

PRE-TREATMENT APPARATUS FOR BATTERY RECYCLING

TECHNICAL FIELD

5 The present application relates to battery recycling technology. In particular, the present application relates to a pre-treatment apparatus for battery recycling.

BACKGROUND

10 Batteries such as lithium rechargeable batteries have become one of the most widely used mobile energy sources in many industrial and daily life applications. With the usage of rechargeable batteries fast increasing, aged and discarded batteries have become a major issue of environmental concern and sustainability of social developments. Industrial players have endeavoured with continuous efforts in developing effective and practical solutions for
15 rechargeable battery recycling for the purposes of possible environmental pollution reduction and the better reuse of the precise metals and other materials from the recycled battery parts.

 Known battery recycling technologies send batteries to the shredding process
20 together with the wrapping material, e.g., wraps or plastic films enclosing the batteries. The wraps or plastic films will have to be removed before the extraction of metal material from the battery scraps to reduce the complexities of the recycling process. Removal of the wraps or plastic films is currently processed by manual operations, which, is both labour-intensive and less efficient.

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SUMMARY

 According to one aspect, the present invention provides a pre-treatment apparatus for battery recycling. In one embodiment, the pre-treatment apparatus comprises a base
30 which defines a platform thereon, a support frame mounted to the base and suspended above the platform, a first jaw, a second jaw, a first cutter and a second cutter. The first jaw and the second jaw are movably coupled to the support frame and positioned above the platform. The first jaw and the second jaw are disposed spaced apart from each other along a lateral

direction. The first jaw is positioned at a first side of a passage formed between the first jaw and the second jaw, and the second jaw is positioned at a second side of the passage opposite to the first side. The first cutter is disposed at the first side of the passage and offset from the first jaw along a longitudinal direction orthogonal to the lateral direction. The second cutter is disclosed at the second side of the passage and offset from the second jaw along the longitudinal direction. When a battery is fitted between the first jaw and the second jaw, the first cutter and the second cutter are positioned to partially interfere with the passage such that advancement of the battery towards the first cutter and the second cutter causes an enclosure of the battery to pass through and cut apart by the first cutter and the second cutter.

Optionally, the first cutter is oriented with a first normal direction facing the passage, and the second cutter is oriented with a second normal direction facing the passage. A component of the first normal direction faces the first jaw, and a component of the second normal direction faces the second jaw.

Optionally, the first cutter is connected to the second jaw and the second cutter is connected to the first jaw, and a movement of the first jaw and the second jaw away from each other reduces a distance between the first cutter and the second cutter.

When a battery is fitted in the passage is brought into contact with the first cutter and the second cutter, a cutting counterforce applied to the first cutter and the second cutter by the battery creates a tendency to cause the first cutter and the second cutter to move away from each other and to cause the first jaw and the second jaw to move towards each other. The battery between the first jaw and the second jaw restricts the first jaw and the second jaw from moving toward each other, such that the first cutter and the second cutter are maintained to partially interfere with the passage.

Optionally, the apparatus further comprises a first resilient member and a second resilient member. The first resilient member is disposed between the support frame and the first jaw, to bias the first jaw towards the passage. The second resilient member is disposed between the support frame and the second jaw, to bias the second jaw towards the passage.

Optionally, the apparatus further comprises a first link bar and a second link bar. The first link bar is arranged across the passage and connects the first jaw to the second cutter. The second link bar is arranged across the passage and connects the second jaw to the first cutter. The first link bar and the second link bar are slidably engaged with each other along the lateral direction to prevent a movement of the first jaw and the second jaw relative to each other along the longitudinal direction.

Optionally, one of the first link bar and the second link bar has a groove formed thereon along the lateral direction and the other one of the first link bar and the second link bar has a projection formed thereon. The projection extends into the groove to prevent the first link bar and the second link bar from moving relative to each other along the longitudinal direction.

Optionally, the apparatus further comprises a retainer movably connected to the support frame for abutting against a battery received between the first jaw and the second jaw.

Optionally, the retainer is movable relative to the support frame towards and away from the passage along a height direction orthogonal to the longitudinal direction and the lateral direction.

Optionally, the second link bar is positioned above the first link bar, the apparatus further comprises a support block positioned between the second link bar and the retainer. A movement of the first jaw and the second jaw away from each other carries the support block away from the retainer to allow the retainer to move towards the passage, for engaging and maintaining a battery received in the passage.

The apparatus may further comprise a third resilient member disposed between the support frame and the retainer to bias the retainer towards the passage, such that the retainer moves towards the passage after the support block moves away from the retainer.

Optionally, the platform may further comprise a conveyor belt movably positioned underneath the first jaw, the second jaw, the first cutter and the second cutter. The conveyor

belt is movable relative to the base for carrying batteries borne on the conveyor belt to pass through the passage along the longitudinal direction such that an enclosure, e.g., a plastic film wrapped around each of the batteries, is carried to slide through the first cutter and the second cutter, and cut apart by the first cutter and the second cutter. In addition, an array of studs may be mounted to the conveyor belt. Adjacent two rows of the array of studs along the longitudinal direction are positioned spaced apart from each other with a gap therebetween, and the gap has a width configured to receive a battery one at a time therein.

Optionally, the apparatus further comprises a motor mounted to the base, a driving gear, a driven gear, a first driving shaft, a first roller shaft, a plurality of second driving shafts, and a plurality of second roller shafts. The motor has a main shaft oriented parallel to the lateral direction, the driving gear is coaxially coupled to the main shaft, and the driven gear is rotatably mounted to the support frame and engaged to the driving gear. The driven gear has a driven gear axis oriented perpendicular to the main shaft. The first driving shaft is coaxially coupled to the driven gear and rotatably mounted to the support frame. The first roller shaft is rotatably mounted to the support frame and oriented parallel to the longitudinal direction. A first driving belt is looped between the first driving shaft and the first roller shaft for transmitting rotational motion from the first driving shaft to the first roller shaft. The plurality of second driving shafts are each rotatably mounted to the support frame and oriented parallel to the first driving shaft, and the plurality of second roller shafts are each rotatably mounted to the support frame and oriented parallel to the first roller shaft. A transmission belt is looped between the first driving shaft and each of the plurality of second driving shafts, for transmitting rotational motion from the first driving shaft to each of the plurality of second driving shafts. The plurality of second driving belts are each looped between one of the second driving shafts and a corresponding one of the plurality of second roller shafts, for transmitting rotational motion from the one of the second driving shafts to the corresponding one of the plurality of second roller shafts. The first roller shaft and the plurality of second roller shafts are rotatable in a same direction, such that upon the motor being activated, the motor drives the first roller and the plurality of second roller shafts to rotate in the same direction.

Optionally, the apparatus further comprises a set of first roller wheels mounted to the first roller shaft and a plurality sets of second roller wheels each being mounted to one

of the plurality of second roller shafts. The first roller shaft and the plurality of second roller shafts are arranged relative to each other with an even pitch, and the set of first roller wheels and the plurality sets of second roller wheels have a same outer roller diameter such that gaps between adjacent sets of first and second roller wheels have a same width for receiving and contacting batteries of same outer battery diameter. Rotations of the first roller shaft and the plurality of second roller shafts cause the batteries to rotate, by frictional force between the batteries and the set of first roller wheels and each set of the second roller wheels.

Optionally, the apparatus further comprises a worm rod coaxially mounted to the first roller shaft, a sleeve shaft rotatably mounted to the support frame above the platform and oriented orthogonal to the first roller shaft, a worm gear coaxially mounted to the sleeve shaft such that the sleeve shaft passes through the worm gear and that the worm gear being engaged to the worm rod, and an array of brushes mounted to a side surface of the sleeve shaft. A rotation of the first roller shaft drives the sleeve shaft to rotate the brushes to sweep a top portion of the batteries carried on the platform.

Optionally, the apparatus may further comprise a blower and a first pipe having a first inlet connected to the blower and a first outlet opening at a front end of the platform. An air supplied by the blower blows out from the first outlet through the first pipe for carrying battery enclosures cut off from the batteries away from the platform, to assist in easy separation and collection of the enclosures.

Optionally, the apparatus may further comprise a second pipe having a second inlet connected to the blower and a second outlet extending into the sleeve shaft. The sleeve shaft has a plurality of perforations formed at a side surface thereof. An air supplied by the blower flows into the sleeve shaft through the second pipe and blows out from the sleeve shaft through the plurality of perforations.

In the context, the term “coupled” refers to connection relationships between two or more parts or components, which include situations where the two or more parts or components are fixedly connected to each other, integrally, directly or indirectly. The connection relationships also include situations where the two or more parts of components

are movably connected to each other, i.e. one part or component is movable relative to the other part or component to which such one part of component is connected to.

BRIEF DESCRIPTION OF DRAWINGS

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The technical solutions and corresponding technical features of the embodiments will be more comprehensively understood in conjunction with the accompanying drawings, in which:

10 Figure 1 is a perspective view showing a pre-treatment apparatus for battery recycling according to one embodiment of the present invention;

Figure 2 is a perspective view showing the apparatus of Figure 1 with batteries carried thereon for processing;

15 Figure 3 is a perspective view showing the apparatus of Figure 1 viewing from a front end;

Figure 4 is a partial exploded perspective view showing the apparatus of Figure 3 with batteries carried thereon during processing;

Figure 5 is an enlarged partial view of portion 5 of Figure 1;

Figure 6 is an enlarged partial view of portion 6 of Figure 2;

20 Figure 7 is an enlarged partial view of portion 7 of Figure 5;

Figure 8 is an enlarged partial view of portion 8 of Figure 6;

Figure 9 is a front view of Figure 5;

Figure 10 is a front view of Figure 6;

Figure 11 is an enlarged partial perspective view of portion 11 of Figure 4;

25 Figure 12 is a partial exploded view of Figure 11;

Figure 13 is a partial top view of Figure 6 showing a battery to be pre-treated;

Figure 14 is a partial enlarged view of Figure 13;

Figures 15 and 16 are partial top views of Figure 11 showing batteries being processed at various stages after the step shown in Figure 13;

30 Figure 17 is a partial top view of Figure 11 showing a battery with a wrap cut off after the pre-treatment process;

Figure 18 is a partial perspective of Figure 1 viewing from another angle;

Figure 19 is a partial enlarged view of portion 19 of Figure 18;

Figure 20 is a partial front view of Figure 18 with batteries carried on the platform for processing;

Figure 21 is an enlarged partial view of Figure 2;

Figure 22 is an enlarged partial view of Figure 21;

5 Figure 23 is an enlarged partial view of portion 23 of Figure 22.

DETAILED DESCRIPTION

As shown in Figures 1 to 4, according to one embodiment, a pre-treatment apparatus
10 100 for battery recycling comprises a base 112 and a support frame 116 mounted on the
base 112, via a set of link beams 114. The base 112 defines a longitudinal direction X, a
lateral direction Y, and a height direction Z, each orthogonal to the other two directions, the
base 112 also defines a back end 102 and a front end 108 along the longitudinal direction X.
Legs 111 are mounted to the base 112 for supporting the base 112 and other parts of the
15 apparatus 100 on a floor or ground. The base 112 has a platform 130 formed thereon, and
the support frame 116 is positioned to suspend above the platform 130. The support frame
116 has a suspension bracket 118 mounted thereon at the front end 108 of the apparatus 100.
Multiple sets of mounting brackets, e.g. four pairs of mounting brackets 119, are mounted
to the suspension bracket 118, such that the four pairs of mounting brackets 119 are fixedly
20 mounted to the support frame 116 through the suspension bracket 118.

As shown with further details in Figure 5 to Figure 12, the apparatus 100 comprises
a first jaw 122, a second jaw 128, a first cutter 124 and a second cutter 126. The first jaw
122 and the second jaw 128 are each movably connected to one of the pairs of the mounting
25 bracket 119, and each pair of the mounting brackets 119 is mounted to the support frame
116 through the suspending bracket 118. The first jaw 122 and the second jaw 128 are
disposed spaced apart from each other along the lateral direction Y. Between the first jaw
122 and the second jaw 128 there is formed a passage 125 for allowing batteries to pass
through. The first jaw 122 and the first cutter 124 are positioned at a first side 125a of the
30 passage 125. The second jaw 128 and the second cutter 126 are positioned at a second side
125b of the passage 125.

The first cutter 124 is positioned offset from the first jaw 122 along the longitudinal direction X, and connected to the second jaw 128. The second cutter 126 is positioned offset from the second jaw 128 along the longitudinal direction X, and connected to the first jaw 122. When a battery, e.g. battery 801, is placed between the first jaw 122 and the second jaw 128 and upon the first jaw 122 and the second jaw 128 being brought into contact with the battery 801, as shown in Figure 13 and Figure 14, the first cutter 124 and the second cutter 126 are positioned to partially interfere with the passage 125. With the first cutter 124 and the second cutter 126 so positioned and when the battery 801 is advanced along the passage 125 towards the first cutter 124 and the second cutter 126, an enclosure 84, e.g. a plastic film wrapping around the external surface of the battery 801, is brought into contact with the blade edges of the first cutter 124 and the second cutter 126. Further forward movement of the battery 801 will cause the enclosure 84 of the battery to be cut and separated apart by the first cutter 124 and the second cutter 126. The enclosure 84 can then be separated from the battery 801, and the core 82 of the battery 801 is ready for the next step of recycling process, e.g. shredding, which is free from the enclosure 84. As shown in Figures 16 and 17, after battery 801 is processed and with the enclosure 84 removed, a subsequent battery 802 and further batteries may follow and be processed in a similar manner.

The positional relationship between the first cutter 124, the second cutter 126, the first jaw 122 and the second jaw 128 are configured such that when the passage 125 formed between the first jaw 122 and the second jaw 128 has a width $125w$ suitable for receiving a battery-to-be-recycled of a predetermined diameter, and when the first jaw 122 and the second jaw 128 are brought into contact with a battery placed therebetween, the first cutter 124 and the second cutter 126 are positioned to partially extend into the passage 125 formed between the first jaw 122 and the second jaw 128, the exposure length of the first cutter 124 and the second cutter 126 extending into the passage 125, e.g. the exposure length 124a of the first cutter 124 and the exposure length 126a of the second cutter 126 shown in Figure 13, is substantially the same or slightly greater than the thickness $84t$ of the enclosure 84 of the battery 801. Another words, as shown in Figure 13, the minimum distance between the blades of the first cutter 124 and the second cutter 126 is substantially equal to or slightly smaller than the diameter $82d$ of the core 82 of the battery 801, upon the first jaw 122 and the second jaw 128 being brought into contact with a battery 801 received therebetween, the

first cutter 124 and the second cutter 126 are positioned to partially interfere with the passage 125, such that advancement of the battery 801 towards the first cutter 124 and the second cutter 126 causes the enclosure 84 of the battery 801 to be cut apart by the first cutter 124 and the second cutter 126.

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As shown with further details in Figure 13 and Figure 14, the first cutter 124 may be oriented with a first normal direction 124n facing the passage 125 and the first jaw 122, and the second cutter 126 may be oriented with a second normal direction 126n facing the passage 125 and the second jaw 128. Specifically, the first cutter 124 is oriented with a first longitudinal component 124x of the first normal direction 124n facing the first jaw 122, and the second cutter 126 is oriented with a second longitudinal component 126x of the second normal direction 126n facing the second jaw 128.

The first cutter 124 is connected to the second jaw 128 and the second cutter 126 is connected to the first jaw 122, by which, movement of the first cutter 124 and the second cutter 126 away from each other reduces a distance between the first jaw 122 and the second jaw 128. Positioned and configured in the above-illustrated manner, the first cutter 124 and the second cutter 126 each has blades inclinedly oriented facing a battery 801 to be carried toward the first cutter 124 and the second cutter 126.

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When the battery 801 clamped between the first jaw 122 and the second jaw 128 is carried to move along the longitudinal direction X through the passage 125 towards and abut against the first cutter 124 and the second cutter 126, the battery 801 exerts a cutting counterforce F1 against the first cutter 124 and the second cutter 126, parallel to the longitudinal direction X. The cutting counterforce F1 generates a component force F2 in the lateral direction Y, at both the first cutter 124 and the second cutter 126 (the force F1 and F2 is only shown in Figure 15 at the first cutter 124 for illustration), which creates a tendency to cause the first cutter 124 and the second cutter 126 to move away from each other along the direction 124y and 126y (both direction 124y and 126y are parallel to the lateral direction Y), as shown in Figure 15, and to cause the first jaw 122 and the second jaw 128 to move towards each other along the direction 122y and 128y as shown in Figure 15. As the battery 801 is clamped between the first jaw 122 and the second jaw 128 and moving along the direction 80x as shown in Figures 15 and 16, movement of the first jaw

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122 and the second jaw 128 toward each other is blocked and restricted by the battery 801 and consequently, the first cutter 124 and the second cutter 126 are maintained stationary relative to each other, to remain partially interfere with the passage 125.

5 The apparatus 100 may further include a first resilient member 121 and a second resilient member 129, both in the form of e.g. helical spring. The first resilient member 121 is disposed between the one of the mounting brackets 119 of the support frame 116 and the first jaw 122, to bias the first jaw 122 towards the passage 125. The second resilient member 129 is disposed between another one of the mounting brackets 119 of the support frame 116
10 and the second jaw 128, to bias the second jaw 128 towards the passage 125. Upon a battery 801 being positioned between the first jaw 122 and the second jaw 128, the first resilient member 121 and the second resilient member 129 are compressed to counteract and maintain the first jaw 122 and the second jaw 128 to abut against the battery 801.

15 The apparatus 100 may further include a first link bar 123 and a second link bar 127. The first link bar 123 is arranged across the passage 125 and connected between the first jaw 122 and the second cutter 126. The second link bar 127 is arranged across the passage 125 and connected between the second jaw 128 and the first cutter 124. Additionally, as shown in Figure 7 to Figure 10, one of the first link bar 123 and the second link bar 127, e.g.
20 the first link bar 123 has a guiding groove 123a formed thereon along the lateral direction Y. The other one of the first link bar 123 and the second link bar 127, e.g. the second link bar 127 has a guiding projection 127a formed thereon. The guiding projection 127a extends into the guiding groove 123a, to guide the relative movement of the first link bar 123 and the second link bar 127 along the lateral direction Y, and to prevent the first link bar 123
25 and the second link bar 127 from moving relative to each other along the longitudinal direction X.

 The apparatus 100 may further include a retainer 170 movably connected to the support frame 116 via the suspension bracket 118, for abutting against a battery received
30 between the first jaw 122 and the second jaw 128. The retainer 170 is movable relative to the support frame 116 along a height direction Z orthogonal to the longitudinal direction X and the lateral direction Y. The retainer 170 serves to provide a holding function to assist

in maintaining a battery 801 in place between the first jaw 122 and the second jaw 128, during the pre-treatment process of the battery.

Optionally, the second link bar 127 is positioned above the first link bar 123, the apparatus 100 further comprises a support block 177 positioned between the second link bar 127 and the retainer 170. Before a battery is received between the first jaw 122 and the second jaw 128, as shown in Figures 1, 5, 7 and 9, the first jaw 122 and the second jaw 128 are biased by the respective first resilient member 121 and the second resilient member 129 towards each other, with a distance d_0 between the first jaw 122 and the second jaw 128 less than the outer diameter of a battery, at which, the support block 177 is vertically aligned with the retainer 170 such that the retainer 170 rests on or abuts against the support block 177.

When a battery is received between the first jaw 122 and the second jaw 128, as shown in Figures 2, 6, 8 and 10, first jaw 122 and the second jaw 128 move away from each other to accommodate the battery placed between the first jaw 122 and second jaw 128. Movement of the first jaw 122 and the second jaw 128 away from each other carries the first link bar 123 and the second link bar 127 to move together. Accordingly, the support block 177 is carried to move away from the retainer 170, such that the retainer 170 is allowed to move towards the passage 125, along a downward direction 170d (Figure 10). The retainer 170 can therefore abuts against the battery 80 received between the first jaw 122 and the second jaw 128, to provide an additional function to hold the battery 80 in the passage 125.

The apparatus 100 may further include a third resilient member 173, in the form of e.g. a helical spring, disposed between the suspension bracket 118 of the support frame 116 and the retainer 170. When a battery is received and clamped between the first jaw 122 and the second jaw 128, the support block 177 moves away from the retainer 170, upon which, the third resilient member 173 bias the retainer 170 to move towards the passage 125 and abutting against the battery, to maintain the battery in place between the first jaw 122 and the second jaw 128.

As shown in Figure 4, Figure 9 and Figure 18, the platform 130 may include a conveyor belt 132 movably coupled to the base 112 and positioned underneath the first jaw

122, the second jaw 128, the first cutter 124 and the second cutter 126. The conveyor belt 132 is movable relative to the base 112 for carrying batteries borne on the conveyor belt 132 to pass through the passage 125, along the longitudinal direction X, such that an enclosure 84 of each of the batteries is carried to slide through and cut apart by the first cutter 124 and the second cutter 126. An array of studs 136 may also be mounted to the conveyor belt 132, such that adjacent two rows of the arrays of studs 136 along the longitudinal direction X are positioned spaced apart from each other, with a gap 136g of a width configured to receive a battery one at a time therein.

As shown in Figure 18 to Figure 20, the apparatus 100 may include a motor 141 mounted to the base 112, a driving gear 142a coaxially coupled to a main shaft 141s of the motor 141, and a driven gear 142b rotatably mounted to the support frame 116 and engaged to the driving gear 142a. The driving gear 142a and the driven gear 142b are bevel gears such that a driven gear axis of the driven gear 142b is perpendicular to the main shaft 141s.

The apparatus 100 further comprises a first driving shaft 143, a first roller shaft 145, a plurality of second driving shafts 147 and a plurality of second roller shafts 149. The first driving shaft 143 is rotatably mounted to the support frame 116 and coaxially coupled to the driven gear 142b. The first roller shaft 145 is rotatably mounted to the support frame 116 and oriented parallel to the longitudinal direction X. The plurality of second driving shafts 147 are each rotatably mounted to the support frame 116 and oriented parallel to the first driving shaft 143. The plurality of second roller shafts 149 are each rotatably mounted to the support frame 116 and oriented parallel to the first roller shaft 145. A first driving belt 144 is looped between the first driving shaft 143 and the first roller shaft 145, for transmitting rotational motion from the first driving shaft 143 to the first roller shaft 145. A transmission belt 146 is looped between the first driving shaft 143 and each of the plurality of second driving shafts 147, for transmitting rotational motion from the first driving shaft 143 to each of the plurality of second driving shafts 147. A plurality of second driving belts 148 are each looped between one of the second driving shafts 147 and a corresponding one of the plurality of second roller shafts 149, for transmitting rotational motion from the one of the second driving shafts 147 to the corresponding one of the plurality of second roller shafts 149.

Connected in the above-illustrated manner, the first roller shaft 145 and the plurality of second roller shafts 149 are rotatable in a same direction. For example, as shown in Figure 19, when the motor 141 rotates in a counterclockwise direction 141d, the first driving shaft 143, the second driving shaft 147, the first roller shaft 145 and the plurality of second roller shafts 149 all rotate in a clockwise direction 143a / 148s.

As shown in Figure 20, the apparatus 100 may further include a set of first roller wheels 155 mounted to the first roller shaft 145 and a plurality sets of second roller wheels 159 each being mounted to one of the second roller shafts 149. The first roller shaft 145 and the plurality of second roller shafts 149 are arranged relative to each other with an even pitch 152p, and the set of first roller wheels 155 and the plurality sets of second roller wheels 159 have a same outer roller diameter 150d, such that gaps between adjacent sets of first roller wheels 155 and second roller wheels 159 have a same width, for receiving batteries 80 of a same outer battery diameter 80d between adjacent first / second roller shafts 145 / 149. Configured in the above-illustrated manner, rotation of the first roller shaft 145 and the plurality of second roller shafts 149 causes the batteries to rotate by a friction force between the batteries and the set of first roller wheels 155 and each set of the second roller wheels 159. Accordingly, the batteries can be rolled over on the platform for easy cleaning and drying.

As shown in Figure 21 to Figure 23, the apparatus 100 may further include a worm rod 152 coaxially mounted to the first roller shaft 145, a worm gear 154 engaged to the worm rod 152, and a sleeve shaft 156 passing through and coaxially mounted to the worm gear 154. The sleeve shaft 156 is rotatably mounted to the support frame 116 above the platform 130 and oriented orthogonal to the first roller shaft 145. An array of brushes 158, e.g. four elongated brushes 158 are mounted to the side surface of the sleeve shaft 156. In operation, the first roller shaft 145 and the worm rod 152 rotate in the worm rod direction 152a to carry the sleeve shaft 156's rotation in a worm gear direction 154a, via the engagement of the worm rod 152 and the worm gear 154, and rotation of the sleeve draft 156 rotate the array of brushes 158, for sweeping and cleaning to top portions of the batteries 80 carried on the platform 130.

In operation, batteries 80 carried by the conveyor belt 132 are received between adjacent rows of first and second roller wheels 155 / 159, and each of the batteries 80 is in contact with adjacent roller shafts on both sides. Driven by the adjacent roller shafts, the batteries 80 are all rotated in a counterclockwise direction 83a. Concurrently, conveyor belt 132 carries the batteries 80 to travel from the back end 102 to the front end 108 of the apparatus 100. In the meantime, the array of brushes 158 rotates to brush the top side of the batteries 80, in combination with the rotational movement driven by the first and second roller wheels 155 / 159, allowing the batteries to be cleaned while travelling as carried by the conveyor belt 132.

The apparatus 100 may include a blower 162, and a first pipe 164 with a first inlet connected to the blower 162 and a first outlet opening at the front end 108 of the platform 130. An air 162a supplied by the blower 162 blows out from the first outlet of the first pipe 164 over the area of the front end, for carrying battery enclosures cut off from the batteries away from the platform 130.

Additionally, the apparatus 100 may further include a second pipe 166 with a second inlet connected to the blower 162 and a second outlet extending into the sleeve shaft 156. The sleeve shaft 156 has a plurality of perforations 156a formed through the side surface of the sleeve shaft 156. An air 162b supplied by the blower 162 can therefore flow into the sleeve shaft 156 through the second pipe 166, and blows out from the sleeve shaft 156 through the plurality of perforations 156a. Batteries 80 carried by the conveyor belt 132 over the area around the sleeve shaft 156 may then be easily dried by the air 162b, for the batteries to be processed in subsequent recycling processes.

Embodiments of the present invention are presented above for purposes of illustration and description of the technical solutions and relevant technical features therein, but is not intended to be understood to be exhaustive or limiting. Modifications and/or variations will become apparent to those of ordinary skill in the art to contemplate and implement based on the inventive concept and technical solutions disclosed herein. The example embodiments are chosen and described to explain principles and practical application of the present invention, and to enable those of ordinary skill in the art to understand the disclosure for various embodiments with various modifications as are suited

to the particular technical solution contemplated and described. Further, while some technical details may be omitted from the description and drawings, for the purpose of clarity and conciseness, such omissions are not meant to be understood that the omitted features are necessarily absent or missing in the relevant structures, parts, processes and/or steps, as described herein, for understanding and practicing the invention.

Thus, although illustrative example embodiments have been described herein with reference to the accompanying drawings, it is to be understood that this description is not limiting and that various other changes and modifications may be effected therein by one skilled in the art without departing from the scope or spirit of the disclosure as sets out and defined the claims appended hereto.

CLAIMS

1. A pre-treatment apparatus for battery recycling, the apparatus comprising:
 - a base defining a platform thereon;
 - 5 a support frame mounted to the base and suspended above the platform;
 - a first jaw and a second jaw movably coupled to the support frame and positioned above the platform, the first jaw and the second jaw being disposed spaced apart from each other along a lateral direction, the first jaw being positioned at a first side of a passage formed between the first jaw and the second jaw, and the second
 - 10 jaw being positioned at a second side of the passage opposite to the first side;
 - a first cutter disposed at the first side of the passage and offset from the first jaw along a longitudinal direction orthogonal to the lateral direction;
 - a second cutter disclosed at the second side of the passage and offset from the second jaw along the longitudinal direction,
 - 15 wherein upon a battery being fitted between the first jaw and the second jaw, the first cutter and the second cutter are positioned to partially interfere with the passage such that advancement of the battery towards the first cutter and the second cutter causes an enclosure of the battery to pass through and cut apart by the first cutter and the second cutter.
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2. The apparatus as recited in claim 1, wherein the first cutter is oriented with a first normal direction facing the passage, and the second cutter is oriented with a second normal direction facing the passage, wherein a component of the first normal direction faces the first jaw, and a component of the second normal direction faces the second
- 25 jaw.
3. The apparatus as recited in claim 1 or claim 2, wherein the first cutter is connected to the second jaw and the second cutter is connected to the first jaw, and wherein a movement of the first jaw and the second jaw away from each other reduces a distance
- 30 between the first cutter and the second cutter.
4. The apparatus as recited in claim 3,

wherein a cutting counterforce applied to the first cutter and the second cutter by a battery brought into contact with the first cutter and the second cutter creates a tendency to cause the first cutter and the second cutter to move away from each other and to cause the first jaw and the second jaw to move towards each other, and

wherein the first jaw and the second jaw are restricted from moving toward each other by the battery whereby the first cutter and the second cutter are maintained to partially interfere with the passage.

5. The apparatus as recited in claim 3, further comprising:

a first resilient member disposed between the support frame and the first jaw to bias the first jaw towards the passage;

a second resilient member disposed between the support frame and the second jaw to bias the second jaw towards the passage,

wherein upon the battery being positioned between the first jaw and the second jaw, the first resilient member and the second resilient member are compressed to maintain the first jaw and the second jaw to abut against the battery.

6. The apparatus as recited in claim 3, further comprising:

a first link bar across the passage and connecting the first jaw to the second cutter;

a second link bar across the passage and connecting the second jaw to the first cutter;

wherein the first link bar and the second link bar are slidably engaged with each other along the lateral direction to prevent a movement of the first jaw and the second jaw relative to each other along the longitudinal direction.

7. The apparatus as recited in claim 6, wherein one of the first link bar and the second link bar has a groove formed thereon along the lateral direction and the other one of the first link bar and the second link bar has a projection formed thereon, the projection extends into the groove to prevent the first link bar and the second link bar from moving relative to each other along the longitudinal direction.

8. The apparatus as recited in claim 6, further comprising a retainer movably connected to the support frame for abutting against the battery received between the first jaw and the second jaw.
- 5 9. The apparatus as recited in claim 8, wherein the retainer is movable relative to the support frame towards and away from the passage along a height direction orthogonal to the longitudinal direction and the lateral direction.
- 10 10. The apparatus as recited in claim 9, wherein the second link bar is positioned above the first link bar, the apparatus further comprises a support block positioned between the second link bar and the retainer, wherein a movement of the first jaw and the second jaw away from each other carries the support block away from the retainer to allow the retainer to move towards the passage.
- 15 11. The apparatus as recited in claim 10, further comprising a third resilient member disposed between the support frame and the retainer to bias the retainer towards the passage, wherein the retainer moves towards the passage after the support block moves away from the retainer.
- 20 12. The apparatus as recited in claim 1, wherein the platform comprises a conveyor belt movably positioned underneath the first jaw, the second jaw, the first cutter and the second cutter, wherein the conveyor belt is movable relative to the base for carrying batteries borne on the conveyor belt to pass through the passage along the longitudinal direction such that an enclosure of each of the batteries is carried to slide through and
25 cut apart by the first cutter and the second cutter.
- 30 13. The apparatus as recited in claim 12, further comprising an array of studs mounted to the conveyor belt, wherein adjacent two rows of the arrays of studs along the longitudinal direction are positioned spaced apart from each other with a gap therebetween, wherein the gap has a width configured to receive a battery one at a time therein.
14. The apparatus as recited in claim 1, further comprising:

a motor mounted to the base, wherein the motor has a main shaft oriented parallel to the lateral direction;

a driving gear coaxially coupled to the main shaft;

a driven gear rotatably mounted to the support frame and engaged to the driving gear, the driven gear having a driven gear axis oriented perpendicular to the main shaft;

a first driving shaft coaxially coupled to the driven gear and rotatably mounted to the support frame;

a first roller shaft rotatably mounted to the support frame and oriented parallel to the longitudinal direction;

a first driving belt looped between the first driving shaft and the first roller shaft for transmitting rotational motion from the first driving shaft to the first roller shaft;

a plurality of second driving shafts each being rotatably mounted to the support frame and oriented parallel to the first driving shaft;

a plurality of second roller shafts each being rotatably mounted to the support frame and oriented parallel to the first roller shaft;

a transmission belt looped between the first driving shaft and each of the plurality of second driving shafts for transmitting rotational motion from the first driving shaft to each of the plurality of second driving shafts;

a plurality of second driving belts each being looped between one of the second driving shafts and a corresponding one of the plurality of second roller shafts for transmitting rotational motion from the one of the second driving shafts to the corresponding one of the plurality of second roller shafts.

wherein the first roller shaft and the plurality of second roller shafts are rotatable in a same direction.

15. The apparatus as recited in claim 14, further comprising a set of first roller wheels mounted to the first roller shaft and a plurality sets of second roller wheels each being mounted to one of the plurality of second roller shafts, wherein the first roller shaft and the plurality of second roller shafts are arranged relative to each other with an even pitch and the set of first roller wheels and the plurality sets of second roller wheels have a same outer roller diameter such that gaps between adjacent sets of first and second roller wheels have a same width for receiving and contacting batteries of a

same outer battery diameter, wherein rotations of the first roller shaft and the plurality of second roller shafts cause the batteries to rotate by frictional force between the batteries and the set of first roller wheels and each set of the second roller wheels.

- 5 16. The apparatus as recited in claim 14, further comprising:
 a worm rod coaxially mounted to the first roller shaft;
 a sleeve shaft rotatably mounted to the support frame above the platform and
 oriented orthogonal to the first roller shaft,
 a worm gear coaxially mounted to the sleeve shaft such that the sleeve shaft passes
10 through the worm gear and that the worm gear being engaged to the worm rod;
 an array of brushes mounted to a side surface of the sleeve shaft;
 wherein a rotation of the first roller shaft drives the sleeve shaft to rotate the brushes
 to sweep a top portion of the batteries carried on the platform.
- 15 17. The apparatus as recited in claim 16, further comprising a blower and a first pipe
 having a first inlet connected to the blower and a first outlet opening at a front end of
 the platform, wherein an air supplied by the blower blows out from the first outlet
 through the first pipe for carrying battery enclosures cut off from the batteries away
 from the platform.
- 20 18. The apparatus as recited in claim 17, further comprising a second pipe having a second
 inlet connected to the blower and a second outlet extending into the sleeve shaft,
 wherein the sleeve shaft has a plurality of perforations formed at a side surface thereof,
 and wherein an air supplied by the blower flows into the sleeve shaft through the
25 second pipe and blows out from the sleeve shaft through the plurality of perforations.
- 30 19. The apparatus as recited in claim 1, further comprising a blower and a first pipe having
 a first inlet connected to the blower and a first outlet opening at a front end of the
 platform, wherein an air supplied by the blower blows out from the second outlet
 through the second pipe for carrying battery enclosures cut off from the batteries away
 from the platform.