cases, current composite grand piano actions do not decrease and generally increase moments of inertia as determined by touch weight on the piano keys.

An increase in overall moment of inertia of a piano action is unacceptable to the pianist. Playing the piano requires a great deal of hand strength. This requirement is amplified when the pianist is playing difficult musical pieces that require the key to respond very quickly for both volume and repetition. It is probably true that virtuosic piano pieces require strength and agility at the very limit of the abilities of

the human hand. A pianist who depends on a key to move with a certain amount of finger strength will reject a piano action that requires more strength to produce the same key motion.

U.S. Pat. No. 6,740,801 (Yoshisue I) and U.S. Pat. No. 7,141,728 (Yoshisue II) have met with limited market acceptance. The object of Yoshisue I is to increase the efficiency of manufacture and maintenance and to extend the lifespan of a grand piano action mechanism. In every claim, Yoshisue I is limited to piano actions with at least one component of the action made of "synthetic resin having electrical conductivity at least on the surface thereof". The goal of this limitation is to eliminate static charge, thereby reducing the tendency of foreign particles to adhere to the action members as the particles cause wear, thereby increasing the lifespan of the action mechanism. Yoshisue I did not include the object of reducing the moment of inertia of the piano action. Yoshisue I teaches away from the use of plastic with a non-conductive surface in a piano action.

The object of Yoshisue II is to increase rigidity of the repetition base of the piano action. Increased rigidity can decrease the moments of the action when the rigidity increase is paired with certain changes in centers of mass of rotating action members and reductions in overall mass of certain action members. The repetition base in Yoshisue II, on the other hand, is without substantial change in repetition base center-of-mass and its overall mass is the same or heavier than the counterparts of this invention. Thus, the moment of the repetition base of Yoshisue II and the overall moment the whole piano action is significantly larger than those of this invention. Yoshisue II and this invention may seek to cure the same problem, i.e. reduce the energy requirements to cycle a grand piano action or improve the performance of the action; however, Yoshisue II failed at this object because it failed to discover and address the main source of the problem, which is inertia, dynamic mass, or moment analysis.

OBJECT OF INVENTION

It is an object of this invention to yield a piano action that has less dynamic mass and is thus more responsive. In order to do this, particular attention was paid to component mass as a function of distance from center of mass of the component to the center of rotation of the repetition or center of rotation of the key. Additionally friction forces are addressed and reduced with the introduction of true half stroke design. As a result, the pianist evaluates the piano action as being quicker, lighter, and more responsive. It is also an object of this invention to tie the collateral benefits of increased efficiency of manufacture and maintenance of a piano action made from composite material with the reduced dynamic mass of a grand piano action. It is also an object of this invention to provide a direct replacement for practically any grand piano action.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a front view of the composite piano action.

FIG. **2** is a front view of the Repetition Assembly.

FIG. **3** is a perspective view of the Repetition Base.

FIG. **4** is a perspective view from a bottom angle of the Repetition Base.

FIG. **5** is a side view of the Repetition Base.

FIG. **6** is a side view of the Jack.

FIG. **7** is a perspective view of the Jack.

FIG. **8** provides multiple views of the Moveable Multiple Height Heel (MMHH).

FIG. **9** is a side view of the Repetition Base with Moveable Multiple Height Heel.

FIG. **10** is a perspective view of the Balancier.

FIG. **11** is a top and side view of the Balancier.

FIG. **12** provides multiple views of a Regulating Button.

FIG. **13** is a perspective view of the Repetition Flange.

FIG. **14** is a perspective view of the Shank Flange.

FIG. **15** is a side view depiction of the Half Stroke Line of a key.

FIG. **16** provides multiple views of the Back Check.

DEFINITION LIST

DEFINITION LIST

Term	Definition
10	Composite piano action
20	Capstan contact point
30	Repetition Assembly
33	Repetition Assembly center of mass
36	Repetition Assembly Effective Radius
40	Repetition center of rotation
50	Key
52	White key capstan contact point at half stroke
54	White key half stroke line
56	Sharp key capstan contact point at half stroke
58	Sharp key half stroke line
60	Key center of rotation
64	Sharp key center of rotation
66	Capstan
70	Repetition Base
73	Stop for the Jack Regulating Button (replaces metal spoon)
75	Hole for "Helper Springs"
77	Adjustment screw location for "Helper Springs"
79	Repetition Base Female Notch System
80	Repetition Base center of mass
85	Repetition Base Effective Radius
88	Jack Assembly
90	Jack
91	Driving end of Jack
92	Hole for Jack regulating screw
93	Hole for Jack Spring
94	Jack center of rotation
96	Jack center of mass
98	Jack Effective Radius
100	Moveable Multiple Height Heel (MMHH)
102	Male Notch with offset key location used to connect to Repetition Base
104	Notch to show orientation
106	MMHH Central Force Transfer Pillar
108	Gluing surface for capstan contact cloth
109	Gluing surface for bushing cloth
110	Repetition Base with Moveable Multiple Height Heel (MMHH)
112	Repetition Base with MMHH center of mass
113	Repetition Base with MMHH Effective Radius
115	Repetition center of rotation (40) to capstan contact point (20) distance
117	Height of MMHH
120	Balancier
122	No lubricant require here as with wooden actions
123	Hole for regulating screw
124	Balancier center of rotation
125	Balancier Assembly
126	Balancier thinned to reduce mass
127	Gluing surface for buckskin
128	Gluing surface for Jack stop felt
150	Repetition Flange
152	Repetition Flange bushed pivot holes
154	Repetition Flange clearance notch
156	Repetition Flange screw hole
158	Repetition Flange "Helper Spring" silk cord notches
160	Shank Flange
162	Shank Flange screw hole
164	Shank Flange drop screw
166	Shank Flange rail cut
168	Hammer shank center of rotation
170	Regulating Button
173	Balancier Regulating Button
176	Jack Regulating Button
180	Back Check
181	Back Check felt gluing surface
182	Back Check buckskin gluing surface
184	Back Check felt area length
186	Back Check length
188	Back Check mount for back check wire
189	Back Check hole for check wire
190	Strategically shaped reinforcement material
200	Material removed to reduce mass

DETAILED DESCRIPTION OF EMBODIMENTS

The primary factors affecting dynamic mass of a piano action are: 1) mass of the composite piano action **10** at the capstan contact point **20**, 2) moment of inertia of the Repetition Assembly **30** about the Repetition Assembly center of rotation **33**, 3) moment of inertia of the Key **50** about the Key center of rotation **60**, and 4) mass of the Key **50**. The Repetition Assembly **30** is the Repetition Base **70** and the following items assembled to it: Jack Assembly **88**, Balancier Assembly **125**, and heel **100**.

The static weight of the Repetition Assembly **30** at the point where the capstan contacts the cushion on the heel, hereafter known as the capstan contact point **20**, is critical to dynamic mass. A mode of this invention has a weight at this point of 14.1 grams. The two prior art equivalents weigh 16.6 grams (Kawai R**2**) and 21.9 grams (Kawai R**1**). We have achieved a 15% reduction over prior art composite grand piano actions.

The moment of inertia of a rigid body rotating about a fixed axis is $\int r^2\,dm$, where r is the distance from center of rotation to the differential mass point of the body dm. The moment of inertia of a piano action component can be approximated by: (the distance from center of rotation to the center of mass)$^2\times$(mass).

Thus, the moment of inertia of the Repetition Assembly **30** can be accurately approximated using the distance from Repetition center of rotation **40** to the Repetition Assembly center of mass center of mass **33**—hereafter know as Repetition Assembly Effective Radius **36**—and the mass of the Repetition Assembly **30**. A mode of this invention has a moment of inertia of 45,599 gmm^2 from Repetition Assembly mass of 16.6 grams and Repetition Assembly Effective Radius of 52.4 mm.

The moment of inertia of the key is hard to calculate because it changes throughout the piano. The main factor affecting moment of inertia of the key is the number of leads added to the front of the key to balance the weight on the back end of the key from the hammers that hit the piano strings. Hammers decrease in weight from the bass to the treble as the mass needed to actuate the strings decreases due to the length of the strings and the frequency of the note. So, there are more leads in the bass keys of a piano than the treble keys. Typically there are 2 to 7 leads of ½" diameter in the bass going to 0 to 1 in the treble. The number of leads in the key is also the primary factor affecting the static weight of the key.

Thus, reducing lead count in the key is the metric we use with this invention to gauge the moment of inertia of the key **50** as well as the static weight of the Key **50**. This invention on average lowers the lead count in keys by 2-4 leads.

In order to help describe the invention further, the inventors have divided the components of this invention into three groups. Different goals were used with the development of the components in each group.

Group 1

Group 1 components are largely irrelevant to the moment of inertia of the piano action **10**, comprising: Repetition Flange **150**, and Shank Flange **160**. These parts are fixed in space and do not rotate. The Repetition Flange **150** provides secures the Repetition Base center of rotation **40**. The Shank Flange **160** secures the hammer. A flange is attached, by a screw, to a rail and thus rendered unmovable. Mass and inertia is not relevant to the performance a flange, as with all of Group 1.

The primary material requirements for these parts are strength, rigidity, stability, and lifespan. In this case, the traditional material of Maple or Hornbeam has been replaced by a composite material.

The best mode composite material is Nylon because Nylon has the highest tensile strength among composites and is also more conducive to gluing. Felt and buckskin must be attached to some action components to function. Additionally, the best mode composite material has glass filler because the glass increases tensile strength of the material. Both glass filled and unfilled composite materials have a non-conductive surface. Combining these two modes, we have determined that the overall best mode material is Nylon 6/6 40% glass filled because of its superior tensile strength and conduciveness to gluing. Maple has a tensile strength of approximately 2500 lbs/in^2. Nylon 6/6 40% glass filled has a tensile strength of approximately 8,000 lbs/in^2.

Additionally, Group 1 is a direct replacement for their wood counterparts in practically any grand piano.

Group 2

Group 2 components are substantially relevant to the moment of inertia of the Repetition Assembly **30**, comprising: Regulating Button **170**, Jack **90**, Balancier **120**, and Back Check **180**. The parts in Group 2 all rotate about the Repetition Base center of rotation **40** or the Key center of rotation **60**. The center of mass of these components is a significant distance from the relevant center of rotation. The mass of this group of parts is felt dynamically by the pianist as part of the touch weight of the piano. Less mass is better to the limit where the part is no longer structurally sufficient for the task of vigorous piano playing. Group 2 includes the same material qualities as Group 1. Group 2 is also fully interchangeable with traditional wood counterparts.

Structural design of each Group 2 component is quite different from that of their traditional wood counterparts. A concerted effort was taken to remove volume/material from the part, at the proper balance with rigidity requirements, and specifically removing volume furthest from the relevant center of rotation.

The Regulating Button **170** uses the increased strength of composite material to make a part that would not be possible with wood. With the increased tensile strength, we were able to produce a Regulating Button **170** with a base member with T-shaped cross section that provides material only where it is needed. Wherever substantial material was "removed by design" from the traditionally shaped grand piano action component, it is designated by **200** on the drawings. Material removed to reduce mass has resulted in substantial weight reduction of the Regulating Button **170**. As with traditional regulating buttons, felt material or other cushion material is glued to the base member with T-shaped cross section to yield a Regulating Button **170**.

A Regulating Button **170** of this invention weights 0.18 grams. Prior art composite regulating buttons range from 0.30 (Kawai R**2**) to 0.40 (Kawai R**1**) grams. In comparison, with our lightest competitor we have achieved a 40% reduction in mass over prior art composite regulating buttons.

Regulating Buttons **170** are used in two locations: at the Balancier **173** and at the Jack **176**. The Regulating Button on the Jack **176** is more critical. Less mass on the Jack **90** is important because the Jack **90** is a relative large action component that is located far from the Repetition center of rotation **40**. Any mass reduction in the Jack Regulating Button **176** will yield an exponential reduction in the moment of inertia of the Repetition Assembly **30**. The Jack Regulating Button **176** and the Balancier Regulating Button **173** are the same design. The Jack Assembly **88** is defined as the Jack **90** with Jack Regulating Button **176** assembled to it. The Balancier Assembly **125** is defined as the Balancier **120** with Balancier Regulating Button **173** assembled to it.

The Jack **90** of this invention could not be made from wood. A traditional wood jack is made from two pieces of wood with a glued joint to connect the two pieces in an L shape. This glue joint is a common point of failure as the parts age. Two piece jacks were required because of the limited properties of wood. A one-piece wood jack that meets rigidity requirements would be too thick. The thick heavy jack would make the action too heavy and the pianist would reject the heavy "feel" of the action.

Our new Jack **90** is a dramatic departure. It is a one-piece composite component. The shape follows the function of the Jack without compromise, meaning that the new shape optimally applies torque on the Balancier **120** in the most efficient right-angle direction, as the two components rotate about the Repetition center of rotation **40**. A similarly shaped wood counterpart would be impractically expensive to produce and would fail anyway, for want of rigidity. Our design allows a substantial reduction of material at various points **200** in the Jack **90**, thus substantially lightening the component, while leaving strategically shaped material **190** to provide increased rigidity over traditional wood jacks. The superior strength of the composite material along with the fact that it is strong in all directions allows a one-piece Jack design that is lighter and better. Note that even though the shape of the Jack **90** is drastically different from that of the traditional wood grand piano jack, this component is a direct replacement with most grand pianos.

The moment of inertia of the Jack **90** can be accurately approximated using the distance from Jack center of rotation **94** to the Jack center of mass center of mass **96**—hereafter know as Jack Effective Radius **98**—and the mass of the Jack **90**. This invention has a Jack moment of inertia of 361 gmm^2 from Jack mass of 1.3 grams and Jack Effective Radius of 17.0 mm.

The Balancier **120** of this invention is somewhat similar in shape to its traditional wood counterpart, but the Balancier **120** still has many advantages. It has been thinned substantially at various locations **126** to reduce mass even though the overall part is only minimally lighter. Also, composite material slides smoothly at **122** about the Knuckle without lubricants while traditional wood balanciers require lubricant at that point. Lubricants inevitably wear off leaving the potential for excessive friction at the knuckle and poor functioning of the action which is perceived by the pianist as added touch weight. Additionally, the best mode material is conducive to gluing and is required at **127** and **128**.

The Balancier is 2.4 grams. Prior art composite balanciers range from 2.5 grams (Kawai R**1**) to 4.4 grams (Kawai R**2**). In comparison, with our lightest competitor we have achieved a 4% reduction in mass over prior art composite balanciers.

The Back Check **180** is mounted on the Key **50**. The mass of the Back Check **180** must be calibrated to balance the weight exactly on each side of the Key **50**. Any reduction in mass of the Back Check **180** will allow the removal of weight on the front of the Key **50**, thus producing a reduction in touch resistance of the piano action.

Our new Back Check **180**, as designed, could not be made from wood. The traditional back check is a solid block of wood that is longer and wider than the Back Check **180** of this invention. Older back checks were designed for a wide range of "checking heights". Our Back Check **180** has a more narrow checking range as we believe there is no reason to have capability for such long checking distances anymore.

The Back Check **180** is 23 mm long at **186**. A traditional back check is about 29 mm long. Our Back Check **180** has a felt area **182** that is 12 mm long. A traditional back check has felt area about that is 17 mm long.

A traditional back check uses a soft felt under buckskin to provide a cushioned catcher for the hammer after the blow to the string. This results in an unpredictable stopping point on the check. Our new Back Check **180** uses a felt that is considerably more dense under the buckskin. This felt compresses less during checking so it provides a straighter inclined plane for the hammer to catch upon. As a result, the hammer comes to a sliding wedging stop. The result is more precise checking, that is, the hammer is stopped at a more consistent height among repetitions. Additionally, the reduced amount of felt and buckskin significantly reduces overall mass of the Back Check with felt and buckskin.

The Back Check **180** is 0.9 grams. Prior art composite back checks range from 1.2 (Kawai R**2**) grams to 1.5 grams (Kawai R**1**). In comparison, with our lightest competitor we have achieved a 25% reduction in mass over prior art back checks.

Group 3

Group 3 components are critically relevant to the moment of inertia of the piano action **10**, comprising: Repetition Base **70** and Multiple Height Moveable Heel **100**. Group 3 components rotate about the Repetition center of rotation **40**. Much of the mass associated with this Group of parts is a significant distance from the Repetition center of rotation **40**. The mass of this group of parts is drastically felt by the pianist as the primary component of the touch weight of the piano key. Less mass is better as long as structural requirements are met. Group 3 includes the same material qualities as Group 1. Group 3 is also fully interchangeable with traditional wood counterparts.

The Repetition Base **70** is not lighter than its wood counterparts, however, the Repetition Assembly's (**30**) moment of inertia is substantially less than that of its wood counterparts. Much of the weight of this part is in the bumper block right above the center of rotation **40** and is thus largely irrelevant. Mass furthest away from the center of rotation **40**, however, has been substantially reduced.

Material was removed at strategic locations **200** in the Repetition Base **70**, thus substantially lightening the component, while leaving strategically shaped material to provide increased rigidity over traditional wood repetitions.

We have integrated the Stop for the Jack Regulating Button **73** into the Repetition Base **70**. Traditionally, a repetition has a metal spoon that acts as a stop for the Jack Regulating Button **176**. This integration allows the Jack to be more strategically positioned below the Knuckle and Balancier center of rotation **124**. Because a metal spoon is much heavier than either plastic or wood, we have integrated this stop into the composite part. In absolute terms this saves weight but the location of the weight loss is also important as a spoon is located far from the Repetition center of rotation **40**. The integration saves weight, reduces parts count, and streamlines manufacturing.

One mode of the invention includes "whippen helper springs". This mode includes a spring that takes weight off the capstan. The spring is attached to the Repetition Base at **75**. The mode includes a screw adjustment for the spring tension at **77**.

The moment of inertia of the Repetition Base **70** can be accurately approximated using the distance from Repetition center of rotation **40** to the Repetition Base center of mass center of mass **80**—hereafter know as Repetition Base Effective Radius **85**—and the mass of the Repetition Base **70**. A mode of this invention has a measure of 15,605 gmm^2 from a Repetition weight of 8.8 grams and Repetition Effective Radius of 42.1 mm.

The bottom of the Repetition Base **70** is designed so that the Moveable Multiple Height Heel **100** can be installed in a variety of positions onto the Repetition Base **70**. The bottom of the Repetition Base **70** has female notches spaced at 3 mm located at **79**. The corresponding male notch **102** in the Multiple Height Moveable Heel **100** is offset from the center of the part by 1.5 mm thus allowing the MMHH **100** to be attached in a variety of positions in 1.5 mm increments (by turning the MMHH around) along the length of the Repetition Base **100**. This allows the Repetition Assembly **10** to be customized to fit in a variety of non standard pianos.

The moment of inertia of the Repetition with MMHH **110** can be accurately approximated using the distance from Repetition center of rotation to the Repetition with MMHH center of mass center of mass **112**—hereafter know as Repetition with MMHH Effective Radius **113**—and the mass of the Repetition with MMHH. A mode of this invention has a measure of 20,951 gmm^2 from a Repetition with MMHH weight of 10.4 grams and Repetition with MMHH Effective Radius of 44.9 mm.

The Multiple Height Moveable Heel **100** allows an unprecedented high degree of control over the location of the capstan contact point **20** on the MMHH **100**. The best mode of the MMHH provides eight different length options—12 mm through 18 mm in 1 mm increments. There is also a 20 mm mode.

The MMHH allows for keyboards to be "tuned" to proper "half stroke line", i.e. allows the sharp and white keys to simultaneously attain proper "half stroke line". This is not achievable with prior art piano actions.

Because the key and the repetition both move in separate arcs, their movement must be analyzed as a system in order to view the overall motion of the piano action **10**. The key and the repetition could be thought of as one teeter totter on the end of another larger teeter totter. The larger teeter totter is the key. The dynamics of the system will yield the optimum "feel" for the pianist when friction forces are minimized. In this system, friction is minimized when the key is on "half stroke design". Half stroke design results in a lighter, faster more responsive piano action.

A "half stroke line" is a theoretical line drawn from the 'Repetition center of rotation **40** to the capstan contact point **20**' depicted by **115** (see FIG. **9**) when the Repetition Assembly **30** is at half stroke, i.e. "when the key lifts the Repetition Base **70** exactly half way through the cycle boundaries of the Repetition Base". That line is then extended down beyond the Key center of rotation **60**. This line is the "half stroke line".

Ideally, the half stroke line of each key intersects the balance point of that particular key. This is ideal because the key and the repetition both move in arcs and the slide path at the capstan will be minimized when the key balance points are in line. A key design with its balance point on the half stroke line will have less friction between the capstan and the heel. A reduction of friction at the capstan results in a lighter, faster, more responsive action.

However, simultaneous half stroke design on each key is not possible because the Repetition center of rotation (**40**), capstan contact point (**20**), and heel size are fixed. Keyboards are designed to half stroke line for the white key only. We ask the question why limit yourself here. In response, we have made a heel to allow variation of the repetition center of rotation (**40**) to capstan contact point (**20**) distance and height **117**. This allows varying the capstan contact point **20** location with respect to the position of the key. This is depicted in FIG. **15** where one can see two half stroke lines. The sharp key half stroke line **58** runs through points **40** and **64**. The white key half stroke line **54** runs through points **40** and **60**. This is proper half stroke design.

One invention disclosed in this application is the first to provide near complete control for a keyboard designer to conduct a full half stroke setup on any grand piano. As discussed, half stroke design minimizes the slide path between the capstan and the repetition cushion and thus lowers friction. Additionally, because the friction does not need to be counterbalanced, less lead is required in the key. Thus, half stroke design also reduces mass in the system. The net result for the pianist is a faster more responsive action.

What is claimed is:

1. A repetition assembly for a grand piano comprising: a repetition base; a heel; a jack; a balancier; and a set of two regulating buttons, wherein: said repetition base is assembled to said balancer by a pin; said jack is assembled to said repetition base by a pin; one of said set of two regulating buttons is assembled to said jack by a rigid threaded member; the other of said set is assembled to said balancier by a rigid threaded member; said heel is attached to a lower base member of said repetition base by a calibrated adjustable connection system, comprising: at least one male notch (**102**) on the upper surface of said heel and a set of female notches (**79**) on the lower surface of said lower base member of said repetition base wherein said notches are appropriately sized so that said at least one male notch fits snuggly inside of any one of said set of female notches and the clearances between the adjacent connection surfaces of said notches is appropriate for connecting these members; and said repetition assembly is a mechanical action comprising three pivot points: a center-of-rotation of said repetition base, a center-of-rotation of said jack, and a center-of-rotation of said balancier, so that an upward force applied to the bottom surface of said heel causes said repetition assembly members to pivot about said pivot points, yielding a general upward motion of said jack.

2. A repetition assembly for a grand piano as recited in claim **1** wherein said set of female notches is a plurality of notches distributed along the lower surface of said lower base member of said repetition base to yield a range of heel connection locations so that when said at least one male notch is connected to any one of said set of female notches there exists a subassembly of said repetition base and said heel with a "repetition center-of-rotation to capstan contact point distance" (**115**) ranging from 12-20 millimeters inclusive.

3. A repetition assembly as recited in claim **2** wherein said repletion base and said heel are made of plastic or composite material.

4. A repetition assembly as recited in claim **3** wherein said repletion base and said heel are made of nylon plastic with 40-60% glass filler material.

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