International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 10 Issue: 12
DOI: https://doi.org/10.17762/ijritcc.v10i12.5892
***Article Received**: 09 October 2022 **Revised**: 08 November 2022 **Accepted**: 14 December 2022*

Load Cell Mechatronic Approach with Finite Element Analysis (FEA) in SolidWorks Design Development of a Small-Scale Egg Sorter

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Abstract—This research was about developing an automated small-scale egg sorting machine, equipped with mechatronic components, that can sort chicken eggs and place them in trays according to five (5) weight classifications: pewee, small, medium, large, and extra-large with the use of an Arduino load sensor. The machine was made up of a load cell sensor, an Arduino mega controller, a suction mechanism hanging from a rail system driven by a National Electrical Manufacturers Association (NEMA) stepper motor, and a set of five egg trays for the five (5) egg weight classifications. The Arduino Mega microcontroller was used to operate the machine's moving parts, pump, sensors, and LCD. The machine was equipped with an alarm system that produces a sound when the suction picks up the 13th egg of a full tray. The Finite Element Analysis (FEA) simulation was done using SolidWorks software to analyze the vacuum pump capacity and the effects of dynamic force on the eggs during the pick and place process. Testing results of the actual fabricated machine indicated that it was able to successfully weigh, pick through suction, sort, and place eggs into 2x6 trays according to weights. The accuracy was 92.55 percent.

Keywords-chicken egg properties; egg sorting; mechatronics; load cell; pick and place; suction cup calculation; FEA simulation

I. INTRODUCTION

Poultry products, including chicken eggs, were popular and frequently consumed in the Philippines (Quilloy et al., 2018). In the Philippines and other parts of the world, many people use chicken eggs regularly as part of their diets. In research on protein preference, Islam et al. found that eggs were the most popular protein choice (Islam et al., 2018). One of the main sources of calories, proteins, and lipids in Filipino households is the chicken egg. As a result, the chicken egg market represented a sizeable portion of Philippine agriculture (Mapa, 2019; Capanzana, 2016). The Philippines, whose egg consumption per capita reached 4.92 kg in 2019, 7.42% higher than in 2018, was ranked 98th among 161 countries in terms of consumption per capita (Stanik, 2022).

The Philippine Statistics Authority noted that in the second quarter of 2021, a projected 167.93 thousand metric tons of chicken eggs were produced, a recorded 13.1 percent increase over the same period in 2020 (Mapa, 2021). Based on the country's increase in chicken egg production from 2015 to 2019, future growth was projected (Mapa, 2020). This necessitated techniques and innovations that will simplify the processing of collected chicken eggs.

The poultry sector had expanded and became more competitive, so there is an important need for ongoing technological and equipment advancement in areas like production, sales, and sorting. Sorting and packaging required a large workforce as well as a significant financial investment. There were many drawbacks to manual sorting that could impede improvements in the productivity and expansion of the egg production sector. The labor cost and inaccurate estimation of the appropriate weight of the egg were the main drawbacks of sorting by hand. A worker, whether using a weighing scale or not, was not fully able to correctly sort eggs with great accuracy or efficiency. Most manufacturers abroad chose to utilize sorting

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machines because of this drawback (Alikhanov et al., 2019). The poultry industry's aim was to develop and make considerable progress in technologies for cutting the cost of sorting and improving the quality control measures of the eggs because hand sorting is inefficient (Yang et al., 2022).

A study in the Philippines stated that: machines were not commonly utilized for egg sorting; there is inconsistency in manually classifying eggs by weight among small-scale to medium-scale farmers, medium scale-farmers, and traders, which is primarily attributed to manual sorting; and the assigned weights per grade by the different farmers and traders were lower than the established PNS standards (Lat & Reyes, 2021).

Post-harvest procedures like grading and sorting were used to prevent needless losses in the selling of chicken eggs. Egg products were often classified in the Philippines depending on weight and quality. With the development of new technologies, it was expected that the sorting of chicken eggs can be improved. Pewee (less than 45 g), small (from 45 g to 54 g), medium (from 55 to 59 g), large (from 60 to 64 g), extra-large (from 65 g to 69 g), and jumbo (greater than or equal to 70 g) were the standard weight classifications (Bondoc et al., 2021). International research revealed that overall production of chicken eggs had improved by reducing manual handling, avoiding inaccurate egg quality evaluation based on weights, and preventing losses due to improper packaging handling (Indirapriyadharshini et al., 2021).

This study focused on the design and construction of a novel form of egg sorting apparatus that can accurately distinguish between different egg classifications and sort them according to weight, utilizing a load cell and a pick-and-place mechanism for the designated categories, to address the issue of placement in a designated tray as part of the sorting in one automation.

II. Materials and Methods

A. *Literature and research materials review*

Patent searches were conducted at the beginning of this investigation. Search results served as conceptual design reference for the proposed egg sorter. Existing characteristics of prior art included: designing and creating a mobile application to go with an egg collection and sorting system for chicken farms and classifying them into three categories: large, medium, and small, in accordance with FAO criteria (Koranteng et al., 2020); the gantry robot which used the three major colors—red, green, and blue—to sort things according to their hues and a gripper as an end effector to pick up the object and place it where it should be based on its color (Sharath et al., 2021); the all-purpose gripper which was capable of holding a variety of products, including heavy objects, industrial parts, eggs, and groceries (Figliolini & Rea, 2011); a machine design aimed to classify date fruits based on their stages of maturity by analyzing the picture (Pourdarbani et al., 2015); grading green coffee beans based on physical flaws and size sorting (Susanibar et al., 2021); developing an automated ginseng weight estimation and sorting system using image processing (Jeong et al., 2017); an egg sorting system that used computer vision and roller conveyors for sorting based on indirect weight and shape assessment (Alikhanov et al., 2019), an image acquisition tool that utilized a CCD camera and illumination boxes to sort eggs into three categories: intact, broken, and bleeding eggs (Nasiri et al., 2020); a single-line automated sorter for Philippine table eggs using mechatronics, which included the use of sensors in conjunction with servo motors (Quilloy et al., 2018); and the use of the YOLO machine vision method to detect and classify fish for automatic sorting (Kuswantori et al., 2022); and a methodology of creating a parts list or bill of materials (BOM), parts assembly, and assembly drawings showing the location and identification of each component (Malonjao et al., 2022).

B. *Conceptual design*

The conceptual design demonstrated that the x, y, and z axes make up the rail and guide mechanism's movements and the direction of the pick and place mechanism (Fig, 1). It included servo motors, a rack and pinion set, and belts. Figure 2 showed the maximum travel distances of the rails along the x and z axes. The maximum travel distance along the y axis was also illustrated (Fig. 3). The suction cup, vacuum pump, rack and pinion, and other components comprised the pick and place mechanism. The egg was weighed using a load cell. The feeder system was an optional auxiliary part used only when the eggs are placed in a basket. By design, around 900 eggs can be sorted per day using the egg sorter.

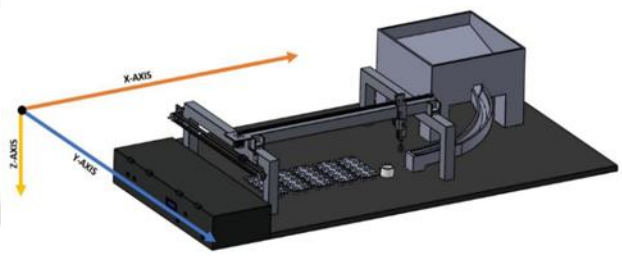

Figure 1. Conceptual design of egg sorter machine with x,y,z axes rail mechanism.

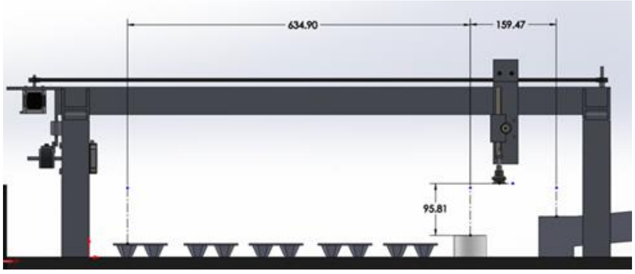

Figure 2. Travel distances of approximately 0.8m in the x-axis and 0.2m in z-axis.

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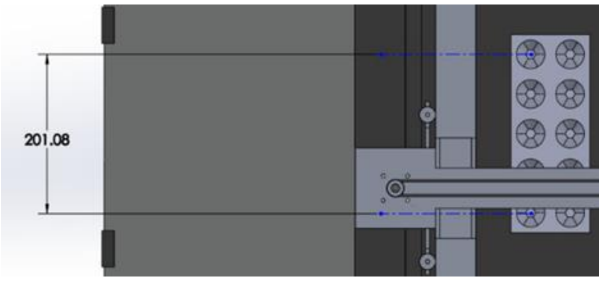

Figure 3. Travel distance of approximately 0.5m in y-axis.

C. Working drawings for X,Y and Z axes of rail parts

Working drawings were used as basis for the parts to be fabricated. It featured various perspectives of the object, including top, front, and side views, as well as an isometric view for proper understanding of each part. The drawings were given a part name and important dimensions were provided for the purpose of the cutting and drilling processes. Separate drawing sheets were drawn for welding, surface finish, treatment, and assembly processes as necessary. Other information like material specification, corresponding fasteners, alternative parts, and other related parts were listed in the separate bill of materials (BOM) for a cost quotation along with the actual fabrication process. Open revisions of dimensions on these parts were made during the fabrication process, whichever gave a favorable result, and drawings were updated in the database for further design consideration, review, or analysis. The components that were developed were the x-axis drive rail, the y-axis driver rail-right, the y-axis driver rail-left, and the z-axis driver holder and were shown below (Fig. 4; Fig. 5; Fig. 6; Fig. 7).

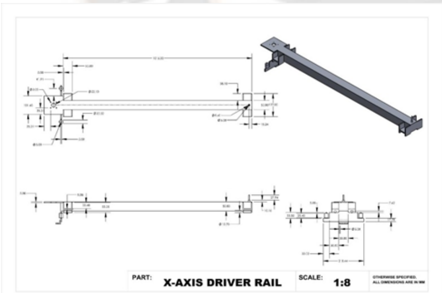

Figure 4. Working drawing of x-axis driver rail.

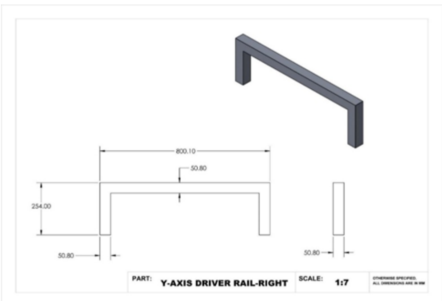

Figure 5. Working drawing of y-axis driver rail-right.

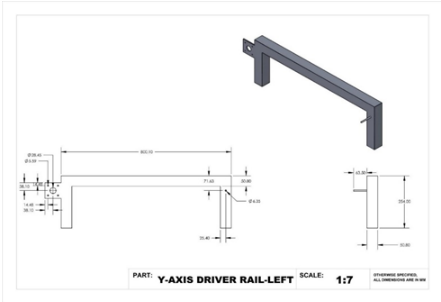

Figure 6. Working drawing of y-axis driver rail-left.

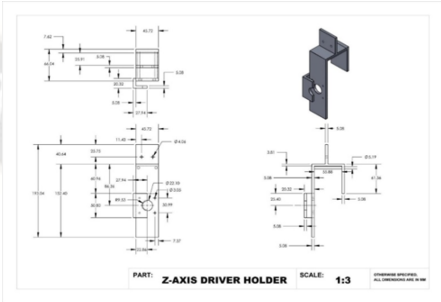

Figure 7. Working drawing of z-axis driver holder.

D. 3D Simulation with Finite Element Analysis (FEA) design parameters

In finite element analysis, the stiffness matrix was derived by higher order integration of the strain energy over the surface or volume of an iso-parametric object model. For boundary curves with irregular shapes, they were represented by elements of nodes and connecting lines to form meshes. Figure 8 in SolidWorks was a mesh of mated three parts, namely the holder, which was made of stainless steel; the suction cup, made from silicon rubber; and the eggshell, which was commonly known as nature's technical ceramic. The type of mesh appropriate for the object was a fine blended-curvature based mesh, as initially assumed. Other types of mesh, like standard and curvature-based, were also used. The assembly was driven by a rack and pinion set connected to the stepper motor, which was mounted on the z-axis driver holder.

1) Design parameter for vaccine pump capacity: Simulation employing static nodal stress under gravitational force was done using SolidWorks as equivalent to suction pressure. A jumbo egg was drawn and weighed 72.79 grams in total during a mass properties evaluation. Because the leak rate of the material is unknown, it is typically impossible to predict the vacuum level that will be reached when computing the holding force for porous materials. The diameter of the suction cup was estimated using the vacuum pressure of a commercially available vacuum pump, and the equation is shown below, where S is the factor of safety.

$$F \times S = P_{vaccum} \times A \tag{1}$$

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According to Brinsea Incubation Specialists (2022), the suction cup mouth diameter of about 8 mm was used, which cannot be larger than the maximum breadth of the egg, which had a mean diameter of 43 mm (Brinsea Incubation Specialists, 2022).

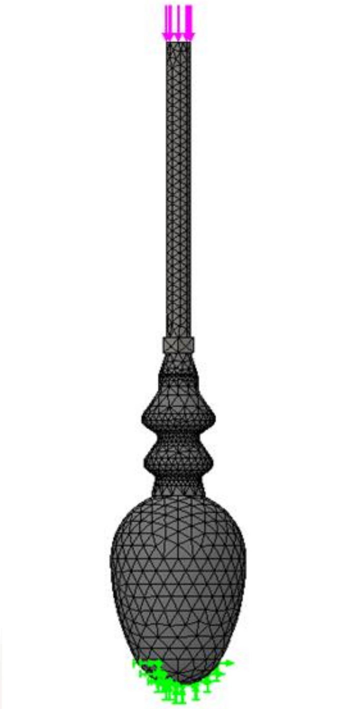

Figure 8. Blended-curvature based mesh.

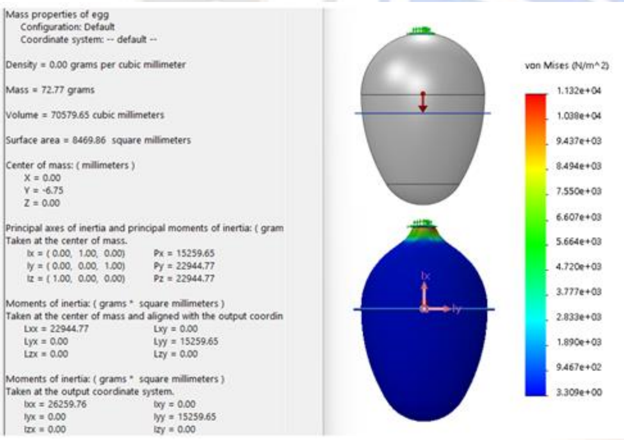

Figure 9. Simulation of egg static stress with center of mass properties from SolidWorks.

The load was situated at the center of the mass at (x = 0, y = -6.75 mm, z = 0). The findings demonstrated that the nodal point's von Mises stress was 11324.042 Pa, as illustrated (Fig. 9). The vacuum pressure for a pump kit available was 46662.8 Pa when utilizing a pump operating at 350 mmHg with a DC voltage of 3.7 V, which was greater than the allowable level of stress determined by the simulation. Hahn et al. (2017) stated that the failure strength of a chicken (jumbo) egg was 21.9 MPa (Hahn et al., 2017).

2) Design parameter for dynamic load effects on eggshell: Simulation of static stress displacement was used to determine the effect of load from the rack and pinion set dynamic load translated to load absorbed by the suction cup up to the shell of the egg during pick and place motion. In contact with the egg, the suction cup and its holder descended with a dynamic force of 2.87 N, or 0.3 kgf. Four sizes, including peewee, small, medium, and large, were used to represent eggs. The eggs were simulated using 0.2 kgf as an initially lower external load test. As seen in the simulation, egg attributes were provided as custom material (Fig. 10). The maximum y-displacement for a peewee-sized egg with a mass of 43.58 g was 0.002514 mm, while for a small-sized egg with a mass of 50.24 g, the maximum y-displacement was 0.002145 mm (Fig. 11). The maximum y-displacement for a medium-sized egg with a mass of 57.86 g was 0.001592 mm, whereas for a large-sized egg with a mass of 62.86 g, it was 0.001382 mm (Fig. 12). The simulation findings revealed that while the movements of the suction cup affecting the eggshell were more pronounced for peewee-sized eggs, their effects were quite small and considered negligible even when increasing them to 0.4 kgf. The result was as high as 0.00539 mm. The eggshell was still strong enough to endure $170X10^6\,Pa$ (Harvard Natural Sciences Lecture Demonstrations, 2022). Dynamic force was computed using equation below,

$$F_D = \frac{3.05+V_m}{3.05} \times F_T \tag{2}$$

where linear speed was shown in equation,

$$V_m = \pi D \tag{3}$$

while the transmitted force was computed in equation,

$$F_T = \frac{2T}{D_p} \tag{4}$$

and torque was determined using equation,

$$T = \frac{F_N D_p}{2} \tag{5}$$

In order to calculate the dynamic force, the governing equation was derived using the most recent American Gear Manufacturers Association (AGMA) standards for the equation describing the velocity factor for the cast profile (Budynas et al., 2008). It provided a larger dynamic force factor value, which was useful when examining the consequences on the eggshell simulation results. SI units were used to solve the equation. As an option, the Buckingham equation can be used to account for errors in the tooth profile, the elasticity of the gear material, and the inertial effect of connected masses.

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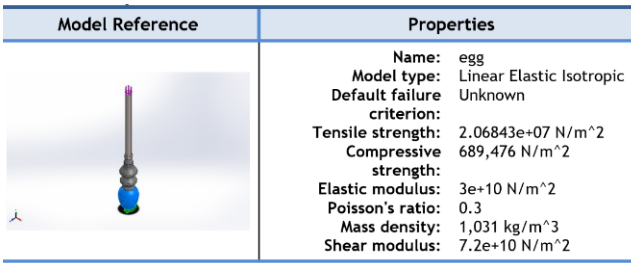

Model Reference	Properties	
	Name:	egg
	Model type:	Linear Elastic Isotropic
	Default failure criterion:	Unknown
	Tensile strength:	2.06843e+07 N/m^2
	Compressive strength:	689,476 N/m^2
	Elastic modulus:	3e+10 N/m^2
	Poisson's ratio:	0.3
	Mass density:	1,031 kg/m^3
	Shear modulus:	7.2e+10 N/m^2

Figure 10. Simulation of holder, suction cup and chicken egg with provided egg attributes from SolidWorks.

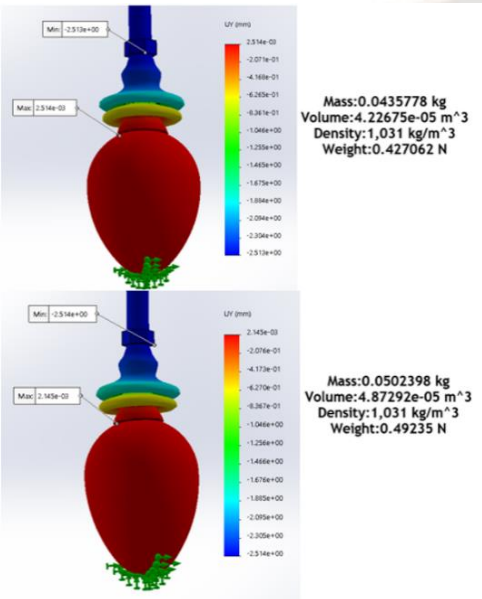

Figure 11. Egg properties with static displacement simulation on peewee and small-sized eggs in SolidWorks.

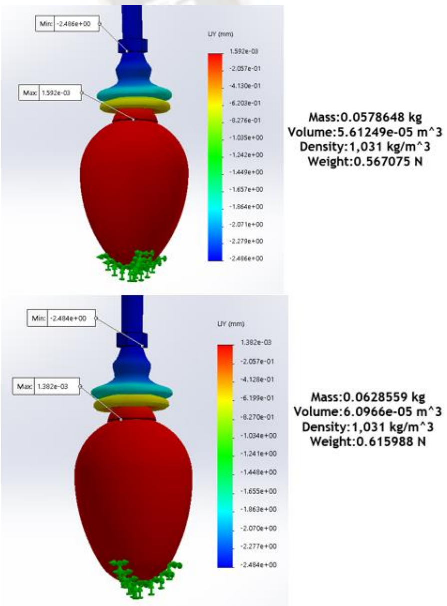

Figure 12. Egg properties with static displacement simulation on medium and large-sized eggs in SolidWorks.

E. Fabrication and assembly of parts

The fabrication had three (3) main components, rail and guide mechanism assembly, suction mechanism assembly and microcontroller system assembly with LCD display, motors, pump, and sensors.

1) Rail and guide mechanism assembly: The z-axis rail holder was installed on the x-axis rail driver rail, which was positioned on top of the two left and right y-axis driver rails as shown (Fig. 13).

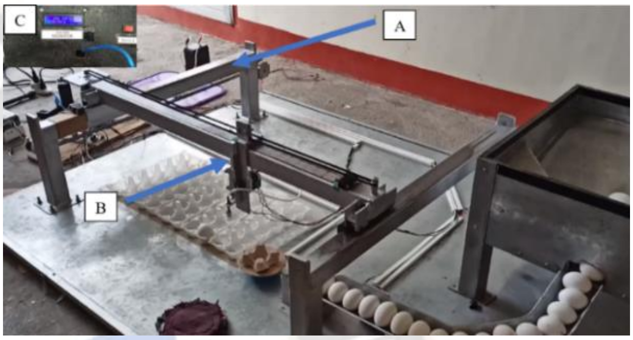

Figure 13. Actual fabricated egg sorter machine.

The leg support for each of the y-axis driving rail's legs was made of two square aluminum tubes, denoted by the letter A (Fig. 13). The y-axis driver rail tube, which was where the x-axis rail movement will travel, was placed on top and welded to the two leg supports. The y-axis rails were bolted to the base using four bolts. The x-axis railing was made of square aluminum tubes and had two rollers made of stainless steel on each side.

2) Suction mechanism assembly: A metal bar was placed on one side of the x-axis driver rail for movement, which was utilized to connect to the y-axis drive belt as shown below (Fig. 14). On top of the x-axis railing, a metal bar connecting the z-axis driver mechanism holder with rack and pinion set to the x-axis belt and pulley mechanism was installed. The z-axis driver mechanism holder was fastened to the x-axis railing with two stainless steel rollers. The z-axis mechanism holder consisted of metal straps that held the vacuum pump and solenoid valve in place. The rack for the z-axis moving mechanism assembly was built out of aluminum, and the vacuum nozzle holder was mounted to one end of the rack and pinion set. The pulleys positioned on the y-axis driving rail for the belt and pulley system for the y-axis movement were made of aluminum.

A tube of air linked the suction nozzle and vacuum pump. The vacuum pump was made up of an electrical conductor with a positive and negative terminal for the power supply, a DC motor with ports for inserting the air tube, and other components as shown labelled as B (Fig. 13), and as illustrated in Figure 14.

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Figure 14. Actual photos of the fabrication of rail and guide mechanism and suction mechanism assembly.

3) Microcontroller system assembly: The parts that controlled and regulated certain machine movements make up the microcontroller system, labelled as C (Fig. 13). This was mostly made up of an Arduino controller and three stepper motors that move the x, y, and z axes in the appropriate directions (Fig. 15). A belt and pulley drive allowed for the movement of the y-axis and x-axis directions, and a suction mechanism coupled to the belt drive moved the eggs in the x and y directions. A stepper motor connected to a rack and pinion set facilitated the suction to travel along the z-axis.

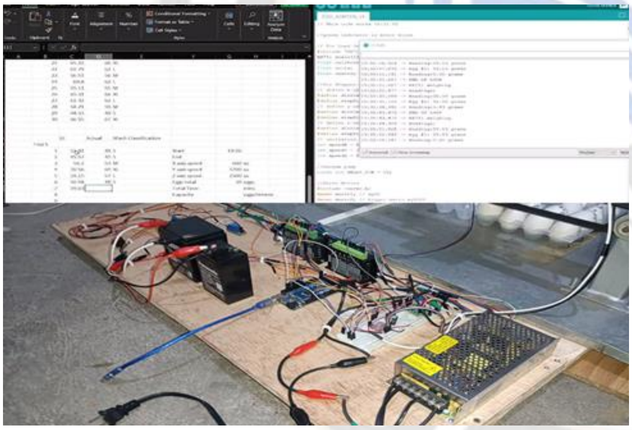

Figure 15. Actual photo of the setting up of the microcontroller assembly.

III. Results and Discussion

A. Load cell reading results

During the testing of the sorting machine's load cell sensor which was done for the purpose of sorting accuracy assessment, ninety-four (94) randomly selected eggs were used. The load cell sensor measurement, which was compared to the measurement obtained from manual weighing, was tracked in the serial monitor of the Arduino IDE and was also visible on the machine's LCD.

The data from the load cell sensor reading was plotted on the y-axis against the reading from the weighing scale on the x-axis in a scatter plot (Fig. 16). These graphs made it simpler to evaluate how the load sensor's weight measurement differs from the manual reading. The root mean square error (RMSE) for the 94 egg samples was 1.49.

Because a root mean square error value close to zero implies that the data points were close to the regression line having a slope of one, the computed root mean square error showed that there was no significant difference between the load sensor reading and the reading taken from the weighing scale. When the load sensor reading and the actual weight were the same, the theoretical result was shown by the regression line in the figure (Fig. 16). In the study of Quilloy et al. (2018), it was observed that the root mean square error was 1.90, and it was suggested that the vibrations or oscillations that occurred when the eggs moved along the conveyer belt caused the error in reading. And since there were no moving elements on the machine when the load sensor was weighing the egg, the vibrations were minimal for this particular machine.

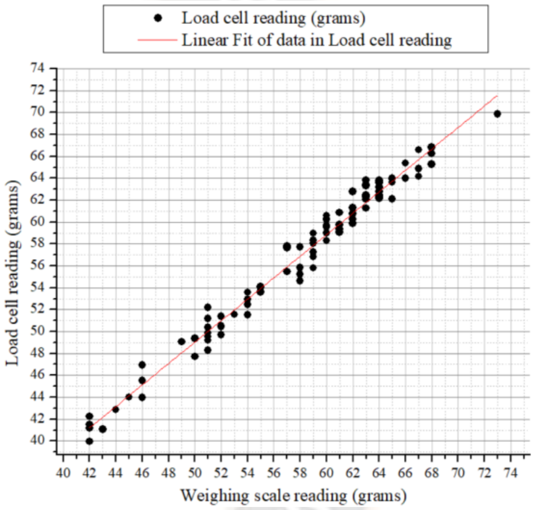

Figure 16. Load sensor reading compared to manual weight reading.

Linear fitting analysis was done using data from weighing scale and load cell reading. There were no masked data and missing values. The statistical results showed that Pearson's r was 0.98996 and the adjusted r-square value was 0.9798. The intercept's standard error was 0.84824, while the standard error of the slope was 0.0146. Using ANOVA, the sum of squares at 92 degrees of freedom was 93.71951 and the mean error was 1.01869 with an F-value of 4511.78265. The regular residual of the data in the load cell with respect to the independent variable was plotted as shown below (Fig. 17). This meant that the accuracy was high under static load testing, referring to the adjusted r-square value of greater than 0.7.

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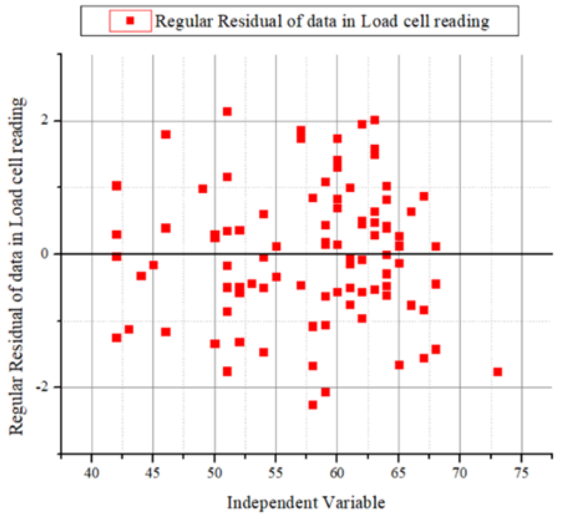

Figure 17. Residual vs. Independent Plot

B. Sorting performance results

1) Machine sorting performance: The feeder was filled with eggs. The egg was positioned at the pickup location. Two cameras were put up to record the machine's operation and the weight monitor, and the switches were turned on. The load cell and digital scale egg weights were recorded and classifications were noted in MS Excel each time an egg was weighed on the load cell and brought to its classification tray. The order of sorting the eggs was identified after watching the camera footage. In order to assess the machine's precision, the eggs were weighed manually (Fig. 18).

Figure 18. Actual egg sorter machine photo of egg sorting test.

The number of eggs that were correctly and incorrectly sorted was displayed. Overall, the machine's sorting accuracy was 92.55% (Table 1). The developed sorting machine in a related study by Quilloy et al. (2018) had an overall sorting accuracy of 91%, which is just slightly lower than the sorting accuracy of this research's egg sorting machine. Both studies showed that weights close to the line separating two neighboring weight classifications were found to be the source of sorting issues for improperly sorted eggs.

TABLE 1. QUANTITY OF CORRECTLY/INCORRECTLY SORTED EGGS WITH OVERALL ACCURACY USING MACHINE

	Pewee	Small	Medium	Large	Extra Large	Total Eggs Sorted
Correctly Sorted	6	24	16	32	9	87
Incorrectly Sorted	2	0	1	4	0	7
Total Eggs						94
Overall Sorting Accuracy						92.55%

The sorting accuracy percentage for each weight category, indicating that the machine's performance in reading weight was 100% accurate for both small and extra-large egg classifications (Table 2). The designed machine had a sorting time capacity of 2 eggs per minute, or 30 seconds per egg, after processing 94 egg samples in 45 minutes. This included setting up the machine, which took three minutes and fifty-seven seconds, as well as the initial loading of the egg into the feeder. The developed sorting machine used in the Quilloy et al. (2018) study had a sorting time of 2.52 seconds per egg, which was considerably less than the sorting time recorded in this study, which is about 30 seconds per egg. However, this study also included initial feeder loading, machine power up preparation, and arrangement of eggs in the packaging tray, which increased the sorting time. The actual time of the distance traveled from the feeder to the load cell was only 1.6 seconds, while the load cell reading the weight only required 2 seconds per egg. It only took 3.6 seconds per egg from the feeder to the weight reading, or about 17 eggs every minute. When the suction picked the thirteenth egg, the machine had an alarm mechanism that sounds, indicating that it is time to remove the full tray and replace it with an empty one.

TABLE 2. PERCENTAGE SORTING ACCURACY PER WEIGHT CLASSIFICATION USING MACHINE

	Pewee	Small	Medium	Large	Extra Large
Correctly Sorted	75%	100%	94.12%	88.89%	100%
Incorrectly Sorted	25%	0	5.88%	11.11%	0

2) Manual sorting performance: As shown in the figure, the manual sorter manually weighed the eggs before placing them in their appropriate trays (Fig. 19). To verify the sorter's accuracy, the placed eggs were weighed again when the entire batch had been completed.

TABLE 3. QUANTITY OF CORRECTLY/INCORRECTLY SORTED EGGS WITH OVERALL ACCURACY OF MANUAL SORTER

	Pewee	Small	Medium	Large	Extra Large	Total Eggs Sorted
Correctly Sorted	6	18	10	23	6	63
Incorrectly Sorted	2	6	7	13	3	31
Total Eggs						94
Overall Sorting Accuracy						67.02%

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The quantity of eggs that were correctly and incorrectly sorted was shown in Table 3. The overall sorting accuracy of manual sorting was 67.02%.

Figure 19. A picture of manual egg sorting test.

The manual sorting accuracy in each weight group was expressed as a percentage without 100% reading accuracy as displayed (Table 4). The sorting machine produced a sorting accuracy of 92.55%, whereas the manual sorter produced a sorting accuracy of 67.02%, as indicated (Table 1; Table 3). According to a comparison of the two sorting accuracy results, the machine had a much higher accuracy compared to the manual sorter.

TABLE 4. PERCENTAGE SORTING ACCURACY PER WEIGHT CLASSIFICATION USING OF MANUAL SORTER

	Pewee	Small	Medium	Large	Extra Large
Correctly Sorted	75%	75%	58.82%	63.89%	66.67%
Incorrectly Sorted	25%	25%	41.18%	36.11%	33.33%

Based on the observation, the incorrect reading during manual sorting was caused by the following factors: hasty decision made by the person incorrectly placing the eggs in the trays; mistake in judgment; fatigue; forgetfulness; and distraction.

C. Suction cup simulation results

The suction cup's effective diameter was estimated using simulation data from SolidWorks (Fig. 20). The effective surface area was not considered to be flat because the egg form has curvature. The 3D CAD drawings and simulation were therefore accurate and effective. The eggshell's dry coefficient of friction was estimated to be between 0.25 and 0.65. The coefficient of friction of 0.5 was used as it was considered most suitable for many dry material surfaces. Depending on how it was positioned horizontally or vertically and the kind of surface it met, the factor of safety ranged from 1.5 to 2.5. It was assumed that the factor was 2.0 (Eurotech-Vacuum, 2022). For the purpose of calculating the various effective diameters of the suction cup, results from different scenarios with simulated stress values from the design study simulation were employed (Table 5). The egg weighed 72.79 grams in the simulation.

TABLE 5. VARIOUS EFFECTIVE DIAMETER WAS SIMULATED IN SOLIDWORKS

Simulated Pressure, Pa	Simulated suction effective diameter, mm	Effective diameter in vertical position with coefficient of friction and factor of safety, mm
13068.79883	7	16.7173
11324.04297	8	17.95904
8195.37793	9	21.1105
7159.236328	10	22.58658
7417.958496	11	22.1892
6356.412598	12	23.97054
5731.931152	13	25.24256
5546.192383	14	25.66176
5193.646973	15	26.51842
4613.206055	16	28.1373
3974.346924	17	30.31454
3302.555908	18	33.25514
3451.457031	19	32.52989
2906.412354	20	35.4491

Initially, the mesh parameters applied were a blended curvature-based mesh with controlled mesh density set closer to a fine value. Then a curvature-based and standard meshes parameter were also used as well, targeting with accurate results, but one the processing time and acceptable aspect ratio percentages in details should also be considered (Fig. 21). These can be checked on mesh advisor.

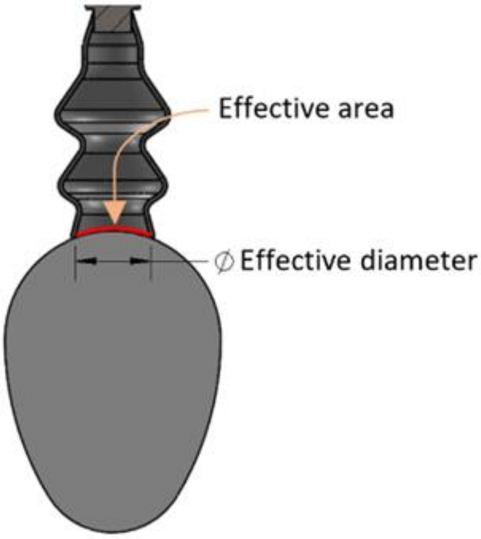

Figure 20. Suction cup in contact with the egg.

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 10 Issue: 12
DOI: https://doi.org/10.17762/ijritcc.v10i12.5892
***Article Received**: 09 October 2022 **Revised**: 08 November 2022 **Accepted**: 14 December 2022*

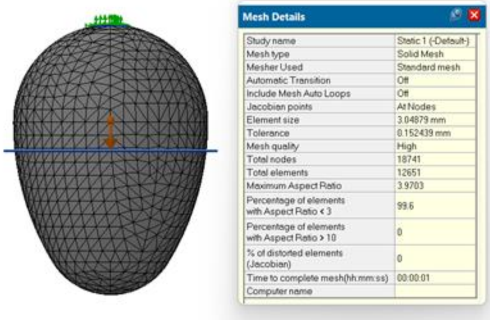

Figure 21. Standard mesh application on eggs with mesh details.

The suction cup's effective diameter, effective diameter without factors, and effective diameter with factors were calculated using simulation data from SolidWorks and plotted (Fig. 20). The parameters used were coefficient of friction of 0.5 and a factor of safety of 2. The values representing effective diameter encircled in blue was a practical and effective diameter that should be used in choosing suction cups. Moreover, the larger the suction cup's effective diameter, the less pressure was applied. An increased use of 6 suction cup mechanisms was accommodated with a pump kit available at 46662.8 Pa using an effective diameter of 26.51842 mm as noted in Table 5.

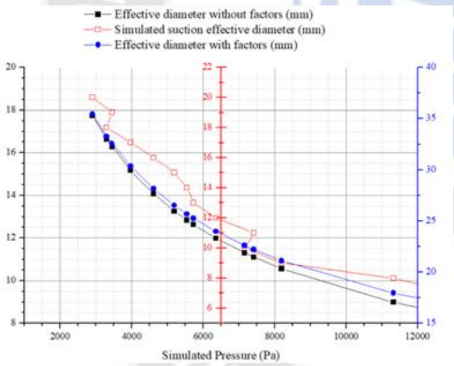

Figure 22. Plotted graph representation of three simulated effective diameters.

IV. Conclusion

Egg sorting was one of the vital post-harvest processes. Sorting by weight was a means to consistently classify eggs. Manual method of egg sorting was common among farmers and traders. This led to inconsistent size classification by weight from farm to market.

This study involved the conceptual design using SolidWorks and actual fabrication of an egg sorting machine. In addition, the machine was capable of sorting eggs by weight and of correctly placing the weighed eggs to trays according to their classification, pewee, small, medium, and large and extra-large.

This study proved that a functional egg sorting machine can be locally designed using SolidWorks and fabricated using mechatronics. This will enable the egg farmers and traders in the Philippines to comply with egg sorting standards as set by PNS. The machine had a potential of reducing the manual, monotonous, repetitive, and inaccurate or inconsistent manual egg sorting.

The automated egg sorting machine fabricated for this study was equipped mainly with 1) rail and guide assembly; 2) suction mechanism assembly; and 3) microcontroller assembly. It was designed and programmed using the Arduino Software (IDE). Testing was done to determine how accurate the automated machine could sort eggs. Results indicate that the use of egg sorting machines has higher classification accuracy compared to manual sorting. Utilizing 94 randomly selected eggs, sorting was done using the machine and the results indicate that the accuracy was 92.55%, which was higher than the actual manual sorting. For future work, the speed can be increased with a National Electrical Manufacturers Association (NEMA 34) stepper motor. The capacity can also be increased by adding more suction mechanisms. The feeder tray can be used for eggs collected with baskets, while those eggs collected with trays can also be sorted in a separate program.

Declaration of Competing Interest

The authors confirm that they have no known financial or interpersonal concerns that could have appeared to have an influence on the findings presented in this study.

Acknowledgment

The authors appreciate the support of Cebu Institute of Technology – University in terms of endorsement from the Mechanical Engineering Department, College of Engineering and Architecture, Research and Development Coordinating Office, Offices of the VP- Academic Affairs and VP-Administration and of the full funding approval by the University President for the Article Processing Charge (APC) for the submission of this research.

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International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 10 Issue: 12
DOI: https://doi.org/10.17762/ijritcc.v10i12.5892
Article Received: 09 October 2022 Revised: 08 November 2022 Accepted: 14 December 2022

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