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Design and Development of Automatic Chip Feeder for Portable Smoker

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Abstract: Portable smoker is an equipment used to cook meat by using only the heat release from the smoke. The source of heat that are used to cook the meat are the woods that are burnt inside the smoker chamber. However, there is a problem detected when smoker chamber needs to always be checked and refilled to make sure the meat is cooked evenly from the smoke releases from the burning wood. Hence, this study intends to fabricate and analyse an automated chip feeder for the smoker to feed the woods from the wood storage to the smoker chamber with less of human supervision by using a screw feeder shaft. The screw feeder shaft transfers the woods from the storage to the smoker chamber with help of an electric motor that rotates the screw feeder shaft. This study discovered that the screw feeder shaft can fed 119.4 mm^3 of woods for 1 second and 597 mm^3 of woods in the next 5 seconds. The volume of woods transferring rate from the wood storage to the smoker chamber is gradually constant to the time taken with the speed of 94 rpm. However, the rpm of the screw feeder shaft is the same even though the value of current changes because of the motor has reached its maximum torque. Moreover, the stall torque for the screw feeder to rotates when it is at rest is 2.9678×10^{-5} Nm until the screw feeder starts to rotate because the stall torque is the torque that is produced by a mechanical device whose output rotational speed is zero. Therefore, the automated chip feeder for portable smoker is made to saves time and energy to manually feed the woods inside the smoker chamber with less of human supervision.

Keywords: Automated Chip Feeder, Portable Smoker, Smoker Chamber, Wood

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1. Introduction

Smoking in terms of using the smoke from any burning or smouldering material to cook food by using the heat of the smoke releases is the process of preserving, flavouring, browning, or cooking the food [1]. Most of the foods that are suitable to smoke are usually meats, fishes, and potatoes. The material for the smoking process is often comes from wood and charcoal. Moreover, other substances are also needed to add the flavouring purpose to the food to make it more flavourful and enjoyable to eat.

Moreover, the smoking process is also good for our health because it kills bacteria and slows down the growth of the bacteria [2]. Other than that, it extends the lifespan of the food before it becomes unhealthy to eat. After that, it also changes the colour of the food for appetizing because it shines the food after the food is smoke. However, the burning material needs to be refilled manually and it is hot when refilling the material into the smoking chamber and because of that, it is very necessary to make the automatic chip feeder for smoker to prevent the injuries that will occur.

Smoking is basically a complex technique that requires time and patience to get the best flavor that can get. There are two smoking techniques which are cold smoking and hot smoking. Cold smoking cooks the meats such as chicken breast, salmon, or steak at temperature between 20 °C and 30 °C for about 12 to 24 hours. However, for the hot smoking techniques tends to tenderize the meat while cooking them by breaking the collagen down of the meat at temperature between 52 °C and 80 °C for small cut meat such as chicken wings or the temperature between 93 °C and 121 °C for larger cuts of meats such as briskets [3]. So basically, the smokers are the barbeque cooking appliances which they will cook food in a regulated chamber. There are many smokers who can go on camping trips from custom-made offset smokers to ceramic outside stoves to little smokers [4].

There are six types of smokers for wood burning or otherwise which are the offset smoker, drum smokers, pellet grill, vertical water smoker and smoker oven [5]. For this project, the offset smoker is used as for the wood chips are the source of combustion in the smoker. The food is cook with the smoke of the burning wood in the smoker itself. The smoker uses the smoke to cook the food to get the smokiness flavor of the food and make the food last longer before it turns bad. The temperature needed to maintain to cook the food is in low temperature because to make sure that the food is cook evenly and perfectly and get the smokiness taste from the smoke.

The conventional smoker is basically consuming many of human supervision activities to manually refill the burning or smouldering material such as wood chips into the smoker before the wood chips runs out for the smoking process to runs smoothly [6]. The woods need to be checks often so that the smoking process is not interrupted before the wood chips runs out inside the smoker. The food cannot be cooked if there is no heat inside the smoker chamber. Moreover, the heat from the smoke of the burning wood is important to make sure the food is cook inside out. Other than that, the wood inside the smoker chamber needs to always be checked and refilled to make sure the food is cooked evenly from the smoke releases from the burning wood. Moreover, it will waste the time and energy to always checking the wood chip inside the smoker chamber to be refilled. The food must be cook evenly with the constant temperature and smoke intensity inside the smoker chamber.

2. Materials and Methodology

2.1 Materials

The structure of the project is mainly from the mild steel material. The frame of the product is made from the mild steel plate as shown in Figure 1 while the edge of every side of the product prototype is made by using the L mild steel as shown in Figure 2.

Figure 1: Mild Steel Plate

Figure 2: L Mild Steel

As illustrated in Figure 3, the earth auger feeder is used to feed wood from storage to smoker chamber. Meanwhile, the 16.000 cm PVC pipe is used to store wood inside the PVC pipe while the steel auger feeder transporting them from the storage to the smoker chamber.

Figure 3: Steel Auger Feeder

Figure 4: PVC Pipe

The woods as shown in Figure 5 are the woods that are used in order to make the heat release the smoke from the smoker chamber. The size of the wood is 3.800 cm long and 4.000 cm in its diameter in each of the woods. The wood is then cut into half to ease the feeder process to transfer them from the wood storage into the smoker chamber. The size of all the woods is also uniform with each other where they have all the same size. After cutting the woods, they will be kept dry under a hot sun for five days to make the combustion process easier.

Figure 5: Pile of Woods

2.2 Research design

The flow chart as shown in Figure 6 shows the overall process for the design and development of the automatic chip feeder for the smoker. The process starting by selecting the topic for the research study and proceed with the preliminary studies which are by reviewing the previous research papers and journals, benchmarking the product in the market and make patent search that are connected to the project.

After that, the design concept is made based on the material selection, calculation that are required and the simulation of the stress analysis. If the calculations and simulations is satisfied, the design is selected and ready for fabrication. After fabrication, the product is tested and if there are any problems occurred while fabricating the product, it needs to be redesigned to improve the product quality. Lastly, the research of the project is documented to complete the project research.

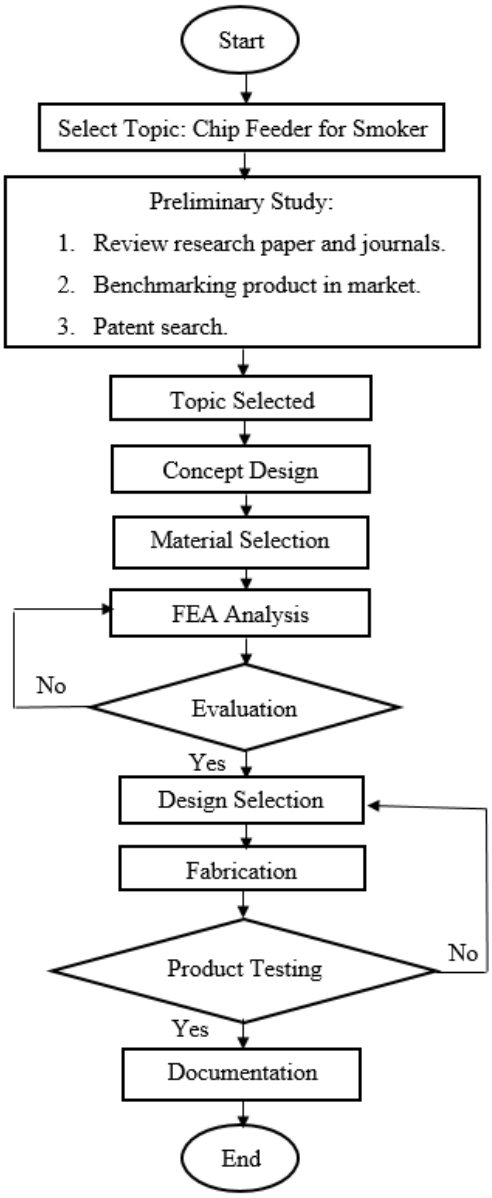


Figure 6: Research Design Process Flow Chart

2.3 Structural Analysis Using Finite Element Analysis

The Finite Element Analysis works by breaking down large structure into smaller and more manageable sections with high degrees of complexities and mathematical discontinuities. It has border conditions within the element with unique mesh that can define more simple equations related to stress, force, inertia, thickness, strength, acceleration, and temperature [7]. It usually consists of three stages as shown in Figure 7 where the first stage of FEA is called pre-processing. At this stage, a design by using Solidworks software is used to produce the model of the product. Next, the part that is needed to be analyse is then meshed into three different level. The higher the meshing number of the part, the more accurate the part will be when analysing the results and solid mesh type is used for making this product analysis. The total number meshing nodes used for his project is 36785 while the total number of meshing elements is 19061. Moreover, the maximum mesh element size is 1.442 cm while the minimum mesh element size is 0.072 cm. The next step is by making the part into its boundary condition. After that, the second stage of the FEA process is to solve the analysis that has been meshed and the test result can be obtain after running the process. After that, the post process of the analysis is to analyse the stress, displacement, and strain of the structural analysis. The 1.500 cm, 2.000 cm and

3.000 cm of screw feeder shaft is tested by using the FEA analysis. It shows that all the screw feeder shaft with different diameter from the FEA analysis in Table 1 have no issues when the screw feeder is rotating with 94 RPM in a free state motion. Moreover, based on the FEA analysis and the availability of the feeder in the market, the 2.000 cm screw feeder shaft is selected to be the actual size and shape that need to be carried out in this project. In addition, the 2.000 cm screw feeder shaft price is also cheaper compare to the 3.000 cm screw feeder and tougher compare to the 1.500 cm screw feeder. The benefit by doing the FEA process is that it can enhanced the design to make the best development of a product. Moreover, it also can increase the productivity and revenue because it will be more likely to produce better quality products in a shorter design cycle with less waste of material and time by doing the FEA process [7].

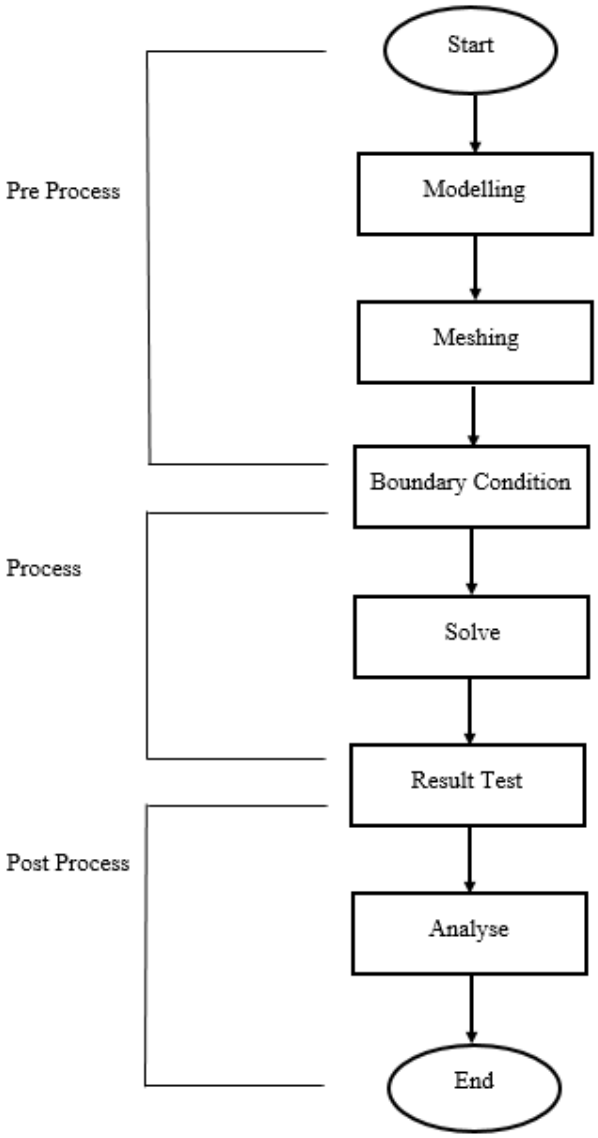


Figure 7: Flowchart of FEA

2.4 Design of prototype model

The selection design concept that has been selected is transferred into the Solidwork software by drawing back the sketching that has been made into specific dimensions as shown in Figure 8 and 9. Moreover, the smoker chamber has a door for maintenance purpose so that the dust inside the smoker chamber can be toss out easily by open the smoker chamber door. However, the shaft of the feeder has been cut until it reaches the opening hole of the smoker chamber. This is because the screw feeder can

reduce it weight to be more efficiently to rotates from both side of feeder shaft bearing. The rpm of the screw feeder that transfer the wood from the storage to the smoker chamber is taken by the amount of revolution of one complete cycle of the feeder rotation per minute. The stall torque of the motor is needed in order to know the amount of friction when the screw feeder shaft rotates. Different value of current is used in order to see if there are any changes in the rpm of the feeder when its rotating.

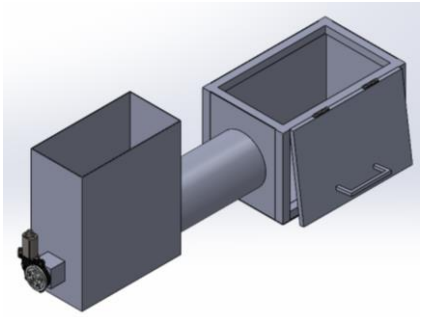


Figure 8: Solidwork Design of the Automatic Chip Feeder

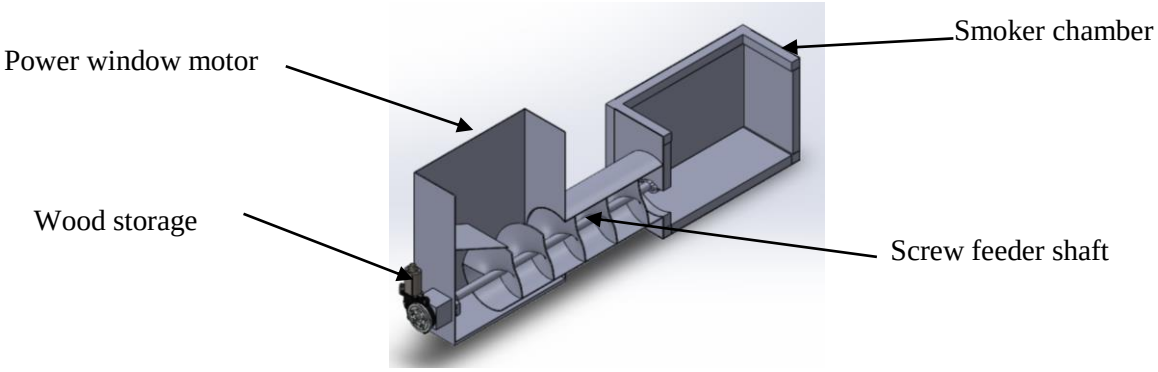


Figure 9: Section View of the Automatic Chip Feeder in the Solidwork Software

2.6 Initial Torque of Screw Feeder

The initial torque screw feeder is used to identify the starting point of the screw when it starts to rotate without the help of the motor but only with bearing in each end for both side of the screw feeder [8]. In addition, it also used to identify the friction gain when the condition of the screw feeder is in a free state form. The mass of the screw feeder when it is starting to rotate from rest is 0.055 kg from the radius of 11 mm from the centre of the screw feeder. Hence, the initial torque of the screw feeder is as calculation below:

$$W = m \times Fg \qquad \text{Eq. 1}$$

$$Weight = Mass \times Gravitational\ force$$

$$W = (0.055\text{kg}) \times (9.81)$$

$$= 0.5396\text{N}$$

$$T = F \times r \qquad \text{Eq. 2}$$

$$Torque = Force \times Radius$$

$$T = (0.5396\text{N}) \times (0.011\text{m})$$

$$= 5.9356 \times 10^{-3}\text{Nm}$$

On the calculation above, the initial torque for the screw feeder to rotates when it is at rest is 5.9356×10^{-3} Nm until the screw feeder starts to rotate. A dial indicator is used to measure the mass of the screw feeder friction from the 11 mm radius of the screw feeder.

2.5 Product testing

The product should be tested in order to know the either the product able to hold the weight of the woods when the screw feeder shaft rotates by using the power window motor specification. The flow of the wood inside the screw feeder shaft needs to be smooth by conducting the RPM, torque and wood volume test in order to prevent from problems occur when the screw feeder shaft rotates when transferring the woods from the wood storage into the smoker chamber.

The screw feeder shaft can only feed five amount of woods that has been cut in half per complete rotation in order to transfer the wood from the wood storage into the smoker chamber. The woods are in the same size as other wood that are fed inside the smoker chamber. The volume of each wood need to be calculated by using the volume of cylinder formula shown as below.

Volume of one wood, $V_1 = h\pi r^2$ *Eq. 3*

Volume of one wood, $V_1 = (3.8\text{cm})\pi(2\text{cm})^2$

$= 47.75\text{cm}^3$

Volume of half wood, $V_2 = \frac{h\pi r^2}{2}$ *Eq. 4*

Volume of half wood, $V_2 = \frac{47.75\text{cm}}{2}$

$= 23.88\text{cm}^3$

Volume of 5 woods fed per one complete feeder rotation = $23.88\text{cm}^3 \times 5$

$= 119.4\text{cm}^3$

Hence, the volume for one feed of the feeder that transfer the wood from the storage to the smoker chamber is 119.400 cm^3. After that, the RPM of the screw feeder shaft need to be determined in order to know the volume of woods that can be transfer for every 5 minutes by using the equation below.

$$RPM = \frac{revolution}{minute} \qquad Eq.\ 5$$

$$RPM = \frac{\text{revolution}}{\text{minute}} = \frac{47}{\frac{30}{60}}$$

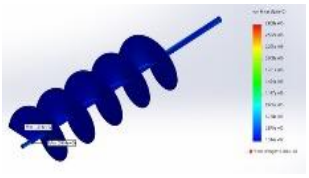
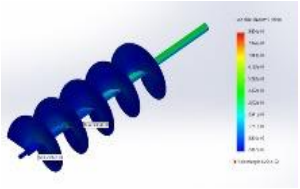
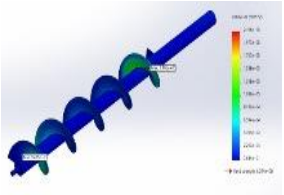
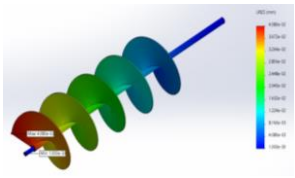
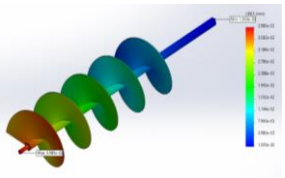
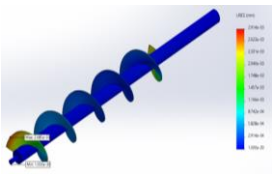
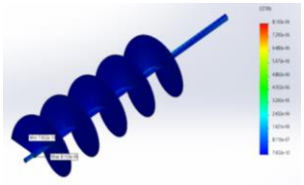
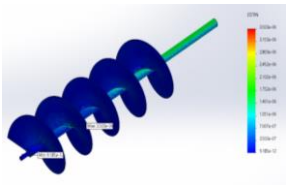
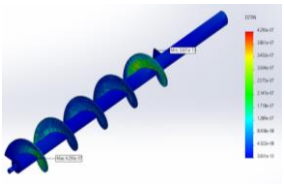
$$= 94 \text{ rpm}$$

3. Results and Discussion

3.1 Screw feeder shaft using Finite Element Analysis (FEA)

Finite Element Analysis (FEA) is a simulation of a physical interaction that are using the mathematical technique that are referred as the Finite Element Method. It is mostly used in the mechanical engineering courses and application. It helps to calculate the stress, strain and displacement of a certain product that is made through the Solidworks drawing software. The FEA is used to determine the strain, displacement and strain of different diameter of the screw feeder shaft as shown in Table 1 and the availability of the screw feeder shaft in the market.

Table 1: FEA of 1.500 cm, 2.000 cm and 3.000 cm Diameter of Screw Feeder Shaft

No	Description	1.5cm diameter	2.0cm diameter	3.0cm diameter
1	Von Mises Stress (N/m^2)			
		Max: 2.868×10^{6} Mid: 1.434×10^{6} Min: 1.314×10^{2}	Max: 8.804×10^{-1} Mid: 4.402×10^{-1} Min: 2.017×10^{-6}	Max: 2.196×10^{5} Mid: 1.099×10^{5} Min: 7.684×10^{1}
2	Resultant Displacement (mm)			
		Max: 4.080×10^{-2} Mid: 2.040×10^{-2} Min: 1.000×10^{-30}	Max: 3.980×10^{-2} Mid: 1.990×10^{-2} Min: 1.000×10^{-30}	Max: 2.914×10^{-3} Mid: 1.457×10^{-3} Min: 1.000×10^{-30}
3	Equivalent Strain			
		Max: 8.103×10^{-6} Mid: 4.052×10^{-6} Min: 7.652×10^{-10}	Max: 3.503×10^{-6} Mid: 1.752×10^{-6} Min: 9.185×10^{-12}	Max: 4.358×10^{-7} Mid: 2.147×10^{-7} Min: 3.601×10^{-10}

Based on the Table 1 above, the strain and stress for three of them are not that very critical in order to use them to feed the woods as a feeder to transfer the woods from the wood storage to the smoker chamber. The FEA analysis shows that there are no issues if the screw feeder is rotating with 94 rpm in a free state motion. Moreover, based on the FEA analysis above and the availability of the feeder in the market, the 2.000 cm screw feeder shaft is selected to be the actual size and shape that are needed to be carried out in this project. In addition, the 2.000 cm screw feeder shaft price is also cheaper compare to the 3cm screw feeder and tougher compare to the 1.500 cm screw feeder.

3.2 Analysis of the Volume of Wood Transfer from Storage to Smoker Chamber

The smoker chamber uses the woods smoke as their source of heat in order to produce heat inside the smoker. The woods need to be uniform in their shape as it was cut according to the same volume of each of the wood that was fed inside the smoker chamber. As for the testing, there are only 5 woods that were cut in half that able to be fed from the storage to the smoker chamber by one complete rotation of the screw feeder with the volume of 119.4 cm^3. The volume of one wood is the same as the others

and it can fit 5 woods at a time when the screw feeder completes it one full rotation. In addition, the time for every 5 seconds are recorded in order to know the volume of the wood that has been transferred from the storage to the smoker chamber with different amount of current as shown in Table 2.

Table 2: Current vs Time to Determine the Woods Volume

Time / Current	1 second	5 seconds	10 seconds	15 seconds	20 seconds
1.8 I	119.4 cm^3	597cm^3	1194cm^3	1791cm^3	2388cm^3
2.0 I	119.4 cm^3	597cm^3	1194cm^3	1791cm^3	2388cm^3
2.5 I	119.4 cm^3	597cm^3	1194cm^3	1791cm^3	2388cm^3

From the Table 2 above, in every 5 seconds, the volume of woods that are transfer from the storage to the smoker chamber is increasing gradually. However, the different value of current did not affect the volume of the woods that are fed into the smoker chamber because the power window motor torque has reached its maximum limit.

4. Conclusion

As conclusion, the project is successfully transfer woods from the wood storage into the smoker chamber automatically. The equipment to transfer the woods is by using the 2.000 cm diameter of the screw feeder shaft. This is because it is very easy to check the availability of the 2.000 cm screw feeder shaft in the market compare to other which are the 1.500 cm and 3.000 cm diameter screw feeder shaft. Other than that, the FEA analysis for all the comparison diameter of the screw feeder shaft also is not that critical to use it to transfer the woods from the wood storage into the smoker chamber.

Moreover, the current versus time analysis is used to determine the woods volume that have been transferred from the wood storage into the smoker chamber for every 5 seconds. The woods volume is uniformly increasing for every 5 seconds, and it shows that the smoker chamber is filled with 2388 cm^3 volume of woods in the next 20 seconds. On top of that, this project helps to reduce the human supervision to fill the woods inside the smoker chamber as this project has been automated to transfer the woods from the wood storage into the smoker chamber with the help of the screw feeder.

Acknowledgement

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References

[1] D. Riches, "Smoking 101: How to Smoke Meat," 2020. [Online]. Available: https://www.thespruceeats.com/smoking-meat-low-and-slow-331486.

[2] S. Slaughter, "How to Smoke Meat: Everything You Need to Know," 2020. [Online]. Available: https://www.themanual.com/food-and-drink/how-to-smoke-meat/.

[3] B. Maxabella, "Cold smoking versus hot smoking: what's the difference?" 2020. [Online]. Available: https://www.sbs.com.au/food/article/2018/10/29/cold-smoking-versus-hot-smoking-whats-difference#:~:text=%20Cold%20smoking%20versus%20hot%20smoking%3A%20what%27s%20the,is%20placed%20alongside%20the%20fire%20that...%20More%20.

[4] D. &. B. S. Riches, "The Rotisserie Grilling Cookbook: Surefire Recipes and Foolproof Techniques," 2017. [Online]. Available: https://www.goodreads.com/en/book/show/31934516-the-rotisserie-grilling-cookbook.

[5] F. Lion, "Grills Vs. Smokers - Differences Between Smoking & Grilling Meat," (2019). [Online]. Available: https://www.foodlion.com/fresh-ideas/grills-vs-smokers-differences-between-smoking-and-grilling-meat/.

[6] Helen, "Electric Vs Propane Vs Charcoal Smoker," 2019. [Online]. Available: https://lovelyflavor.com/electric-vs-propane-vs-charcoal-smoker/#:~:text=Conventional%20smokers%20require%20that%20the%20flame%20be%20kept,much%20safer.%20They%20are%20easy%20to%20start%20up..

[7] M. Tool, "The Benefits of Finite Element Analysis in Manufacturing," 2020. [Online]. Available: https://www.manortool.com/finite-element-analysis#:~:text=Key%20Benefits%20of%20the%20FEA%20Process%201%20Increased,Virtual%20Prototyping.%20...%205%20Fewer%20Hardware%20Prototypes.%20.

[8] K. Agrawal, "Special-Purpose Motors," 2001. [Online]. Available: https://www.sciencedirect.com/topics/engineering/stall-torque.