MIE 221 Term Project Proposal

Group 5

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1. Executive Summary / Intro

The document is the final proposal of the detailed assembly process of 2-inch chair casters. As a consultant group, the team focuses on the general design of the automated assembly process, including but not limited to sorting, process plan, machine selection, quality control, and cost analysis.

The team puts the plan of sorting, orientation, and feeding each component as our priority. Considering each component has different stable orientations, different sorting methods were designed for each part specifically. The team has concluded that a vibratory sorting method can be applied to parts such as housing, wheels, nuts, and washers; the nonvibratory method was used on axles and bolts due to its limited number of stable orientations. The feeding mechanism was designed based on the way they leave the sorting system. Housing and axles are both fed using slider escapement, nuts and washer were decided using rubber tubes as their centers of mass can be easily changed along the way. The Wheel has a customized design mechanism that allows it to slide down into the work cell and the bolt uses common feedback that fixes its vertical orientation.

To properly proceed with the assembly process, the team has decided to use a rotary table to complete the whole process. The robots and fixtures were then designed accordingly in each small station on the rotary table. To minimize the cost, only 3 robots were chosen: 2 axis positioners, a scara robot, and an automatic screwdriver. Fixtures were designed to minimize the usage of the robot, which provides a force that contributes to the wheel assembly and torque for the screwing process.5 fixtures are considered to be installed on the rotary table, followed by 5 stages of the assembly process: housing was picked into the fixture, horizontal axle placement, fixture apply force after wheels sliding in, screwing, and final inspection.

The inspection will mainly use infrared rays that ensure each component is in the designated place. The process control has also ensured the process is thorough and thoughtful that failure is not likely to happen. In the end, the team validated a whole assembly is an economic approach through cost analysis, where the whole assembly has an estimated cost of $37750.5 in total.

2. Details of Sorting / Orientation / Feeding of all parts

<u>Part 1: Housing:</u>

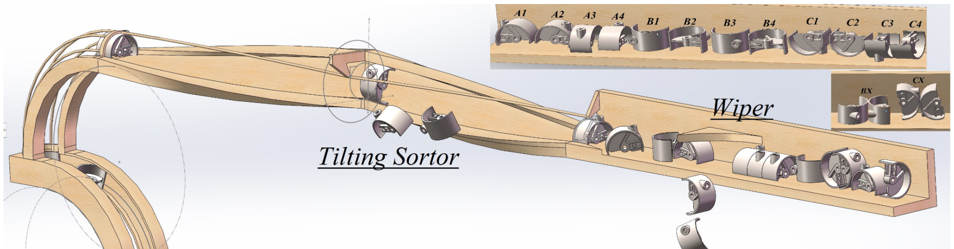

Figure 1 – Housing Sorting & Orienting, maximum track warping is 85° ccw; **read right to left.**

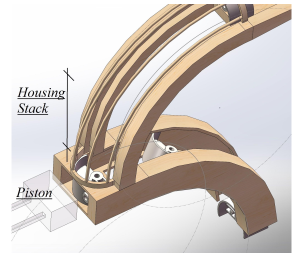

Figure 2 – Housing Feeding Mechanism

<u>Sorting and orientation:</u> Due to complicated stable orientations(Figure 1 top right), we could utilize vibrational feeders to sort and orient. The above specifies the procedure(Figure 1, read right to left). **1)** The <u>Wiper</u> rejects Misc. orientation CX, which will cause clutter at the start of Tilting Sorter. It could potentially reduce CX down to A, B, or C series. **2)** In <u>Tilting Sortor</u> the track tilts to a maximum of 85° accompanied by a guide rail which is designed to lift only the bulge of the housing to hold only A4 and rejects all other orientations (detail orientation in Appendix A1-1, Appendix A1-2), and guides A4 to the Feeding mechanism, thus achieving Sorting and orientation.

<u>Feeding:</u> The feeding of Housing is a Slider Escapement(Figure 2), in which the piston expands and contracts per one signal requirement releasing exactly 1 unit to the assembly apparatus mounted right under it. Note the Housing stack can be enlarged to stack more oriented housing waiting for Feeding.

<u>Part 2: Wheel</u>

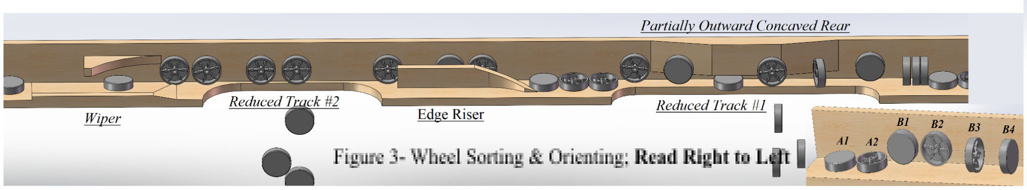

Figure 3- Wheel Sorting & Orienting; **Read Right to Left**

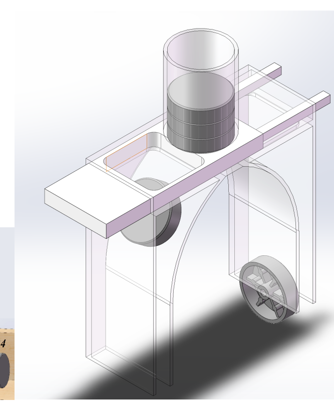

Figure 4- Wheel Feeding mechanism

<u>Sorting and orientation:</u> Wheels are small and light parts, we, therefore, utilize Vibratory feeders to sort and orient wheels. **1)** The <u>Partially Outward Concave Rear</u> + <u>Reduced Track #1</u>(top view in Appendix A2-2) rejects B3 and B4, allowing A1, and A2 to pass under and B1 and B2 to roll past. **2)** The <u>Edge Riser</u> rises every A series to B1, B2. Now, every wheel is in orientation B1 of B2. **3)** The <u>Reduced Track #2</u>(detail in Appendix A2-1) rejects B1 utilizing the

center of gravity. B1 will fall back to the bowl and leave only B2 on the track. **4)** The Wiper once again transforms B2 to A1, The A1 wheel will enter a vertical circular tube that leads to feeding.

Feeding: The wheels are delivered in two orientations: B1 and B2. Orientation A1 makes this transformation easy: a Slider Escapement (Figure 4) has a piston that collects A1, then upon receiving signal requirement, either contract or expand quickly to guide A1 to left or right, the geometric design then transforms A1 to either B1 or B2, as per demand.

Part 3: Axel

Sorting and orientation: Since Axel is of simple geometry with only 2 stable orientations (Figure 1), this will be sorted and oriented by the Non-Vibratory Feeding method identical as discussed in class(Regard Figure 2). The reciprocal up and down motion of the blade will sort and orient Axles at the same time. The incline of the blade will proceed axles into Tubular feedback. Given the design shown in Figure 2 with no horizontal plane present, the upright(Figure 1 Right) stable orientation is eliminated.

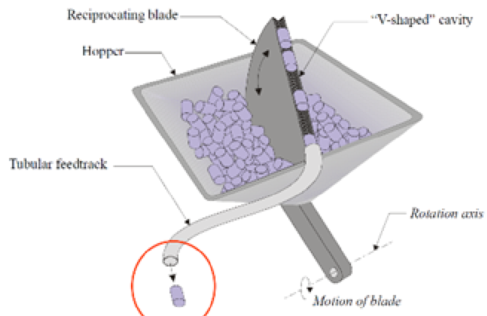

Figure 5: Axle Non-Vibratory Soring & Orientation

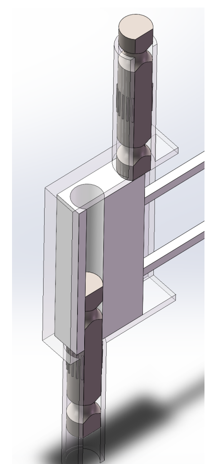
Figure 6: Axel Slider Escapement section view

Feeding: Upon the blade with groove rise, it collects and orientates the axles which then flow into the outlet tube by gravity. The axle traverses to a Slider Escapement(Figure 3) in which the piston expands and contracts per one signal requirement releasing exactly 1 unit to the assembly apparatus mounted right under it.

Part 4: Bolt

Sorting and orientation: Bolts have a head which implies a unique yet convenient and efficient handling method (Figure 7 right)Therefore bolts in this design will be sorted using a less efficient and cheaper design: Non-Vibratory Feeding. Regard Figure 7. The reciprocal up and down motion of the blade will sort and orient Axles at the same time, the blade will proceed to bolts into the feed track. Note the new blade design "chipped

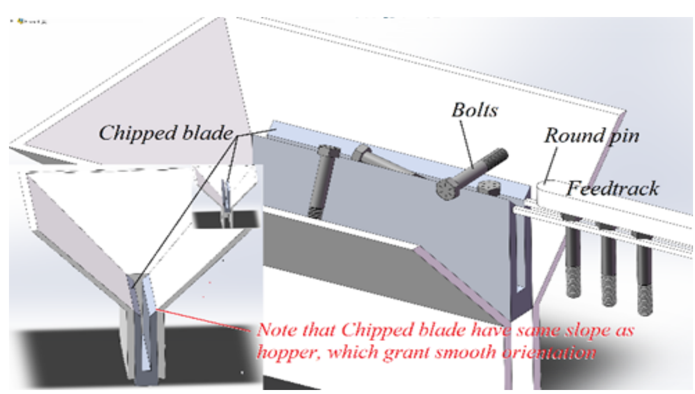

Figure 7: Bolt Sort & Orientation

blade"(Figure 7) has an identical slope to the hopper, allowing bolts to slide smoothly into the groove on the blade, thus reducing orientation A2 and C series down to A1.

Feeding: The bolts will slide through the blade to Feedtrack, and be brought to assembly using gravity on a continuous feed track identical to that introduced in Figure 7 "Feedback" mechanism.

Part 5: Washer

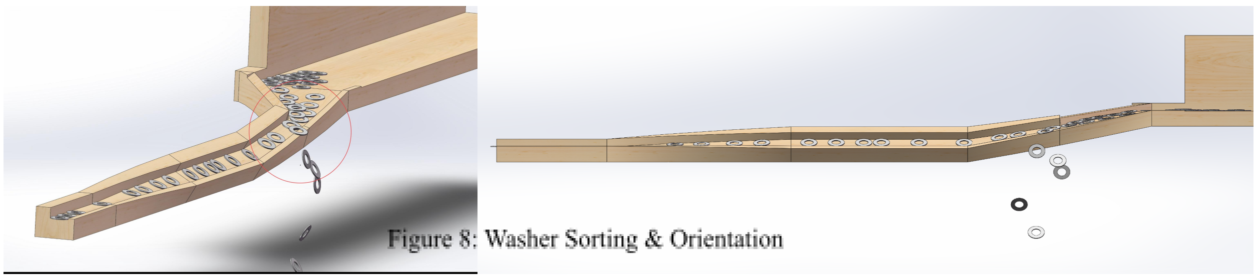

Figure 8: Washer Sorting & Orientation

It is reasonable to assume that the washer only has one stable state on the flat surface. However, due to the thickness of the washer, it is possible for some of the washer stacks to move together on the track of the vibratory table. Accounting for this case, two mechanisms are used. The first one is to set the width of the track(Figure 8) a little bit larger than the diameter of the washer. This mechanism is used to sort the washer into a one-by-one straight line. The second mechanism is to add an incline to the track(Figure 8), by which the washers on the top of another washer will slide out of the track due to gravity. Then, the sorted washers will fall into a rubber tube and are brought to the rotary table by gravity—the same design as the nuts.

Part 6: Nut

Figure 9: Nut Sorting & Orienting

To sort all nuts into a single shape into a straight line, a long v shape track is used. In the v shape track, only two possible stables occur. The first one is only one flat surface of the nut is in contact with the track, whatever the wall of the left on the right, and the other, which is the type selected by this mechanism, is the nut with two flat surfaces in contact with the pipe, contacting to both left and right wall of the pipe. To reject all nuts which belong to the first kind of stable state, part of the track was hollowed out and the track is introduced with a slight degree change(Figure 9). Therefore, only the nuts with only one flat surface in contact with the track will lose equilibrium and fall out of the track.

Then the sorted nuts will fall into a rubber tube with the same shape as the nut to keep the body of the nuts, and the gravity will bring the nut to the rotary table.

3. Robots /Positioners

The **number** of positioners will be determined through the steps of assembly and the **types** of positioners will be determined through the process of the assembly.

The first is to identify the main part which has been put onto the indexing (rotary table). The choice made by the team is the housing. Undoubtedly housing is the main part where all the assembly process is going to happen. Next, we will illustrate the details of how the assembly is going to be made and what robots/positioners we will be using to address these steps.

<u>Assembly Step 1: Fixing housing</u>

Due to the nature of housing and the steps we are taking later, we will fix the housing onto the index table using a **4-axis robot/positioner** to perform an up-down, rotation, and gripping action to put the housing tightly onto the table. The housing will be put vertically through the fixture onto the table. The robot choice for this step is a **scara robot** since this process has a large **pick and place** need and scara is the most commonly used for this purpose. The process of it moving around the housing can be seen in Figure 13. This robot is an economical choice because from research it is $6k whereas a 2 axis positioner price is typical $10k. This robot can also be used for **removing** completed assemblies from the table.

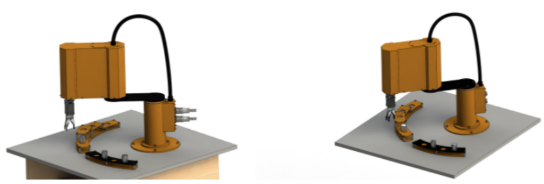

Figure 13: 4 axis positioner [2]

<u>Assembly Step 2: Housing and axle assembly</u>

Since we are having vertically fixed housing, the next step is to apply an axel to the housing so that wheels can be attached to the axel. The process is shown in Figure 14. The arrow indicates the direction (2 dof required) where the axle is being pushed.

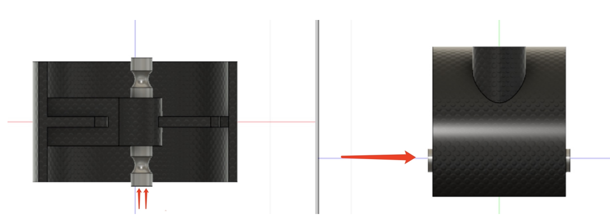

Figure 14:Housing and axle assembly

Figure 15: 2-axis positioner [3]

This robot/positioner choice for this process is a **2-axis positioner**. [Figure 15]. Guided by two linear links one performs an up and down movement to make sure that the axel is at the same altitude as the opening on the housing. The other performs a horizontal movement which is the desired assembly process for this step [Shown in red arrow in Figure 14].

<u>Assembly Step 3: Wheel and axle assembly</u>

Next step are to attach both wheels to the axle at the same step [Appendix B-1]. The positioner requires a large pressing force, but the team believes a **pneumatic positioner** will be able to perform the task. The robot/positioner choice for this step is **none**. This assembly process will be introduced in the fixture section.

<u>Assembly Step 4: Screw and housing assembly</u>

The screw assembly is the last puzzle we are going to put on our assembly and attach to the housing. [Figure 16]. The process will be rotating the screw towards the washer and then the nut.

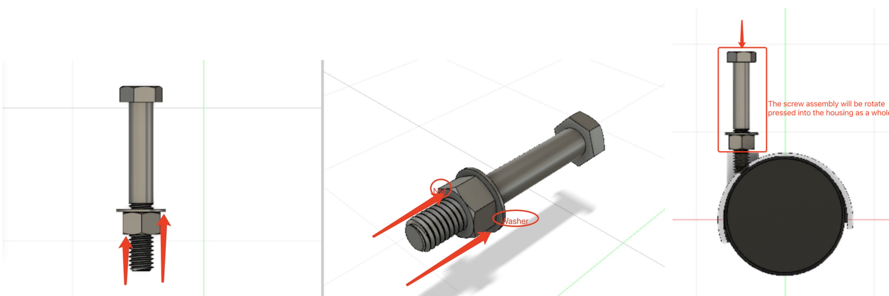

Figure 16: Screw assembly

Figure 17: Robot Type Automatic Screwdriver [4]

This is the last part of an assembly which is putting the screw assembly to the housing and kicking the piece out of the indexing table. The robot choice for this step will be **an automatic screwdriver.** This process only requires one screwdriver robot thanks to the fixture design which will be introduced later. [Figure 17] The feed track of the washer and nuts is designed right below the screwdriver and every time the screwdriver is tightening the screw, washer, and nut will drop onto the panel on the fixture designed for them, which makes an assembly [Figure 16].

4. Fixtures and Grippers

In our design, fixtures are used for locating and holding the workpiece on the rotary table, without providing a built-in guidance to the manufacturing tool. That is, the fixtures are only for immobilizing the workpiece but do not influence the functioning of the positioners or robots. To reach a specific assembly goal, the team has designed a fixture that is divided into two parts and can translate with the control of an air-powered toggle clamp [5] (see Figure 18). The material of the fixture is chosen to be the Cold Rolled AISI 1020 Steel, which could provide high strength at a relatively low cost (see Appendix C-1). The left part is mounted on the bottom plate and the right part can translate in the horizontal direction by the clamp.

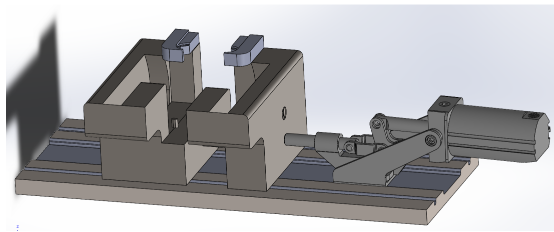

Figure 18. Overview of the Fixture

The fixture is designed to

a. **Fix the housing** after the orientation steps. The localizers on the bottom will fix the locators and the design follows the 3-2-1 rule (see Appendix C-1); b. **Provide rolling tracks** for the left and right side wheel to slide to the desired location, concentric with the inner axle of the housing (see Appendix C-2); c. **Locate and stabilize the axel** along the center of the housing and the wheels; d. **Provide support for assembly of Bolt, Nut, and Washer** (see Appendix C-3); e. **Removal of the workpiece** after assembly by the Push Clamp on the right. After localizing the housing and the wheels, the clamp is pushed and the two fixture parts are combined together (see Appendix C-5).

The design does not need other gripping methods because:

- The 4-axis positioner, the scara robot, has the grippers installed (refer to section 3, Assembly Step 1); - The 2-axis positioner for axle assembly is only responsible for pushing and does not need to grip the axle; - The washer and the nut are located on the fixture so the automatic screwdriver can move up and down directly, and does not need gripping.

5. Workcell layout / Process plan

The team has proposed to use an indexing table to complete the assembly of the wheels.

At the first stage of the assembly, the fixture will be set in an open state, a scara robot will be responsible for picking the housing from the top of the housing into the middle part of the fixture that has designated points of support after it slides down through warped feedback. Next, as the axles go off from the feedback, they enter a stable track that holds sorted axles that are awaiting the assembly. At the same time, 2 axis positioners will be placed beside the track to pick the end tail of the axle and move horizontally into the hole to complete the placement of the axle. Since the fixture is designed to have a slope for wheels to roll in, the wheels will travel through angled feedback that ensures the wheels will not misplace or change orientation along the way. Then the fixture will close with the force applied to the wheels so that the wheels are subjected to enough force, which ensures the quality of the assembly. The closed fixture will provide a complete screw holder and a place for holding both nuts and washer, which means it potentially provides torque when the screwing action takes place. The nuts will come off from the v-shaped feed track first and drop down to the nut holder, and the washer comes right next through a feed track that is placed close to the hole so that the washer does not change the orientation when falling. As the assembly continues proceeding, the automatic screwdriver that connects to the feed track of the screw will bring the screw down to the threaded insert and provide enough torque for screwing. Finally, the whole assembly will go to the last station of the work cell, where the inspection will take place (infrared rays) as described in the next section.

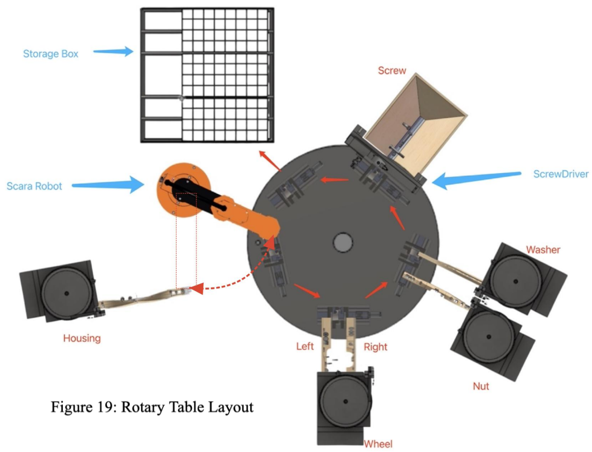

Figure 19: Rotary Table Layout

6. Process control

The whole process in our part can be roughly divided into 5 parts. The whole process is controlled based on events rather than time. Therefore, only when the infrared sensor on the delivery product machine detects that there are no more products on the machine, the infrared sensor will tell the rotary table that they are available, and the rotary table will start to assemble new products. After the rotary table starts to assemble, it will send feedback to the escapement to require new parts. In the previous words, all steps are based on the feedback from the next step. However, the reaction for the first three steps shown in the flow chart only depends on how many parts are on the feeding track, only when the number of parts on the track is below a certain threshold, the sorting and orientational machine will start to work. The number of Stranded units on the feeding track can be detected by the weight of the feeding track. Therefore, only when the weight is below a certain threshold, the machine will start to work again. The PLC technique can be applied to realize the feedback system between each step**.**

7. Quality control (inspection/testing)

The first inspection is a post-process inspection of raw material or the manufacturing source, different parts for the chair caster in this case. Accounting for the cost factors, the sampling inspection will be applied. Therefore, a batch of the random sample will be chosen and tested, and all the results will be recorded on the X-bar chart, where the y-axis on the chart tracks the variance of the test unit, and the x-axis tracks the sample that has been tested. The variance shown on the pattern can determine the quality of the sample chosen. The smaller the variance, the better the quality is. If the variance of the sample is less than the tolerance in the specification, all materials will be accepted. If not, another sample batch can be randomly selected to determine whether the lousy quality occurs systematically or randomly. The second inspection, which is realized in the same way as the first inspection by applying the sampling inspection, is an in-line inspection during the assembling process to check whether the product's features such as weight are achieving the requirements of the specification. Finally, the last stage will be a test used to find defective products and avoid those being sold in the marketplace. Therefore, 100 percent inspection is needed to find every defect part in this stage. However, due to the cost, it is almost impossible. Therefore, several more sample batches will be chosen and tested in the final stage. Only if all of their variances fall into the tolerance range will all final products be accepted.

8. Cost Analysis

The team has tried to minimize the cost of the robots to make the whole design economical.
1） to minimize the degrees of freedom of the robot since the major costs come from the complexity of the robots. 2）feed tracks were designed to be near the fixture so that the part can slide into the fixture directly without the usage of the robots 3) the shape of the feed track was designed to maximize the success rate as curvature and width limitations are set. 4) the fixture itself will allow both the stabilization of the screw installation and housing,

Therefore, the fixture was carefully designed to have the most efficient way of assembling. In the whole design, all the machines and components used in the process plan will be listed in the chart. Prices were selected based on their dimensions and average market price as references, and the total cost was determined to be $37750.5 (see Appendix D for component detail).

9. Conclusion

The team aimed for an economical approach to the design. Therefore, the least possible amount of robots is used to minimize the process. The team has ensured that the assembly process is complete with minimum possible failure and the quality check is thorough and technology-based to ensure every product made meets the standard.

10. References

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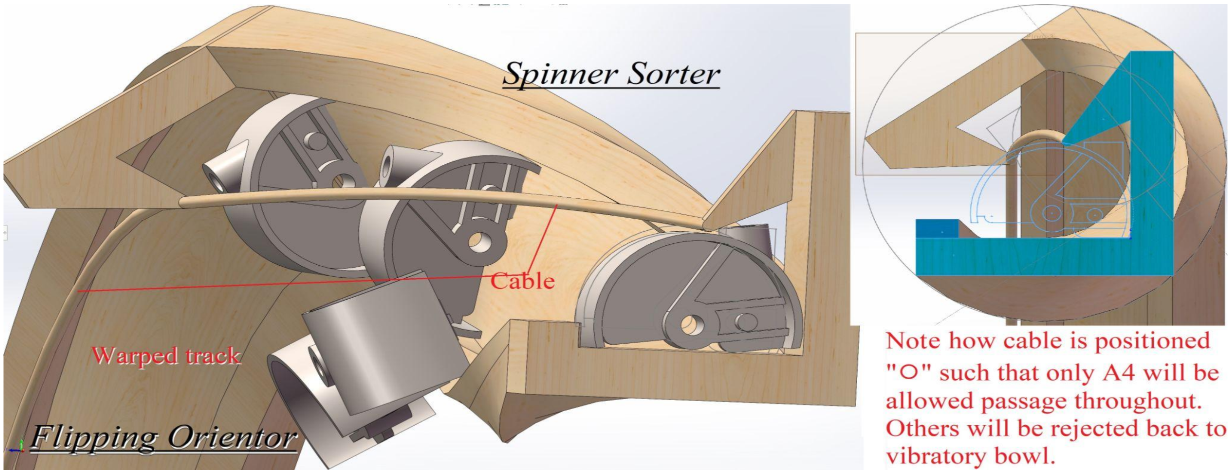
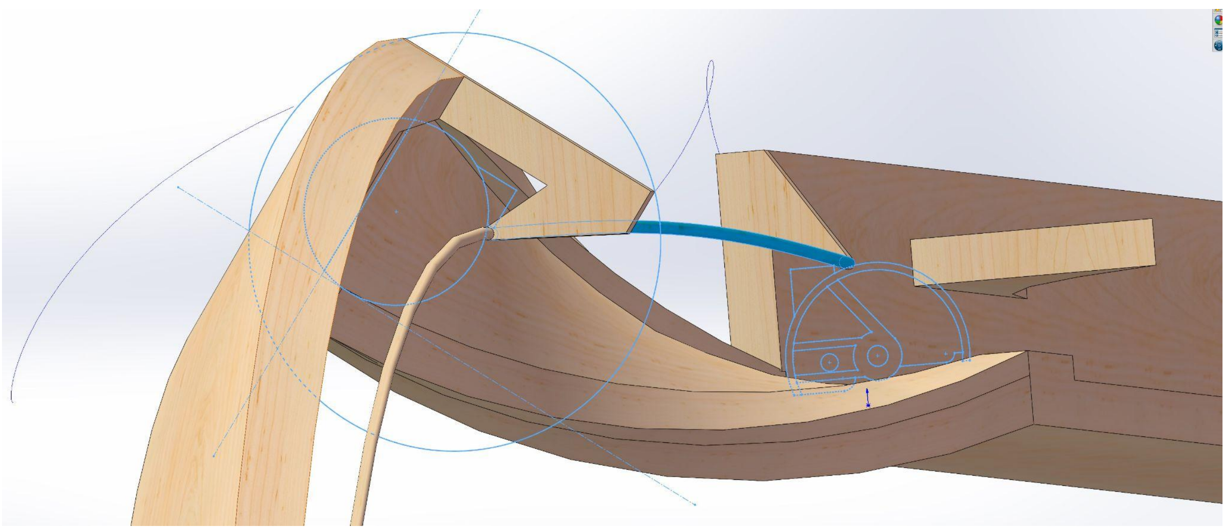
Appendix

A. Detail sorting, orientation

1. Housing

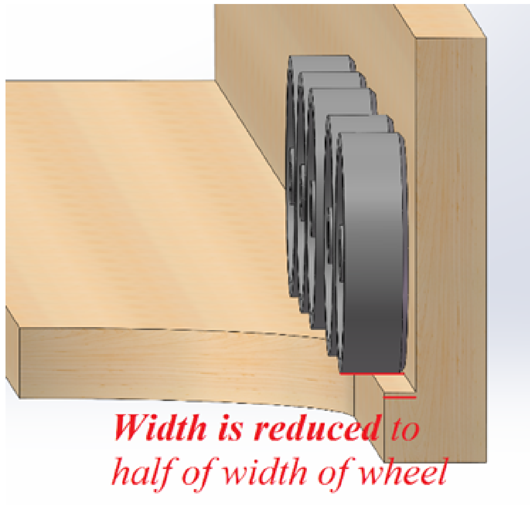


Appendix A1-1 Detailed look of sorting design, maximum track warping is 85 ccw

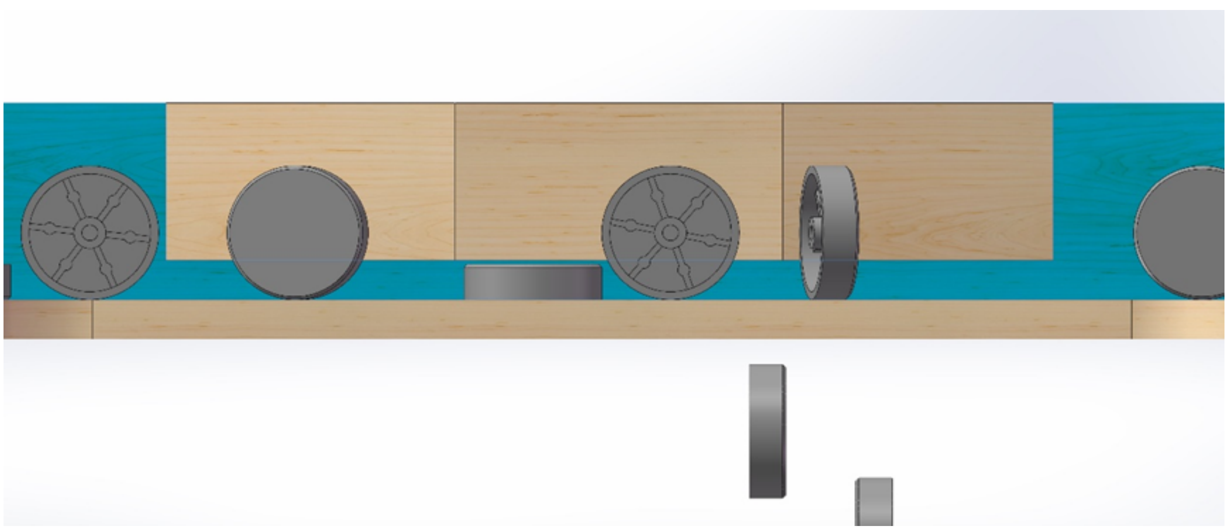


Appendix A1-2 Detailed look of sorting design, maximum track warping is 85 ccw

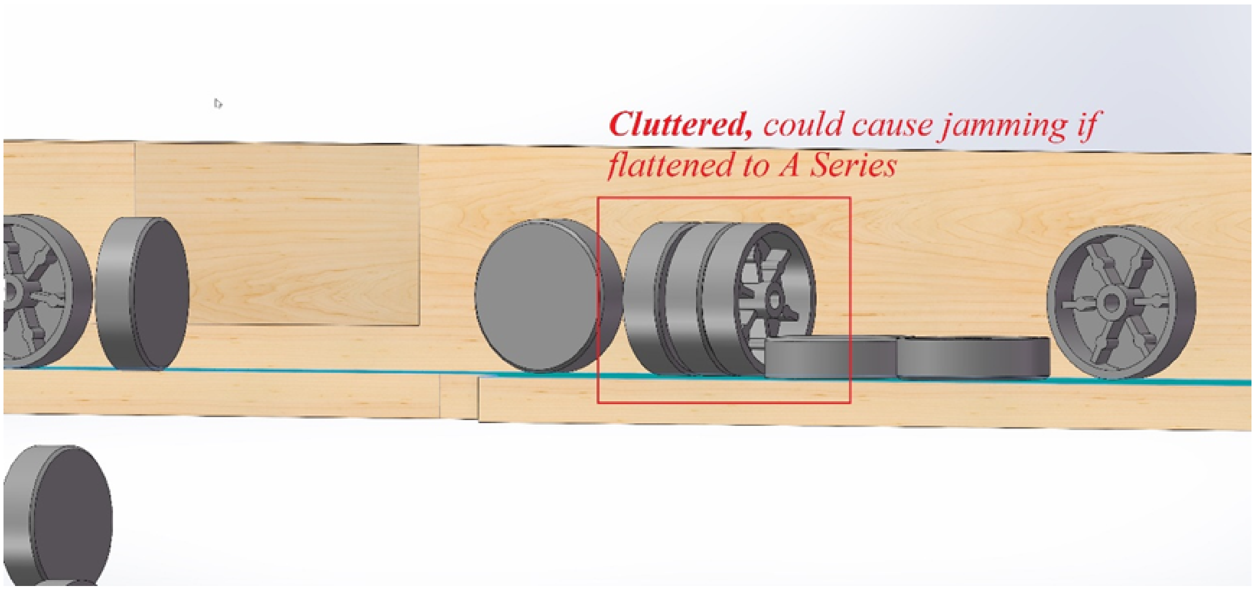
2. Wheels



Appendix A2-1 Wheel sorting reduced wall up view detail

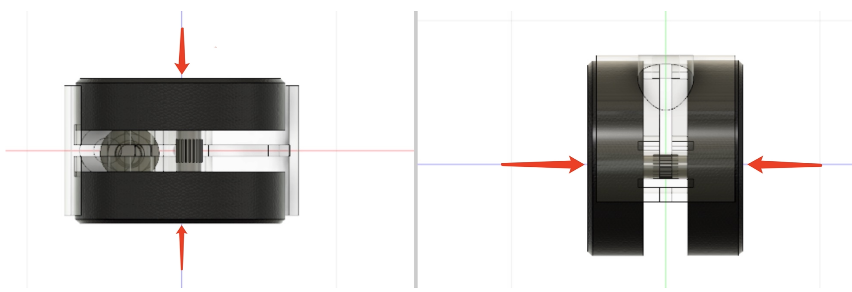


Appendix A2-2. Wheel sorting reduced wall up view detail



Appendix A2-3 : reduced track

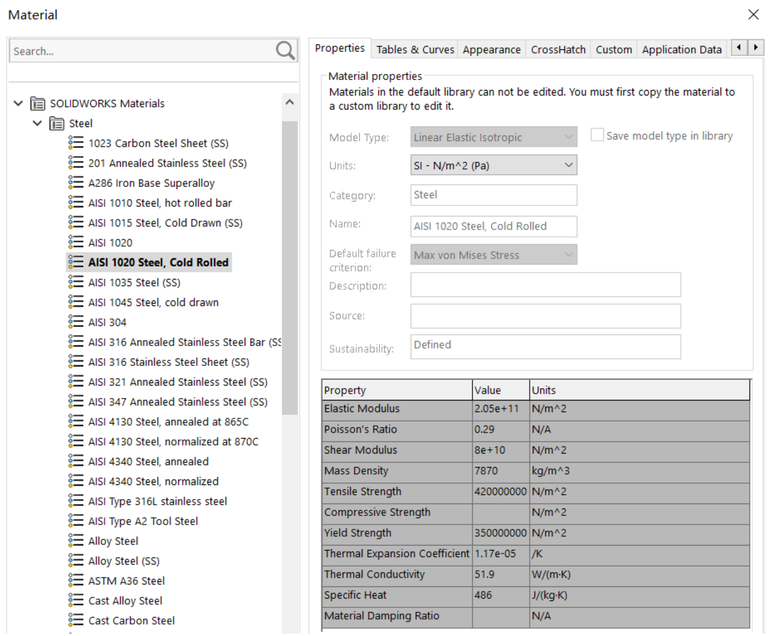
B. Assembly Step for Wheel and Axle



Appendix B-1. Wheel and Axle

C. Fixture Design

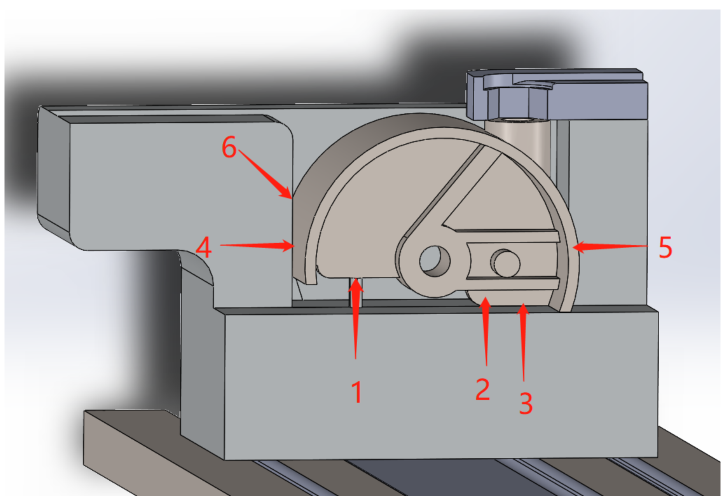
1. Material Selection of the Fixture Component



Property	Value	Units
Elastic Modulus	2.05e+11	N/m^2
Poisson's Ratio	0.29	N/A
Shear Modulus	8e+10	N/m^2
Mass Density	7870	kg/m^3
Tensile Strength	420000000	N/m^2
Compressive Strength		N/m^2
Yield Strength	350000000	N/m^2
Thermal Expansion Coefficient	1.17e-05	/K
Thermal Conductivity	51.9	W/(m·K)
Specific Heat	486	J/(kg·K)
Material Damping Ratio		N/A

Appendix C1-1 Material Property

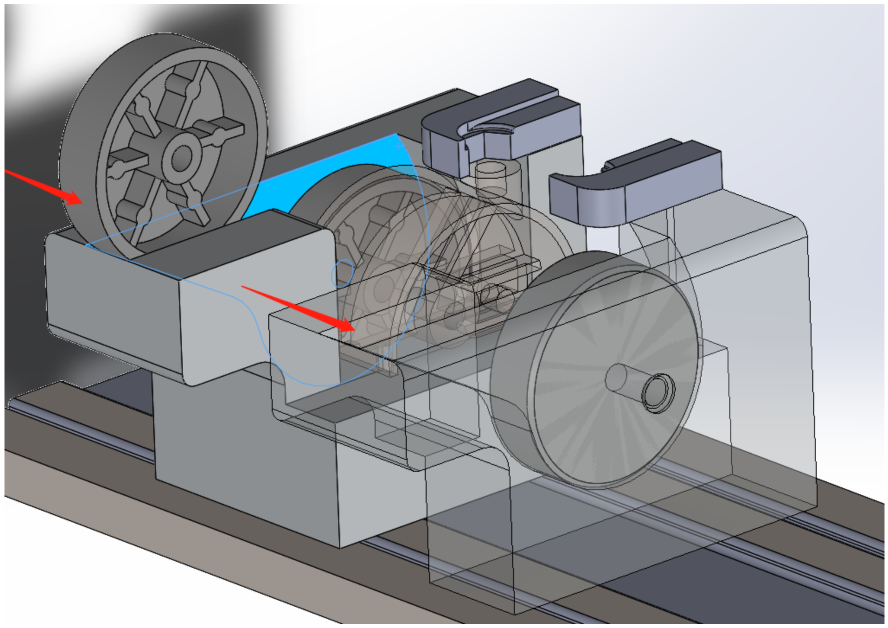
2. "3-2-1 Rule" Applied in Fixture Design



Appendix C2-1 Fixture 3-2-1 Method

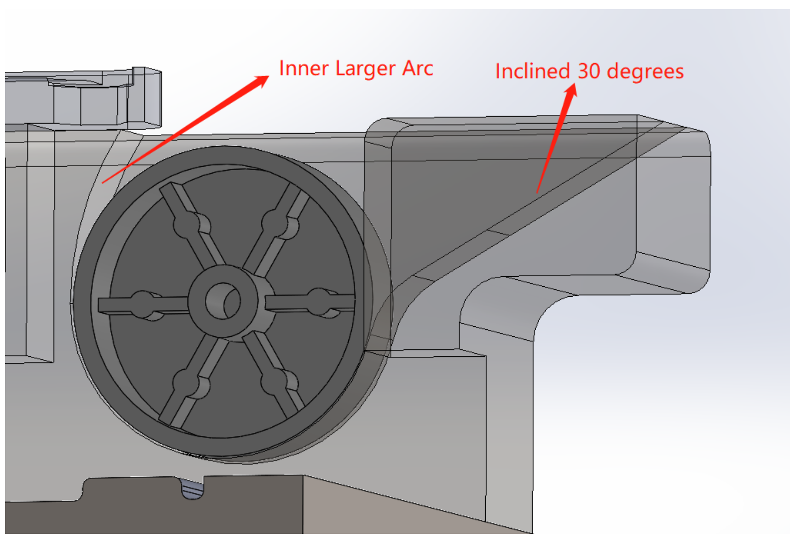
The fixture will provide 3 locators at the bottom with one cylindrical support on the left and two shorter support on the right (points 1,2 and 3). The left and right walls provide two extra point support to the circular surface of the housing (points 4 and 5) and the wall on the back support the housing on the third axis (point 6).

3. Rolling Tracks for the Left and Right Wheels



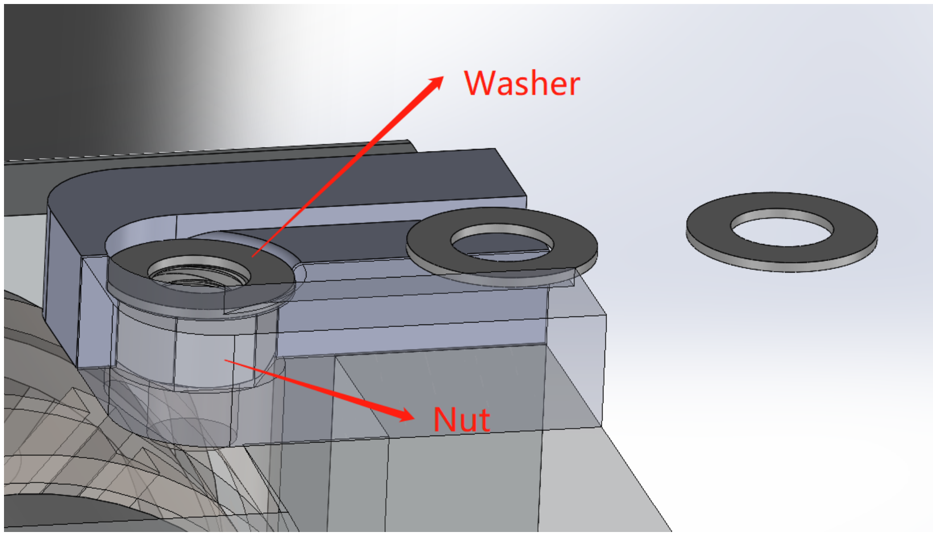
Appendix C2-2: Rolling tracks

The rolling tracks for the wheels are designed to incline about 30 degrees and the larger arc (see the below picture) will localize the sliding and eliminate the vibration when the wheel hits the bottom.



Appendix C2-3: Rolling degree

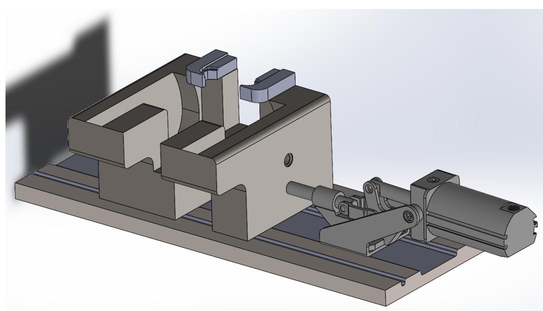
4. Support for the Bolt, Nut, and Washer Assembly



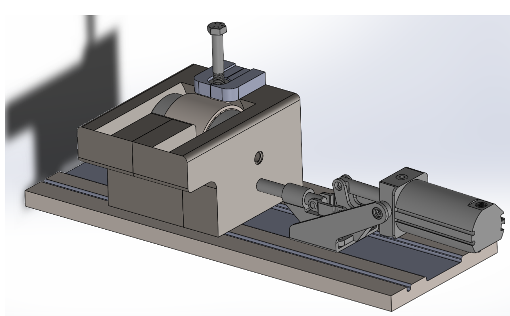
Appendix C2-4: washer placement

The upper parts of the fixture ensure the nut and the washer can be slid vertically and horizontally to the desired locations. Each side has ± 0.1 mm to allow for random movement.

5. State of the Fixture



Appendix C2-5: (a) Before the Localization of Components



Appendix C2-5: (b) After the Localization of Components

D. Cost analysis Table (Cost List)

Table 1: Cost List

Component Name	Quantity	Additional notes	Price
Vibratory feeder	4	50-100 pc/min (washer, wheels, and nut) 30-35 pc/min (housing)	$850*3 [6] $1000 (with customized flipping orientor)
Non-vibratory feeder	2	200 pc/min (bolt, axle)	$2700 *2[7]
Scara robot	1	The robot is selected specifically due to its economical advantage	$6000[8]
2 axis positioner	1	Composed with high complexity and accuracy	$11000[9]
Automatic screwdriver	1	/	$1500[10]
Fixtures	5	Approximation based on the material used and manufacturing cost	$2000 each
Slider escapement (axel and housing)	2	/	$400[11]
Feeding mechanism (wheels)	1	/	$400
Rubber tube (washer)	1	/	$0.1/100m[12]
Air-Powered Push Toggle Clamps	1	/	$200[5]
PLC	1	/	$500[13]
Rotary Table	1	/	$1500[14]
Total cost	/	/	$37750.5