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DEPARTMENT OF MECHANICAL AND INDUSTRIAL ENGINEERING

MEC 825 – Mechanical Design
Interim Project Report

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Electric Powered Food Processor

Marvel Engineering Consultants

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1. Introduction

1.1 Project Scope

The objective of this project is to design an electric powered food processor that has the ability to chop fine cuisine into desired shapes and sizes. It will be light-duty with reciprocating blades in order to improve use in both household and industrial settings. To complete this project, a series of requirements must be met to maximize the efficiency of the design. The key design is the 3D mechanisms with single input and multiple coordinated outputs. There are also various properties and components that must be implemented which include adjustable stroke, adjustable angular feed, twin blades, enhanced durability and affordability, quiet and finally a multi-stage PGT to reduce the speed from the motor shaft to desired linear/angular speeds at the output shafts/joints for a compact design and improved efficiency. In order to fulfill these requirements 3D modeling within SolidWorks, material research, and prototype design/testing will be mandatory. Deliverables that will be provided at the end of the project include design sketches, concept charts, material research, engineering drawings, and 3D models.

1.2 Project Requirements

Knowing and determining the pros and cons of each addition to the product, will allow us to quickly and efficiently adapt to making this the best food processor on the market. The mechanical design courses taken throughout the four year program allow us to use the knowledge on Solidworks or other design softwares, will allow us to design a food processor that will work, be efficient, and meet all the requirements from the guidelines. As a team we will look at these different products on the market to find different alternatives to make the product better, more lightweight, and most importantly, more efficient. Not every idea, or design will be successful, there are many things to take into account when designing a part, product, or even doing a brief sketch. Some things

we are looking for when designing is, does our product complete the task? Is it user friendly? But most importantly, does it fulfill the requirements provided in the description. With these requirements in place, it gives us some guidance on what we should focus on. We will centralize our focus on the best chosen material and size of the pieces within the mechanism. We believe that, for making this processor work efficiently, the size and shape of the pieces, along with the orientation of them will be the deal breaker on if the mechanism will succeed or fail.

1.3 Design Vision

We decided to go for a more simplistic approach when designing our food processor. To compete in a growing market of new appliances and technology, our goal is to be user-friendly enough so we can grasp the 95 percentile of people that can use and operate the product. While diving into our research on previous designs and products already surfacing the market, we came across many sizes, models, and shapes of food processors. There are many products on the market that range from 200-300 dollars, which for some people, is on the higher end of what they would like to spend. There are also products that are on the cheaper end that can't do a lot of the big work and chopping like the larger, expensive ones can. Our goal is to meet the market in the middle to be able to accommodate as many people and consumers as possible and have a product design that is able to perform the same tasks as the very expensive products can do.

1.4 Design Intent

Our first major step is determining the size of each and every part that will be going into the system. Having the general size of each part will allow us to visualize what we are working with and how we can either improve or scrap the design. To be competitive in the market, researching old models and looking for feedback on those products, will help us learn and identify the strengths and weaknesses of what is already out there. This can stem from looking into the motor speed, how fast will our blades go and go slow can they go but still work, also looking at how we can keep the motor cool and resist it from overheating. There are many factors that we will look at beyond just the

physical aspect of looking at the product first hand. We believe the game changing design is what happens internally within the product, not just how it looks or how big it is.

2. Literature Review and Background Research

2.1 Existing details of products on the market

Currently on the market there exists several designs of an electrical food processor. These machines all currently have the ability to finely chop food into designated sizes. To name a few, these machines include the Ninja Professional 9-cup food processor, the Cuisinart Elemental 13 cup food processor, and the Breville Sous Chef food processor. These 3 food processors are named to be some of the top food processors currently available on the market with their prices ranging from upwards of around 400$ to around 150$. Surprisingly even with the vastly varying prices range, the Ninja Professional food processor comes in on the lower end of the range at about 150$ and is ranked as one the best food processors currently available on the market. This detail indicates that it is possible to design a highly functional food processor while also keeping the market price relatively low in order to still attract the majority of consumers in the market currently seeking a food processor [1].

2.2 Pros and cons of some food processors on the market

These current designs on the market come with many positive reasons as to why consumers should buy the products. For one looking specifically at the Ninja Professional food processor it is evident that the current market contains highly functionable products while maintaining a relatively low cost. Thus the design the team comes up with must stay within this lower end price of the market in order to successfully compete with what is on the current market or else the final product will be easily beat out by competition. The Ninja Professional food processor also includes varying programs that allow for chopping, pureeing, doughing, and discing. This allows for users to select the appropriate way, shape and size in which they would like the food to be processed. Although this is not a feature present in every design on the market. Some designs like the Cuisinart

Elemental food processor have varying cup sizes allowing for much easier cleaning for someone making smaller dishes. This allows for the user to be efficient in the use of their time. A design such as the Breville Sous Chef implements a highly powerful processor in which such a design allows for no trouble in cutting/chopping very dense foods. A feature such as this may be preferred for users in need of high power as they consistently cut.chop highly dense foods. Currently on the market there also exists cordless food processors such as the KitchenAid Cordless Food Chopper. A design such as this would be highly beneficial for users that may need to chop/cut food for events while outside, for example a picnic. It also comes in handy for users that may not have enough room for more cords within their kitchen and it also allows the user to move around freely in the kitchen [1]. Although many of these designs have their upsides, they do come with several downsides. For example the Ninja Professional food processor has only one food bowl. This means if the user is only looking to make a relatively small dish they still have to use the one large bowl available. This makes cleaning for the user a huge hassle as it would have been much quicker had there been a smaller bowl available to them. Another current design on the market, the Cuisine Elemental food processor comes with blades that aren't multi-layered. This means that it will take significantly longer for the food to be properly chopped up and thus multi-layered blades would be highly preferred. In a market where consumers want to be efficient with their use of time it is important to make the food processor highly efficient in the time it takes to process the food. These 2 processors also lack the option to multiple chute options, which would allow the user to feed varying sized foods into the processor while it's running. Instead the user would have to stop the processor each time and progressively add it in manually if the chute is too small for the desired food. With the Breville Sous Chef, although it supplies very high power cutting highly dense food at efficient rates, an issue arises with it not being gentle on delicate foods. Although a design such as the Kitchenaid Cordless allows for the user to utilize the food processor anywhere, such as being outdoors, it faces the exact opposite issue that the Ninja Professional food processor faces in which its container has a very small capacity. This means the user is very limited on the amount of food they can

process at one given time making for highly inefficient use when a large dish is being made [1].

Figure 1:Ninja Professional Plus Kitchen System with Auto-iQ [2]

Figure 2:Breville BFP660SIL Sous Chef 12 Cup Food Processor [3]

2.3 Thermal properties of existing processors on the market

Thermal properties are prevalent in almost all food processing operations. Throughout the analysis and design of various food processes and food processing equipment involved in heat transport, with respect to heat transfer or energy use, such as extrusion cooking, drying, sterilizing, frying, and so on, knowledge of the thermal characteristics of foods is crucial. The most essential thermal parameters in food

processing, such as specific heat capacity (cp), thermal conductivity (k), and thermal diffusivity of food materials, are mostly determined by the composition, temperature, and density of the food itself. They have a major impact on the rate of heat transfer into the food product's particles. The thermal conductivity of the food is significant when considering heat transmission during food processing [6]. The three main forms heat transfer can take within electric food processors include conduction, convection, and radiation. However conduction is most prevalent due to the significance of direct transmission through contact. This action refers to interparticle and wall to particle contact [7]. From a theoretical standpoint, our design will be supplying a constant temperature (tw) from the motor in the lower vessel of the processor. For this calculation specifically, we assumed heat losses to the environment and radiation effects were negligible. As a result, direct conduction was the main form of heat transfer within our system. When two particles of different temperatures collide and exchange energy through the surface area in contact, particle-to-particle conduction occurs. Heat flux exchanged by particles i and j:

$$Q_{ij} = H_{cij}\left(T_j - T_i\right)$$

Equation 1 [6]

In which Tj and Ti are the temperatures of the respective particles and Hcij is the heat conductance. And conductance between two touching particles of circular contact area is:

$$H_{cij} = 2k_{ij}a_{ij} = 2k_{ij}\sqrt[3]{\frac{3F_{Nij}r_{ij}}{4E_{ij}}}$$

Equation 2 [6]

The conductance is a function of kij (effective particle thermal conductivity), and the contact radius (aij) between particles i and j. The contact radius and normal force (FNij) are related, along with geometric mean of the particle's radii (rij) and the effective Young's modulus (Eij). The sum of the heat fluxes from touching particles, the particle density (ρi), the particle volume (Vi), and the specific heat capacity (Cpi) are heavily

relied on by particle “i”. As displayed in the below equation:

$$\frac{dT_i}{dt} = \sum_{j}^{N_i} \frac{Q_{ij}}{\rho_i V_i C_{pi}}$$

Equation 3 [6]

Our central focus was the agitation rate of the particles in relation to thermal properties corresponding to heat transfer. Specifically rates in the range of 0 to 100 rpm.

2.4 Blade speed and configuration of existing models on the market

Blade speed and blade configuration is one of the most important features within the design of a food processor. When looking at the blades, there are a few points to look at in order for the blade to chop, rotate, and stabilize when moving at any given speed. The configuration and design of the blade works hand in hand with the speed of the motor by allowing the blade to have that power to do the required job. The blade must be able to chop, dice, slice, shred, and blend many different types of foods and liquids successfully. Within our concept designs, we looked at different ways to orient the blade on the rotating shaft, the best position is having two blades about ⅜ from the base of the shaft. What this will do is have the blade closer to the bottom so that food underneath won’t get stuck but the blade will still go low enough to do the task it's given. From previous designs, we took a look into the Kitchenaid 12-cup Ultrawide Mouth [4]. The orientation of the parts are different to the design of our processor. From the design drawings of the different view of this Kitchenaid, the location of their blade is a lot higher on the shaft and does not move up and down. What this lacks is the opportunity to finely complete the chop at the bottom of the cup. This design lacks the ability to chop at the bottom of the cup and loses the ability to the option. Our design will focus on breaking down the food and liquid from the bottom up, allowing for a smoother action by the blade. In figure 3 below, is a visual representation of the blade orientation in a size 12 cup and how high the blade is and all the space below it.

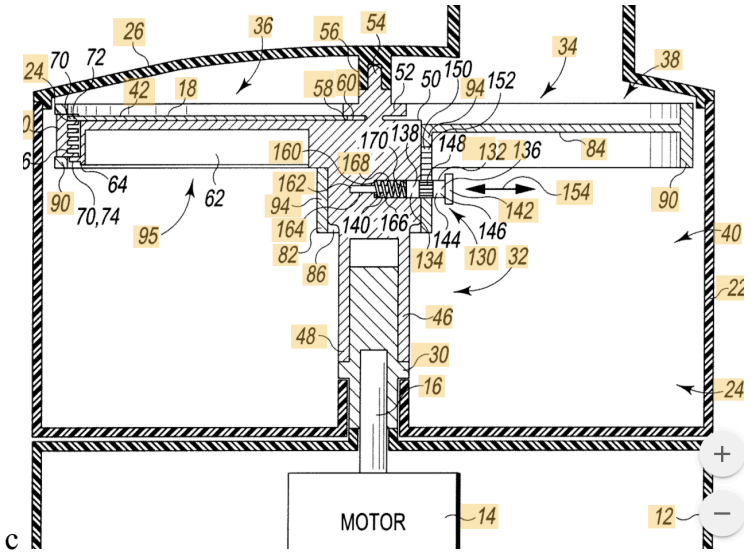

Figure 3: Blade Configuration for Kitchenaid 12-cup Ultrawide [4]

Another point to note is that the blades are on the same plane, our idea is to keep one blade a little higher than the other to allow for uneven size foods. This will allow the blade to perform the action at two different levels so that it offsets the motion. We feel this design of the kitchenaid 12-cup lacks that ability to offset chop. When dealing with food inside the cup, the food will not always be symmetrical, or one distinct size, so having that option to offset the chop, gives that extra advantage for us. In addition, we took a look at an example where we thought there was too much congestion within the cup. In figure 4 below, it includes a product of a 4 blade system [5]. Using this design may have an advantage when having the ability to perform tasks very finely, but also has a negative impact. Within the cup, the goal is to minimize congestion as if moving at a slow speed or trying to chop large foods, the blade has the chance to get caught and stuck, which could lead to further damage within the machine and can possibly fry the motor. Trying to achieve the goal of being user friendly, the more blades and internal pieces, adds issues when trying to take it apart and or tryin to clean the system. Our design will mitigate that and be more user friendly for cleaning, and other uses.

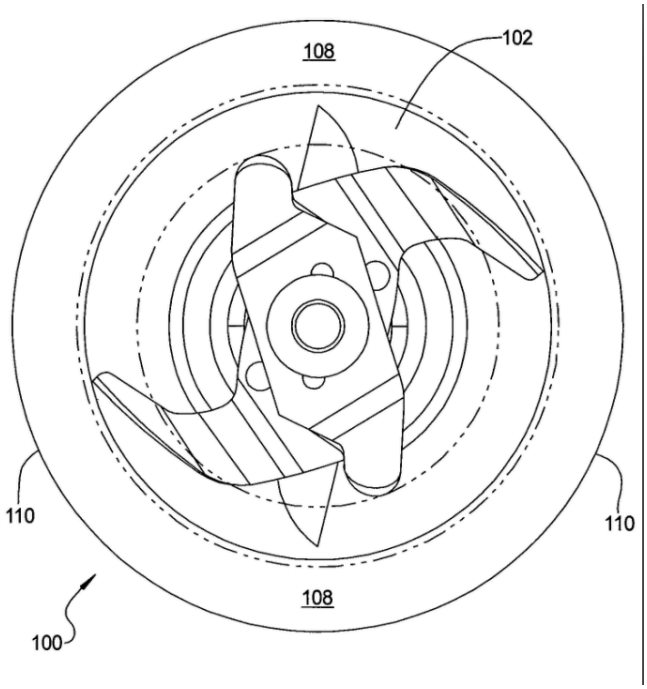

Figure 4: Blade orientation for patent US7641380B2 [5]

2.5 Noise implications on existing models on the market

Food processors usually do create a lot of noise when it is being used to break down foods. There are many different ways to suppress the noise of a food processor such as changing the speed at which it operates, but this compromises the efficiency/power of the food processor to break/process foods. Using a soft material for the base of the blender would help minimize the amount of noise coming from the processor, if we implement a damp rubber isolation system it can limit the amount of noise/suppression coming out from the blender. However there will still be noise coming from the blender as it operates at high speeds to break down vegetables and meat. These pads that are shown below can be sized for home appliances such as our Food processor and these should reduce the amount of vibration/noise coming from the food processor. These damping pads will be also used for giving the food processor stability in holding itself up when the food processor has the motor turned on at high speeds to keep the machine itself from moving [8].

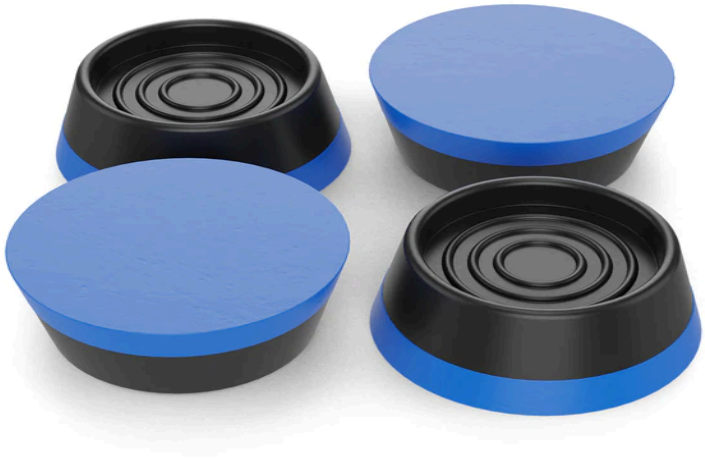

Figure 5: Damping pads for vibration [10]

2.6 Motor configuration and motor speed

AC/DC motors can be used for this processor as both have it's strengths and weaknesses in some areas. AC motors are considered to be more powerful than DC motors as they can generate higher torque which would mean the blades would be able to break down foods a lot faster and with more strength, however DC motors are more efficient and make better use of the energy that is supplied to it. Since this food processor will be processing foods that are a little more tough to break down such as meats (preferably unfrozen meats) a 500-Watts DC motor should be sufficient to process meats, vegetables, fruits and everyday food items that can be obtained at home. The motor will have enough power such that it will be able to process the food and not overheat over periods of time when operating at high speed. Although it is recommended to periodically process foods at short intervals when processing tougher meats. There would be 3 different speeds on the food processor such as high, low and burst. Burst is when it

periodically processes the food at different intervals of time but at high torque. The weight of the motor must also be taken into account as it will ensure that the food processor won't move when the motor is running.[8] A shaft would be connected upwards from the dc motor to connect the blades. The figure below shows a dc motor but the dc motor we will be using will be about 450 W dc motor such that it can process a lot more tougher foods. This motor will obviously be bigger than the one currently shown and it will be placed vertically so that the other components can be connected such as the shaft, the blades inside of the food processor.

Figure 6 : Motor for Food Processor [9]

4. Member Responsibilities

5. Preliminary Design Drawings/Conceptual flowcharts Descriptions

6. Material

7. 3D Solidworks Model and 2D Engineering Drawings Description

8. Conclusions and Recommendations

9. References

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10. Appendix

10.1 Appendix A (Calculations)

10.2 Appendix B (Engineering Drawings)

https://www.engineersedge.com/socket_head.htm