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Design of an Automated Fasteners Sorting Machine for Accurate Types and Sizes Differentiation in Assembly Lines.

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Abstract

This project addresses the critical need for efficient and accurate fastener sorting (bolts, nuts, washers) in industries like automotive, aerospace, electronics, construction, and machinery, where manual processes are slow and error-prone. The primary goal was to design a compact, portable, semi-automated machine capable of accurately identifying and sorting up to 18 different fastener types by size and type. Methodologically, a systematic design process used SolidWorks for 3D modeling and simulation, resulting in a machine engineered with parameters to maximize sorting speed and minimize manual work. Its core feature is a semi-automated mechanism that uses an accurate measurement machine for precise recognition and categorization, significantly reducing errors. Findings demonstrate high sorting accuracy, boosting assembly line productivity, with a durable, corrosion-resistant design ensuring longevity in industrial settings. The machine is projected to streamline production by drastically cutting sorting times and enhancing overall operational efficiency. In conclusion, this project demonstrates the feasibility of a compact automated sorter suitable for small-to-medium industries, offering a practical solution to revolutionize fastener management by overcoming manual inefficiencies and delivering substantial gains in productivity and operational effectiveness. The automated fastener sorting machine weighs 31.925 kg and has dimensions of 1014.83 mm (L) × 1694.25 mm (W) × 1003.94 mm (H).

1. Introduction

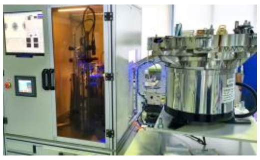
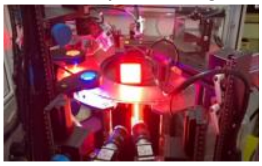
Industrial automation has become the cornerstone of modern manufacturing efficiency, driven by the global transition toward Industry 4.0 standards. In assembly-intensive sectors such as automotive, aerospace, and electronics, the management of fasteners—including screws, bolts, nuts, and washers—is a critical operational task. These components vary drastically in geometry and application, ranging from micro-sized M3 screws essential for printed circuit boards to high-strength M16 bolts required for structural integrity in construction [1]. As production volumes increase, the ability to sort and feed these components accurately becomes a defining factor in overall line efficiency.

Despite the availability of advanced manufacturing technologies, manual sorting remains the predominant method in many Small and Medium Enterprises (SMEs), particularly in developing industrial economies like

Malaysia. However, relying on manual labor for such high-precision tasks is increasingly untenable. Research indicates that manual sorting is inherently inefficient and prone to significant error rates, largely due to the visual similarity between small fastener variants (e.g., distinguishing between M2.5 and M3 screws) [2]. Furthermore, the repetitive nature of this task has been directly linked to physical fatigue and cognitive decline in workers. Studies in industrial ergonomics suggest that prolonged attention to minute details leads to a rapid drop in inspection accuracy after just a few hours of operation, creating bottlenecks that delay downstream assembly processes [3].

To address these limitations, the academic and industrial communities have introduced various automated sorting technologies. The most prominent among these are machine vision systems, which employ high-resolution cameras and image-processing algorithms to analyze fastener dimensions and surface defects. While these systems offer high precision, they often require controlled lighting environments and substantial computational power to process images in real-time [4]. Alternatively, robotic solutions utilizing articulated arms and adaptive grippers have been developed to handle complex geometries. However, "bin-picking"—the ability for a robot to grasp a small, randomly oriented screw from a pile—remains a complex challenge, often resulting in slow cycle times and requiring expensive, high-maintenance hardware [5]. Vibratory bowl feeders are also widely used for aligning parts, but they generally lack the versatility to sort mixed batches of different fastener types without extensive mechanical retooling [6]. Table 1 below shows the available products in the market.

Table 1: *Available products in the market.*

Detail	Product 1	Product 2	Product 3
Product Name	Rotary Disk Optical Sorting Equipment	Screw Sorting Machine	PSR-1500 Rotary Disk Sorting Machine
			
Manufacturer	Taiwan Metiz Alliance	Harbin Rainbow Technology CO.,Ltd.	Ching Chan Optical Technology CO., Ltd.
Machine Type	Rotary Disk Optical Sorting Equipment	Screw Plate	PSR-1500 Rotary Disk Sorting Machine
Sorting Speed	200-800 pcs/min	300-500 pieces/min	100 to 800 pieces/min
Size of Products	Diameter M3-M16; Length 6-135 mm	1 mm - 15 mm; Length 3-90 mm	5~16 mm; Head Width: φ5~25 mm
Sorting Accuracy	±1 pixel	±1 pixel	±1.5 pixels
Detecting Length	6 mm to 135 mm	3-90 mm (up to 150 mm with lens)	Up to 80 mm
Number of Cameras	4 (standard mode); 6 (special mode)	6-Feb	Available for 2-4 cameras
Dimension	Not specified	5 x 35 x 74 in	Not specified
Types of Fasteners Sorted	Bolts, nuts, washers (5 mm to 250 mm)	Screws (various sizes)	Screws (M5 to M16)
Tools Required	None for camera adjustments	Add an extra telecentric lens for detecting length up to 150 mm	High-resolution cameras

Critically, a gap remains between these high-end technologies and the needs of smaller manufacturers. Market analysis reveals that most commercial sorting systems are engineered for high-volume, low-mix mass production. These systems are often impractical for SMEs due to their massive spatial footprints and prohibitive capital costs [7]. There is a distinct lack of portable, affordable solutions designed for "high-mix, low-volume" environments where flexibility is key.

Therefore, this project aims to bridge this gap by designing and fabricating a compact, semi-automated fastener sorting machine specifically tailored for the SME context. Unlike complex vision-based or robotic systems, this study proposes a weight-based and mechanical separation approach to categorize up to 18 distinct fastener types. By utilizing SolidWorks for design optimization, the proposed solution seeks to provide a cost-effective alternative that reduces labor dependency, minimizes human error, and enhances operational throughput in smaller workshops.

2. Methodology

The engineering design process provides a structured approach to developing solutions through defined steps. Methods by experts like Pahl and Beitz, Dieter, and Eggert offer frameworks for this process. This project employs George E. Dieter's methodology, which organizes design into three key phases: conceptual, embodiment, and detail. The first phase, conceptual design, involves four stages: problem definition, information gathering, concept generation, and concept evaluation. This establishes a clear understanding of requirements and potential solutions. The second phase, embodiment design, comprises three stages: product architecture, configuration design, and parametric design, during which concepts are refined into functional layouts. The final phase, detail design, finalizes specifications for manufacturing. Figure 1 illustrates this sequential process, guiding development from initial problem analysis to technical specifications.

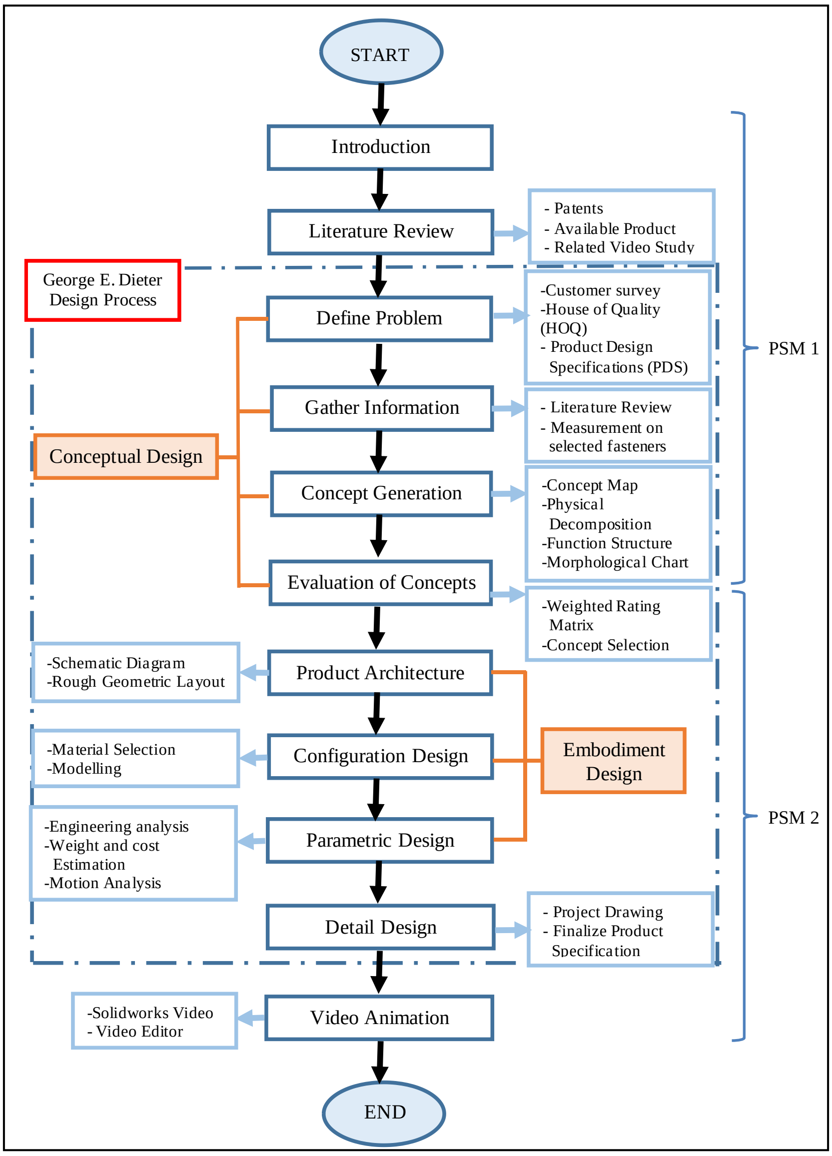


Figure 1: *Flowchart of design process.*

3. Design Process

The design process guides students through a logical sequence of activities to solve real-world problems with effective solutions. To determine customer needs for an automated fasteners sorting machine, a Google Forms survey titled "Survey of Product Design Specification for Automated Fasteners Sorting Machine" was conducted. The objective tree method analyzed survey responses, using relative weighting to establish Product Design Specifications (PDS).

Survey responses were systematically analyzed using an objective tree methodology. This approach applied relative weighting to prioritize requirements, translating them into precise Product Design Specifications (PDS). The objective tree clearly visualizes essential product criteria for the design phase, with finalized agreement preventing misunderstandings between stakeholders and designers. An automated fasteners sorting machine's objective tree diagram is presented in Figure 2 and Table 2 shows the comprehensive product design specification.

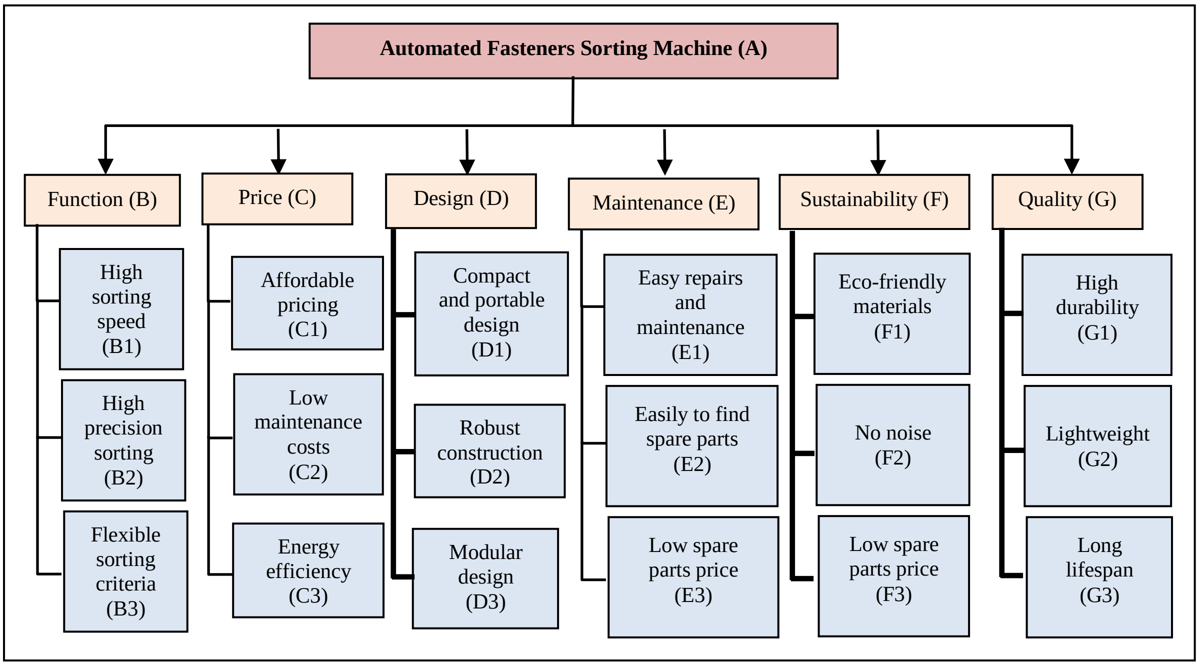


Figure 2: *Objective tree of Automated Fasteners Sorting Machine.*

Table 2: *Product Design Specification (PDS).*

Introduction	
Title	Design of an Automated Fasteners Sorting Machine for Accurate Types and Sizes Differentiation in Assembly Lines.
Design Problem	To accurately sort various types and sizes of fasteners (e.g., bolts, screws, washers, and nuts).
Intended Purpose	To improve efficiency and accuracy in sorting fasteners for industrial and construction applications.
Target Customer	Automotive, aerospace, electronics, construction, and machinery, manufacturing plants, construction companies and hardware suppliers.
Special Features	Compact design, customization sorting categories.
Customer Requirements	
Functional Performance	• The machine should sort at least 10 types of fasteners. • Sorting speed should exceed 50 fasteners per minute. • Easy to maintain and operate. • Compact and space-saving design. • Capacity of the machine can be store up to 300 fasteners.
Design	• Aesthetic and ergonomic design. • The machine weight should be less than 38.00 kg. • Modular components for easy upgrades.
Price	• The selling price should be less than RM 10,000. • Low operating and maintenance costs.
Sustainable	• Durable materials with corrosion resistance. • Energy-efficient operation. • Lifespan of over 5 years.
Operating Environment	• Suitable for factory floors, workshops, and construction sites.
Geometric Limitation	• Compact size for easy placement. • Can be integrated into existing production lines
Maintenance, Repair, Retirement	• Minimal maintenance is required during its lifecycle. • Spare parts are readily available.
Reliability, Robustness	• High reliability during continuous operation. • Capable of operating for 8 hours per day without failure.
Safety	• Equipped with safety mechanisms to prevent jams or accidents. • Complies with industrial safety standards.
Ergonomics	• Intuitive user interface. • Easy to assemble, disassemble, and clean.

4.1 Concept Generation

Methods including morphological charts, physical and functional decomposition, and brainstorming were employed during this stage. The aim was to generate product concepts capable of fulfilling all required functions. The Automated Fasteners Sorting Machine's functional construction is shown in Figure 3.

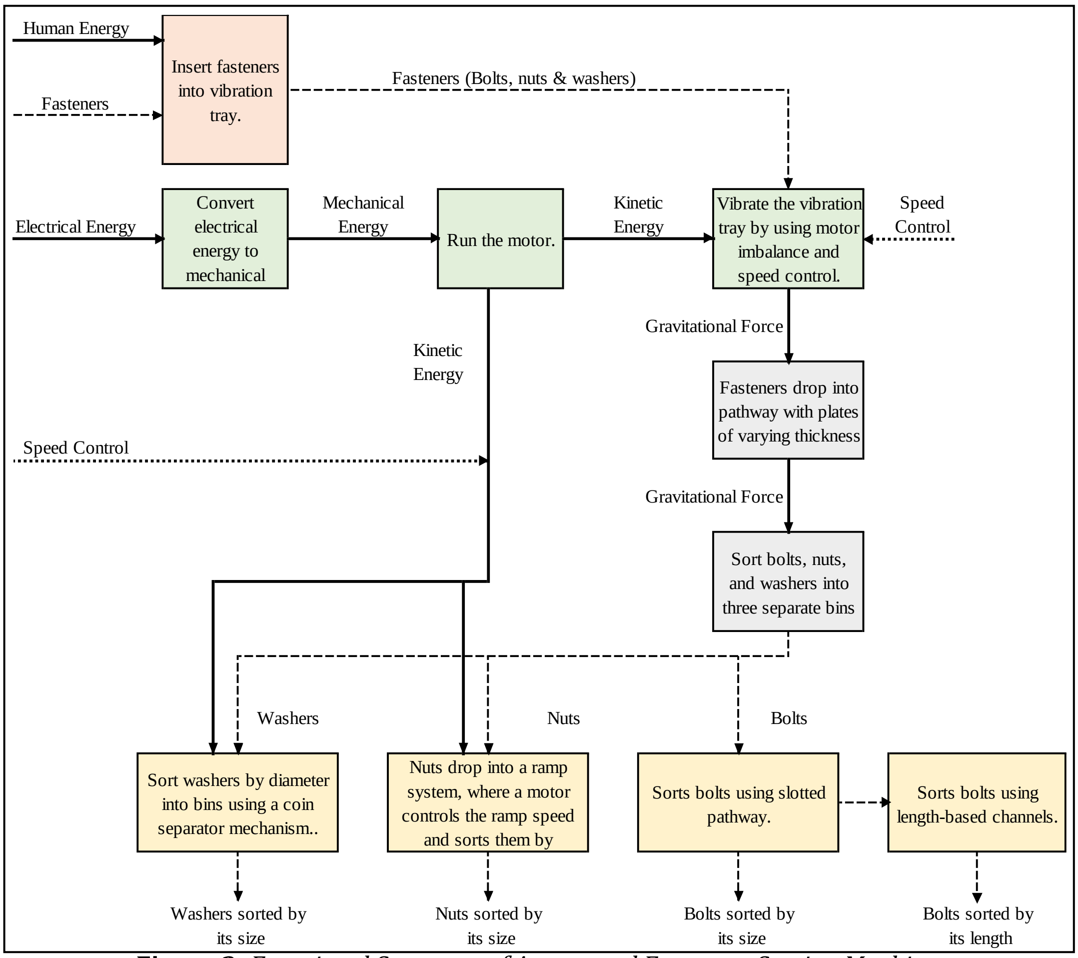


Figure 3: *Functional Structure of Automated Fasteners Sorting Machine.*

By combining weighting factors from the objective tree survey with design requirements, a weighted decision matrix evaluated three alternatives options from the morphological chart. This method identifies the best concepts meeting customer needs. After review, the concept combination that receive the highest rating concept advances to the next phase. The chosen concept appears in Table 3.

Table 3: *Selection of alternative concept..*

		Combination 1		
No	**Function**	**Alternative 1**	**Alternative 2**	**Alternative 3**
1.	**Store fasteners**	Flat tray	Hopper	Bowl feeder
2.	**Move fasteners to sorting system**	Vibration system with motor	Conveyor belt	Gravity-fed ramp
3.	**Sort washers by diameter**	Coin separator mechanism	Rotating disc with diameter slots	Vibrating sieve with diameter holes
4.	**Sort nuts**	Ramp slots	Slotted pathway	Rotating disc
5.	**Sort bolts by types**	Optical sensor	Slotted pathway	
6.	**Sort bolts by sizes**	Optical sensor	Slotted pathway	Length channels

4.2 Product Architecture

Product architecture is most important in development. It establishes the product's physical structure and components that carry out its functions. This architecture comes from the function structure developed during concept generation. Its purpose is to group functional elements into modules. A schematic diagram in Figure 4 shows the arrangement and interaction of these physical elements.

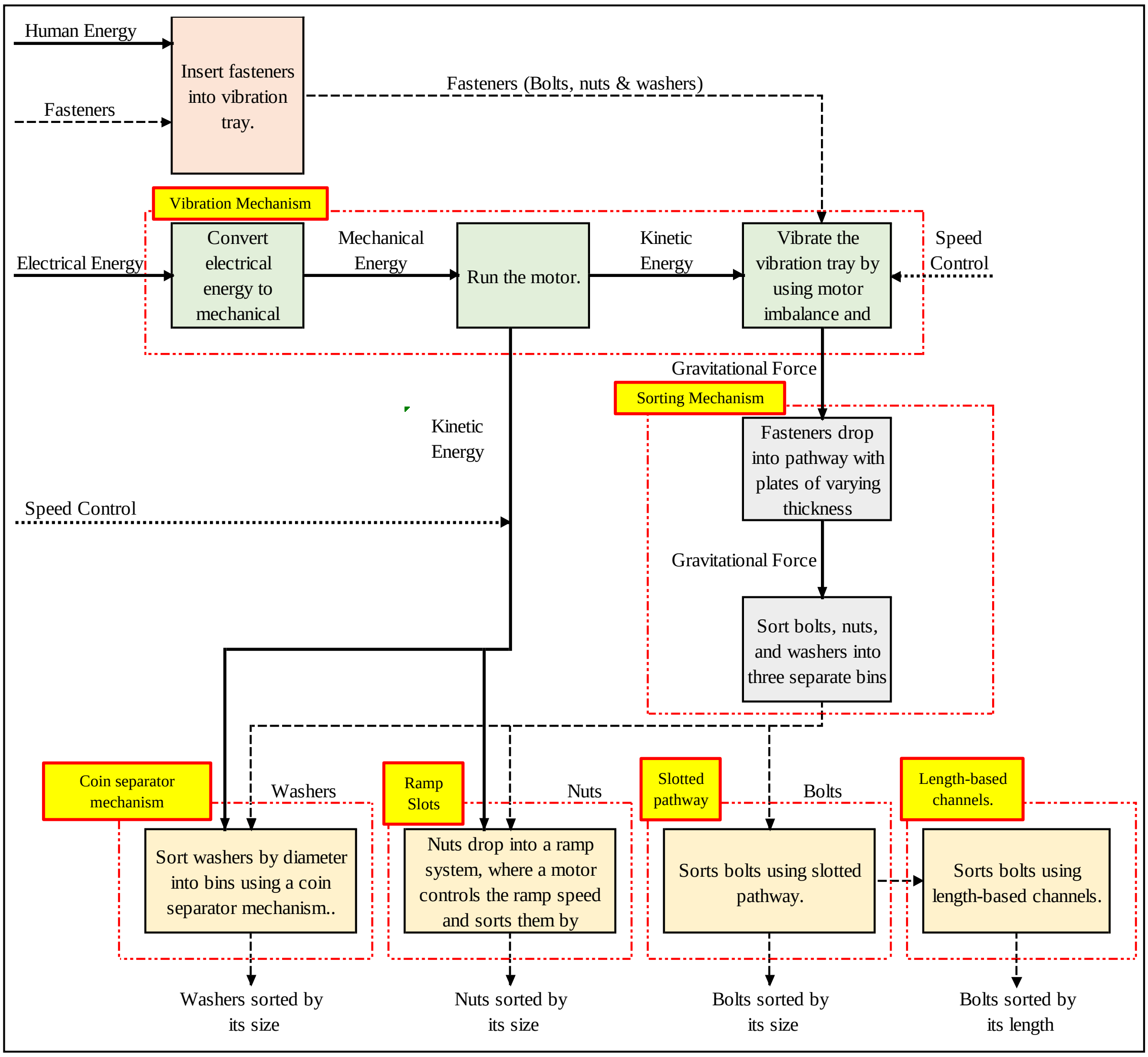


Figure 4: *Schematic diagram with clustered elements.*

4.3 Modelling

The 3D models of the Automated Fasteners Sorting Machine were created using SolidWorks software, a computer aided design tool. These models were developed from concepts selected in earlier project stages. The components were then combined to form the final product. Figure 5 shows the full assembly of the machine.

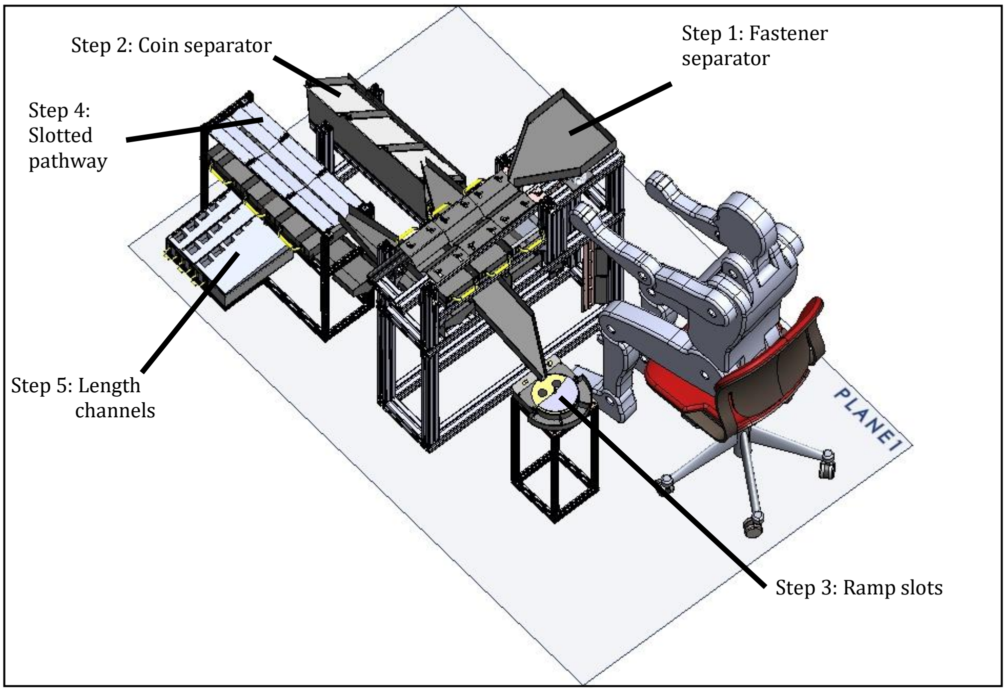


Figure 5: *Full assembly of Automated Fasteners Sorting Machine.*

4.4 Power Source

The machine uses two motors for operation. First, a 42 Series stepper motor creates vibrations by turning an imbalance weight on its shaft. This powers the fasteners separator as shown in Figure 6 part a, and coin separator (Figure 4.50 part b), These vibrations move fasteners smoothly.

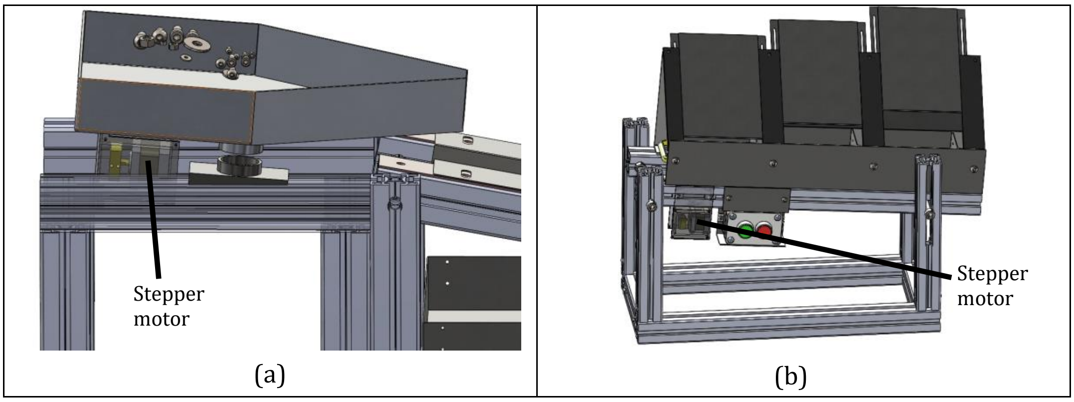


Figure 6: *Motor with imbalance to create vibration on (a) fasteners separator, (b) coin separator.*

Second, a TT yellow geared DC motor turns connected gears as shown in Figure 7. This rotation spins a sloped plate in the ramp slot mechanism, sorting nuts by size

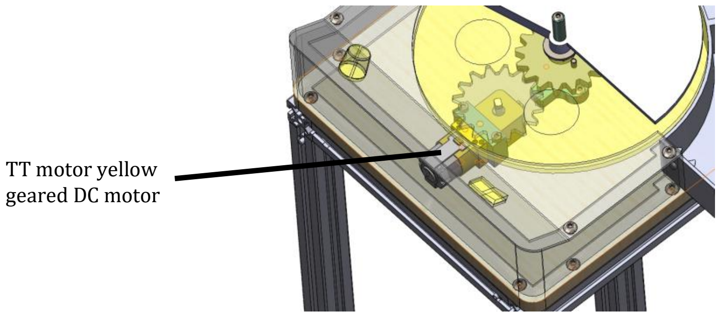


Figure 7: *TT motor yellow geared DC motor rotates interconnected gears.*

4.5 Sorting Mechanism

The sorting process employs a five stage mechanism designed to separate fasteners by type and size. Utilizing gravity and vibration forces, the fastener separator shown in Figure 8 shakes the tray with a stepper motor, moving components toward sliding plates. Next, three sliding plates with progressively wider gaps sort washers, nuts, and bolts based on thickness differences.

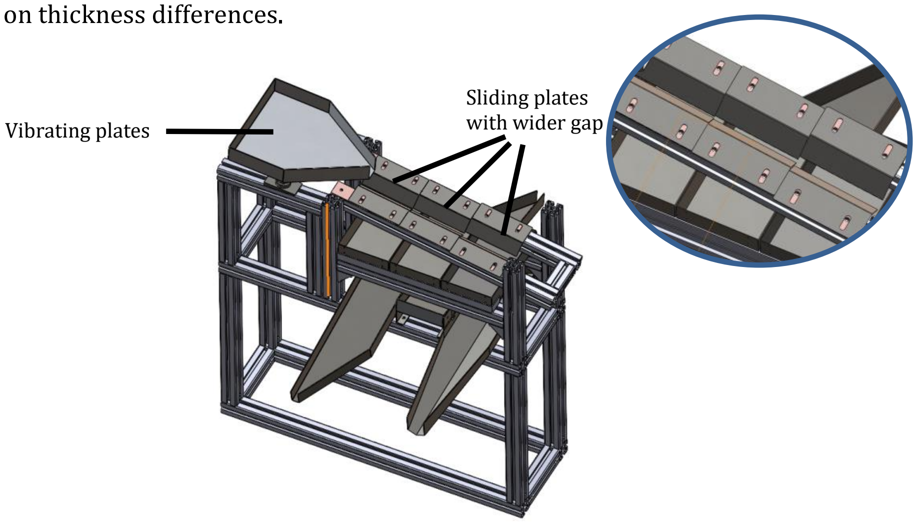


Figure 8: *Fastener separator with vibration mechanism.*

Washers enter the coin separator as shown in Figure 9, where vibrations and ramps sort them into M3, M5, and M8 sizes.

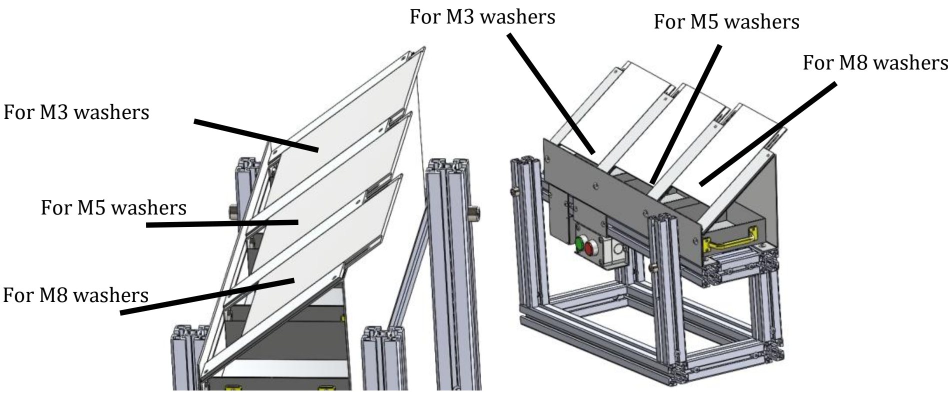


Figure 9: *Ramps with predefined gaps sort different sizes of washers.*

Nuts enter the ramp slots mechanism as shown in Figure 10, where a TT Motor spins a sloped plate. They roll down an adjustable ramp, sorting by size: M8 drop first, then M5 and M3.

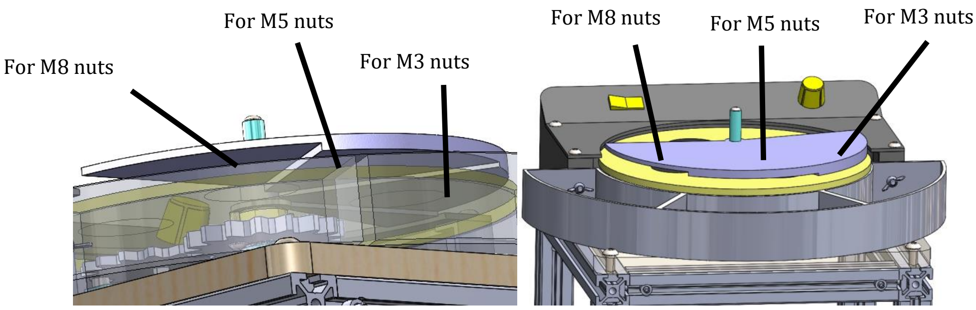


Figure 10: *Height-adjustable ramp sort different sizes of nuts.*

The slotted pathway as shown in Figure 11 sorts bolts in this sequence: M3 button head, M3 cap, M5 button head, M5 cap, M8 button head, and M8 cap.

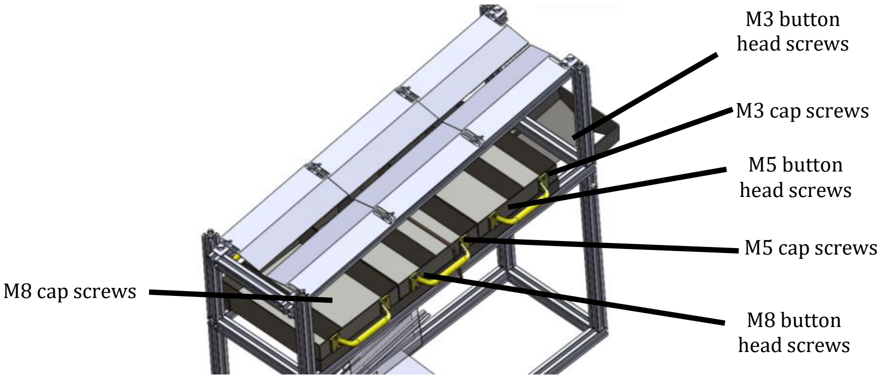


Figure 11: *Slotted pathway used to sort different types of bolts (cap and button head bolts).*

New length-sorting channels as shown in Figure 12 classify bolts of identical type by length. Button head bolts use an additional pathway segment; cap screws require no modification.

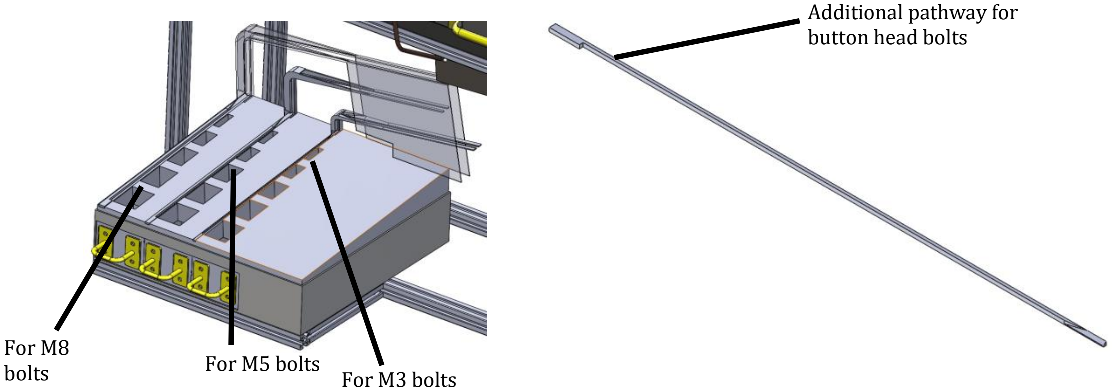


Figure 12*: Length channels sort different sizes of bolts.*

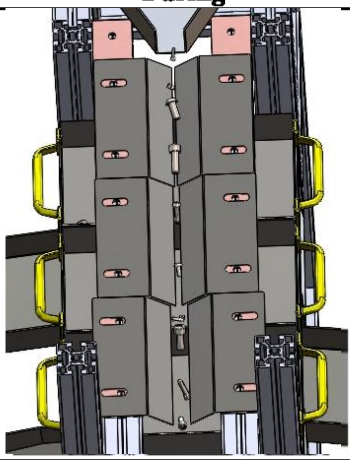
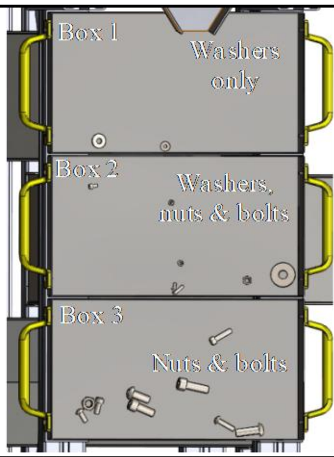
4.5 Sorting Result

Across nine documented steps before, during and after, the machine successfully sorted 18 fastener types including M3, M5 and M8 cap bolts, button head bolts, nuts and washers.

4.5.1 Step 1: Fasteners Seperator

Table 4 below shows the fastener sorting process before, during, and after for Step 1: the fastener separator.

Table 4: *Fasteners sorting process in step 1: Fasteners seperator.*

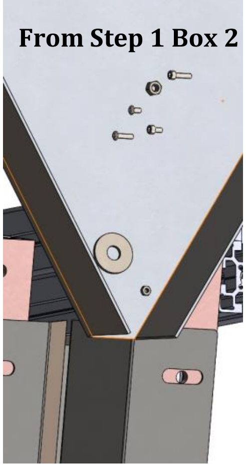
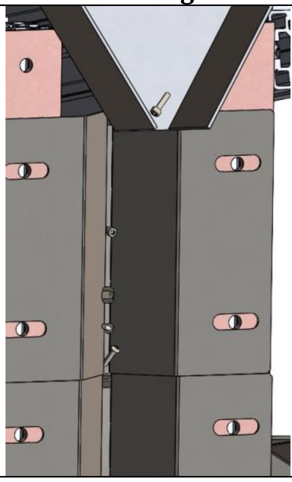
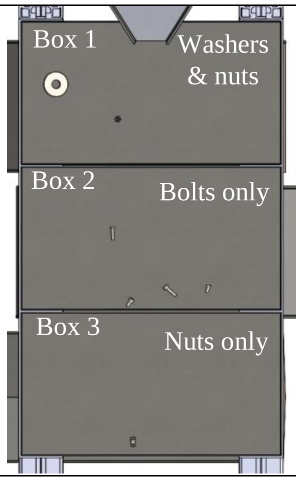
Before	During	After
		

Box 1 holds all washers so no sorting is needed. Boxes 2 and 3 containing mixed washers, nuts and bolts will be sorted again by the Fastener Separator as shown in Table 4.11.

4.5.2 Step 2: Fasteners Seperator for second box in step 1

In Step 2, Box 1 (M8 washers and M3 nuts) is re-sorted via the Coin Separator as shown in Table 5. Boxes 2 (bolts) and 3 (nuts) require no further sorting, completing the separation.

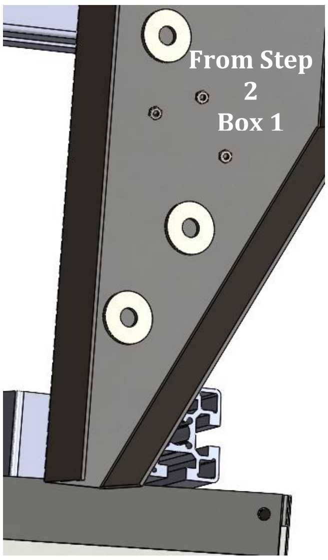
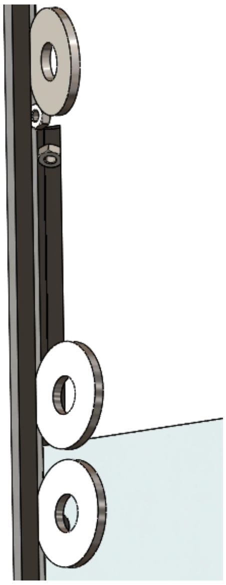
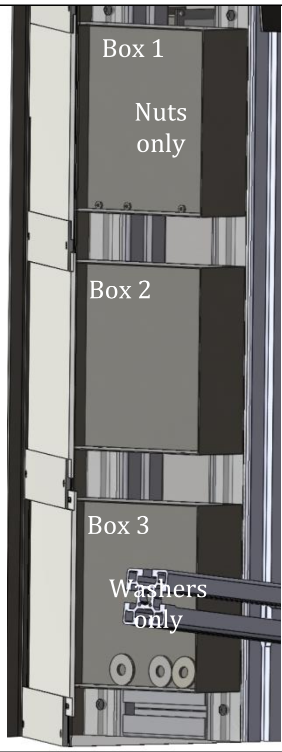
Table 5: *Box 2 fasteners in step 1 undergo re-sorting using the fasteners seperator.*

Before	During	After
		

4.5.3 Step 3: Coin seperator for Box 1 in step 2

Step 3 uses the coin separator to split Box 1's mix fasteners, M3 nuts will drop into Box 1, while M8 washers drop into Box 3 as shown in Table 6, completing the separation.

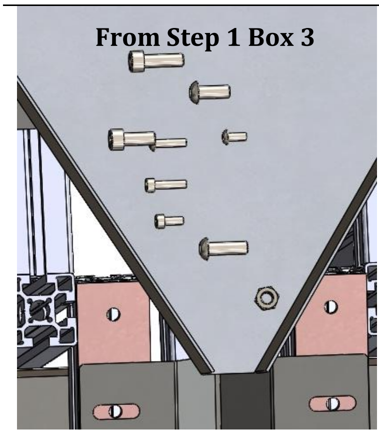
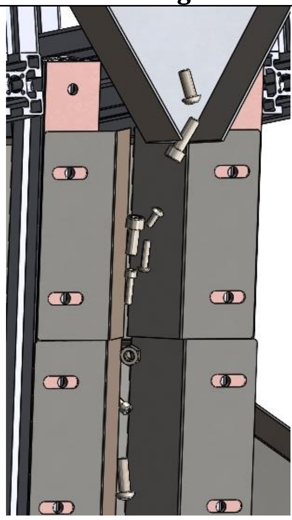
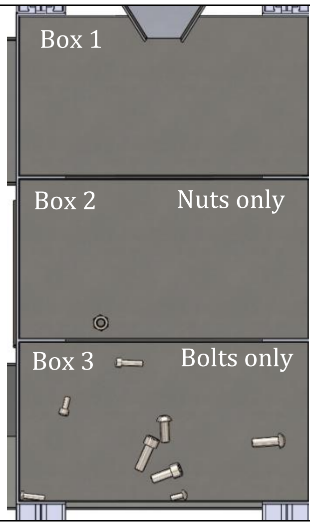
Table 6: *Box 1 fasteners in step 2 undergo sorting using coin seperator.*

Before	During	After
		

4.5.4 Step 4: Fasteners Seperator for Third box in step 1

In Section 4.5.1 Step 1 the Fastener Separator re-sorts Box 3, sending nuts to Box 2 and bolts to Box 3 as shown in Table 7, completing the separation.

Table 7: *Fasteners from box 3 step 1 undergo secondary sorting via the fastener*

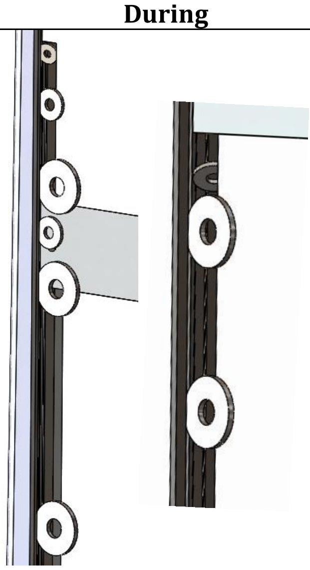
<table>
<tr><th>Before</th><th>During</th><th>After</th></tr>
<tr><td>
</td><td></td><td>
</td></tr>
</table>

Steps 1 to 4 (Sections 4.5.1 to 4.5.4) sorted all 18 fastener types into washers, nuts, and bolts.

4.5.5 Step 5: Sorting different washer sizes (M3, M5, M8) using the coin separator mechanism

The coin separator mechanism sorts washers by size: M3 washers into Box 1, M5 washers into Box 2, and M8 washers into Box 3 as shown in Table 8.

Table 8: *The coin separator sorts different sizes of washers (M3, M5, and M8).*

<table>
<tr><th>Before</th><th>During</th><th>After</th></tr>
<tr><td>
</td><td></td><td>
</td></tr>
</table>

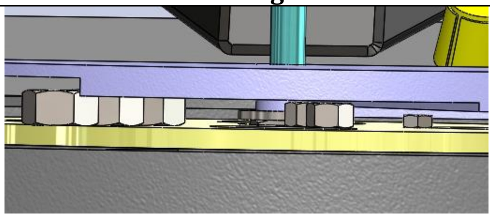
4.5.6 Step 6: Sorting different nut sizes (M3, M5, M8) using the ramp slots mechanism

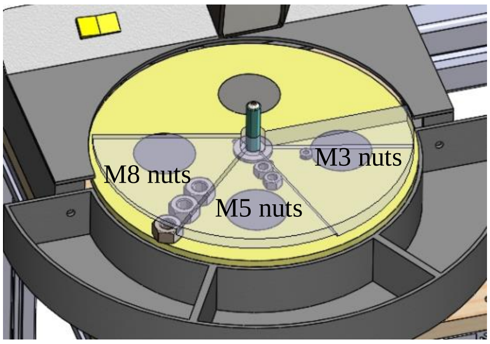
The ramp slots separate nuts by size: M8 nuts into Box 1, M5 nuts into Box 2, and M3 nuts into Box 3 as shown in Table 9.

Table 9: *The ramp slots sorts different sizes of nuts (M3, M5, and M8).*

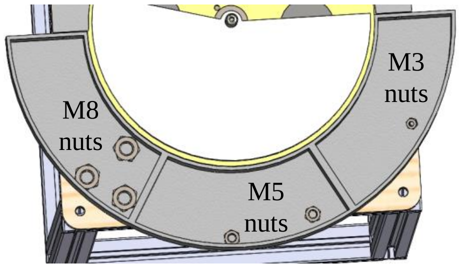
Before

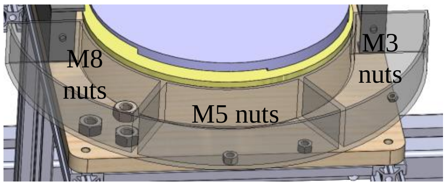
During





After



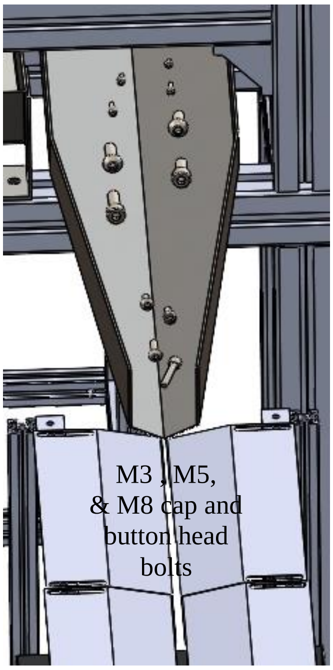


4.5.7 Step 7: Sorting different bolts types (button head and cap) using the slotted pathway mechanism

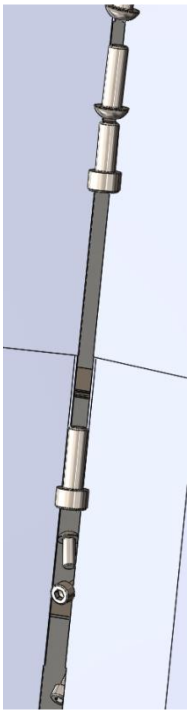
Table 10 shows the slotted pathway using a plate to release bolts into six boxes in this order: M3 button head in Box 1, M3 cap in Box 2, M5 button head in Box 3, M5 cap in Box 4, M8 button head in Box 5, and M8 cap in Box 6, sorting head types. Length sorting is handled in Step 8 for cap bolts and Step 9 for button head bolts.

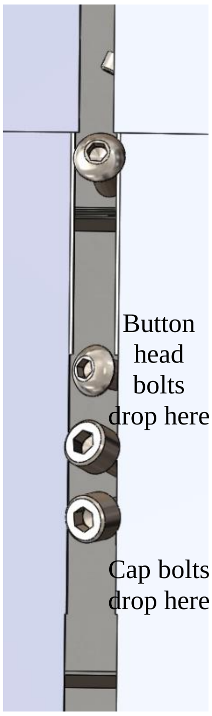
Table 10: *The ramp slots sorts different sizes of nuts (M3, M5, and M8).*

Before

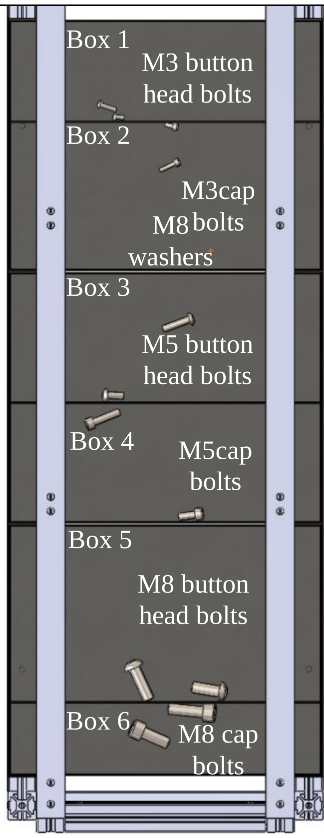


During





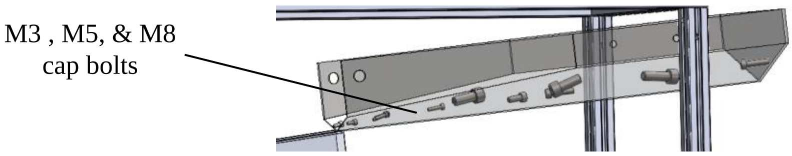
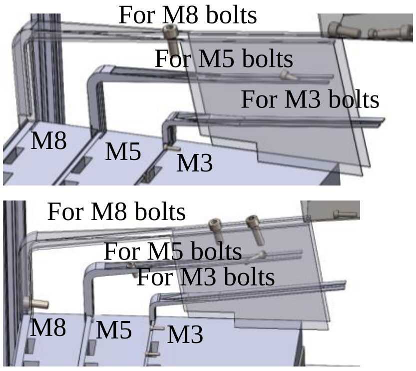
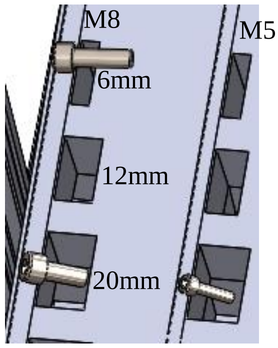
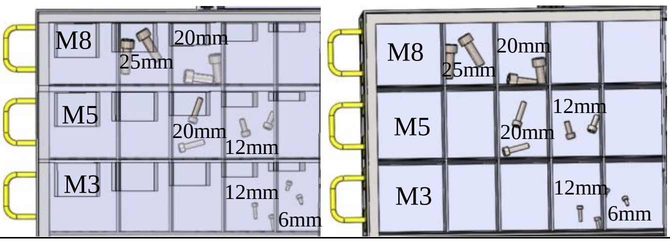
After



4.5.8 Step 8: Sorting different bolts sizes (cap bolts only) using the length channels mechanism

Table 10 shows the slotted pathway using a plate to release bolts into six boxes in this order: M3 button head in Box 1, M3 cap in Box 2, M5 button head in Box 3, M5 cap in Box 4, M8 button head in Box 5, and M8 cap in Box 6, sorting head types. Length sorting is handled in Step 8 for cap bolts and Step 9 for button head bolts.

Table 11: *Cap bolts length-sorted using the length channel.*

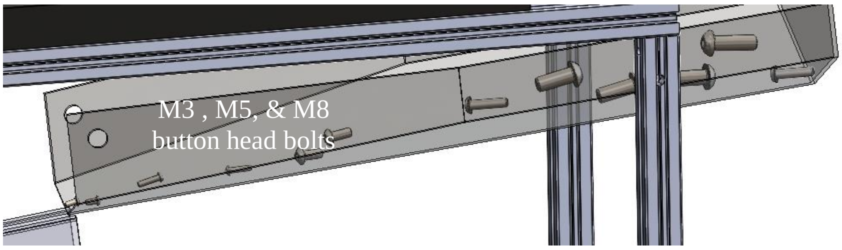
Before

During
 
After


4.5.8 Step 9: Sorting different bolts sizes (button head bolts only) using the length channels mechanism

Step 9 operates similarly to Step 8 but incorporates an additional pathway for button head bolts. While the sorting results mirror those for cap screws, this step processes button head bolts exclusively. Results are shown in Table 4.18 below.

Table 12: *Button head bolts length-sorted using the length channel.*

Before



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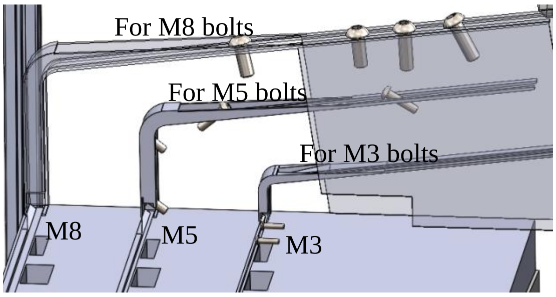

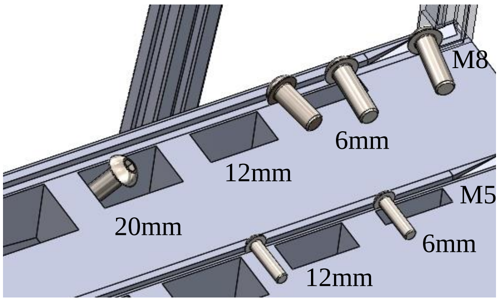

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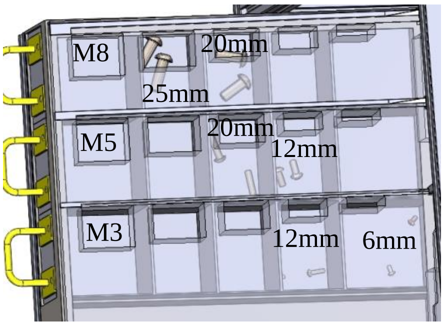

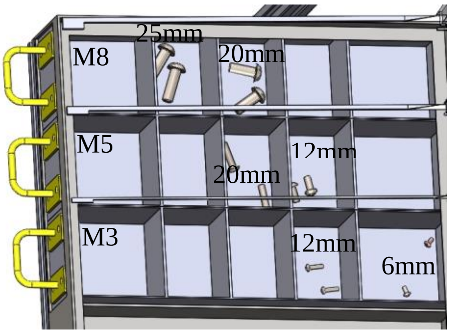

4.6 Product Specifications

Product specifications act as a guide. They outline the product's requirements to direct development and guarantee it meets quality and customer needs. Table 13 below shows the Automated Fasteners Sorting Machine specifications.

Table 13: *Product specifications of machine.*

Detail	Product Specification
Capacity	Maximum 100 fasteners per cycle
Dimension	1014.83 mm (L) x 1694.25 mm (W)
Maximum height (mm)	1003.94 mm
Types and Sizes of fasteners can be sorted	Up to 18 types and sizes of fasteners (including M3, M5, M8 cap bolts, button head bolts, nuts and washers)
Sorting Speed	50 fasteners per minutes
Sorting Accuracy (%)	100.0 (In 4.5 sorting result, all the samples sorted accurately)
Total machines	5
Weight (kg)	31.925 kg
Estimated Price (RM)	RM 6147.41

4. Conclusion

In conclusion, this design applies George E. Dieter's principles to create a compact automated machine that sorts up to 50 fasteners per minute across 18 types and sizes including M3, M5, and M8 cap bolts, button head bolts, nuts, and washers. It replaces manual sorting to improve speed, accuracy, and efficiency. Developed in SolidWorks, all components were simulated and refined into detailed engineering drawings. At 31.925 kg total weight, it is lighter than comparable market machines and uses durable, corrosion resistant materials with standard parts for reliable industrial operation. This solution exceeds sorting speed requirements and outperforms manual methods, offering industries a practical advancement in sorting technology to boost productivity.

The automated fastener sorting machine handles 100 fasteners per cycle with a sorting speed of 50 fasteners per minute. Its compact dimensions measure 1014.83 mm length, 1694.25 mm width, and 1003.94 mm height, weighing 31.925 kg for easy relocation. The machine accurately categorizes 18 fastener types and sizes including M3, M5, M8 cap bolts, button head bolts, nuts, and washers, achieving 100 percent verified sorting precision. Constructed with durable materials and standardized components, it ensures reliable long term operation in industrial environments. This portable system significantly outperforms manual sorting methods, offering a practical solution for manufacturing sectors. As automation advances, this innovation promises enhanced production efficiency and represents notable progress in industrial sorting technology.

Three enhancements are recommended for real-world performance: an emergency stop button for safety; increased input capacity to prevent collision-induced misalignment at high volumes; and a full-scale physical prototype to validate sorting accuracy under varied operational and environmental conditions.

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Conflict of Interest

Authors declare that there is no conflict of interest regarding the publication of the paper.

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