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3D Design & Modeling of Manual Onion Crusher

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ABSTRACT

This research focusing on designing a new onion crusher tool that operates manually relying on the principal of pounding and grinding referring to worldwide used traditional tool which is mortar and pestle. Design is made regarding user friendly concept by simplifying onion crushing work effectively without marginalizing authentic taste quality. This research also covered the operating mechanism, material and modeling respectively by identifying spring which capable to tolerate maximum force of 166 N, suggesting the appropriate material for kitchen tool and produce a 1:2 scale model of the designed tool by Spectrum Z510 3D Printer.

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INTRODUCTION

Product design is very vital to not only the success of any product but to its survival. The design of a product bears directly on its acceptability in the market. Quality product design can only come if designer think and plan well. Product design and development, has a direct relationship to the success of any product or service. It has been proven over the years that consumers patronize products based on the emotional fundamentals.

Onion defined as a swollen edible bulb used as a vegetable, having a pungent taste and smell and composed of several concentric layers. Crushing the onion is one of the popular methods to prepare this ingredient aside from slicing, dicing or blending it. This research highlights to design and build a model of kitchen tool that utilized pounding and grinding principle. The initial tool that applies both of the principles is a mortar and pestle.

The word crusher is a noun derived from the word crush means deform, pulverize, or force inwards by compressing forcefully [Oxford Advanced Learner Dictionary]. Crush synonyms with smash, squash, squeeze, press, pulverize, grind and pound [The Oxford Thesaurus]. For this specific project, onion crusher concludes as tool used to pulverize onion by compressing forcefully by means of grinding and pounding. Many cooks and kitchen culinary experts from around the world using a set of mortar and pestle either made of wood, stone, marble, metal and other materials in their kitchen. This is because they adore a tantalizing taste to the dish most probably because of distinctive flavor and aroma derived from the crushed ingredients as its essential oil released.

Although there is kitchen tool that is able to crush onion automatically or manually on the market, but the creation of tool using manual mechanisms such as mortar and pestle remains rationale. This tool is targeted to specific users who seek an option that produces results similar to earlier crushing tool. The limitation of output produced by this tool is not only limited to onion but also other ingredients that suits to its capability.

2. Methodology:

In order to achieve the objective of this project, details consideration on design aspect including the physical shape of onion crusher, material concerned, ergonomics factors, spring and stress analysis would be included as follows.

Mortar and Pestle:

The most popular tool used for crushing is a set of mortar and pestle. A mortar must be made of a hard material which also having impact-resistant characteristic [G, Deepak, 2011]. As an addition, the heavier the mortar the greater the impact to facilitate faster pulverization of the ingredient during pounding, somehow the drawback is that user have to use more energy. Another crushing method by mortar and pestle is grinding

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process where the centered rotation movement be applied onto the ingredient. Grinding work is easier with the friction between two coarse surfaces so relying on that basis, an unfinished surface always score more. The tool made of various materials, offering a wide variety for personal taste.

Fig. 1: White Marble Mortar and Pestle.

Table 1: Advantages and Disadvantages of Mortar and Pestle.

Advantages	Disadvantages
Easy clean up	Mostly made of heavy metal
Simple operation	Its operation consume lots of energy
	Difficulty to scoop the paste

Table 2: Stainless Steel and Food Processing Industries [http://www.bssa.org.uk Accessed on January 2013].

Types	Typical Applications
420 (martensitic)	Cooks and professional knives, spatulas etc
430 (ferritic)	Table surfaces, equipment cladding, panel (i.e. components requiring little formability or weldability)
304 (austenitic)	Vats, bowls, pipework, machinery parts (i.e. components requiring some formability or weldability). Corrosion resistance superior to 430.
316 (austenitic)	Components used with more corrosive foods (e.g. meat/blood, foods with moderate salt contents), with no stationary solids and not under excessive stress.
1.4539 (austenitic)	Used with corrosive foods (e.g. hot brine with solids that act as crevice forms, stagnant and slow moving salty foods).
1.4462 (duplex)	Used with corrosive foods (e.g. hot brine with solids, stagnant and slow moving salty foods). Higher strength than austenitics.
6%Mo.Types (austenitic)	Used with corrosive foods(e.g. hot brine with solids, which act as crevice formers, stagnant and slow moving salty foods)

Human Factor: Arm Strength Value:

Maximum allowable stress or force human hand (From USA - Adjusted (reduced) values based on tests on (From USA - Adjusted (reduced) values based on tests on young men 80% of (5th percentile group).

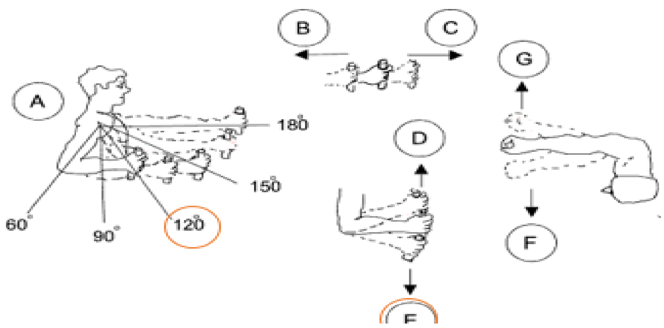

Fig. 2: Working Degree and Direction [http://www.roymech.co.uk. Accessed on March 2013].

The maximum allowable working strength for 120° of A image in downward direction, E for right hand is 92.8 N or 9.46 kilogram-force.

Operating Mechanism: Compression Spring:

Springs can be classified depending on how the load force is applied to them. This project will manipulate the beneficial of compression spring attach to a shaft to produce manual repetitive pounding operation once force is applied and release. Compression spring will store energy once compress and release it as the backward motion proportional to the force. When a spring is compressed or stretched, the force it exerts is proportional to its change in length. The rate or spring constant of a spring is the change in the force it exerts, divided by the change in deflection of the spring. That is, it is the gradient of the force versus deflecting curve. An extension or compression spring has units of force divided by distance like N/m. A test then is run base on highest possible load to lower.

Table 3: Strength for Specific Working Degree and Direction.

A	B		C		D		E		F		G	
	L(N)	R(N)	L(N)	R(N)	L(N)	R(N)	L(N)	R(N)	L(N)	R(N)	L(N)	R(N)
180^0	177,6	184,8	149,6	177,6	32	49,6	46,6	60,8	46,6	71,2	28,8	49,6
150^0	149,6	199,2	106,4	149,6	53,6	64	64	71,2	53,6	71,2	28,8	53,6
120^0	120,8	149,6	92,8	128	60,8	85,6	74,4	92,8	71,2	78,4	36	53,6
90^0	113,6	132	78,4	128	60,8	71,2	74,4	92,8	56,8	64	36	56,8
60^0	92,8	85,6	78,4	120,8	53,6	71,2	60,8	71,2	42,4	60,8	L	R

[http://www.roymech.co.uk. Accessed on March 2013]

Using a spring calculator, a design of open end type compression spring is tested to withstand load up to 107.87 N or 11 kg.

Table 4: Inputs for Testing Spring Design.

Inputs			
Please select your desired unit of measure:		English	Metric
Diameter of spring wire, d:	3.5	IN	MM
Outer diameter of spring, D_{outer}:	38	IN	MM
Free length of spring, L_{free}:	100	IN	MM
Number of active coils, n_a:	11		
Please select a material:	Stainless 316 A316		

Table 5: Spring Loads, Rates and Travel.

Answers	
Loads & Rates	
True Maximum Load, *True* F_{max}:	255.061 N
Maximum Load Considering Solid Height, *Solid Height* F_{max}:	166.632N
Spring constant (or Spring rate), k:	2.873N/mm
Safe Travel	
True Maximum Travel, *True* $Travel_{max}$:	88.780 mm
Maximum Travel Considering Solid Height,	58.000 mm

Table 6: Possible Loads and Spring's Height.

Possible Loads	
0.000 N @ 100.000 Loaded Height	✔
16.663 N @ 94.200 Loaded Height	✔
33.326 N @ 88.400 Loaded Height	✔
49.990 N @ 82.600 Loaded Height	✔
66.653 N @ 76.800 Loaded Height	✔
83.316 N @ 71.000 Loaded Height	✔
99.979 N @ 65.200 Loaded Height	✔
116.643 N @ 59.400 Loaded Height	✔
133.306 N @ 53.600 Loaded Height	✔
149.969 N @ 47.800 Loaded Height	✔
166.632 N @ 42.000 Loaded Height	✔

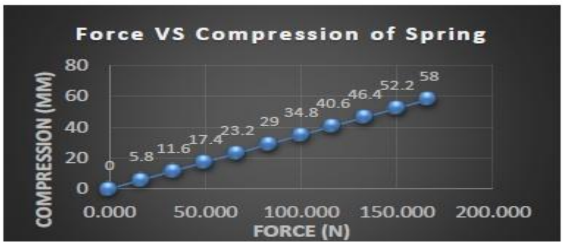

Fig. 3: Force vs Compression.

Once the force goes beyond 255. 061 N, the linear line will drop and the efficiency of the tool cannot be relied on this chart anymore.

RESULT AND DISCUSSION

Analysis: Pro/ENGINEER Mechanical:

Stress and displacement analysis is a primary task for designed parts used in the maintenance of such structures, and to investigate the causes of structural failures. The output data is typically a quantitative description so the design can be improved based on result.

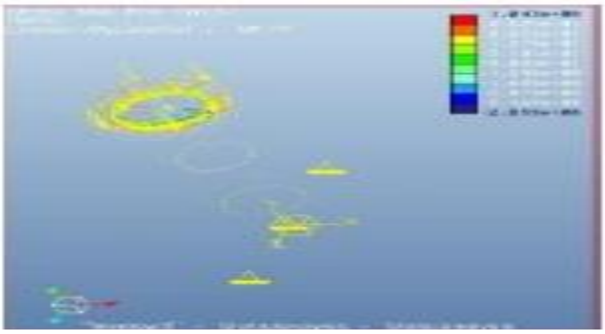

Fig. 4: Result for Stress Maximum.

The figure shows maximum stress point of the tool. The result centered where contact surface of energy starts.

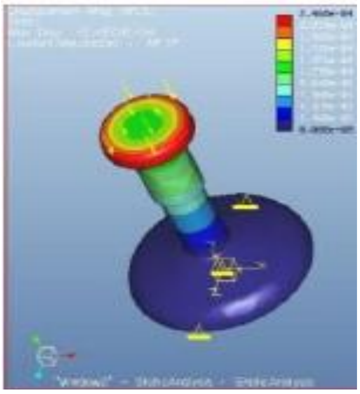

Fig. 5: Result for Displacement Analysis.

Displacement analysis shows how the force being exerted into tool and displacing it from the top to down. The highest contact surfaces are showing vibrant red colour while the least is greyish blue.

Rapid Prototyping:

Rapid Prototyping is a group of techniques used to quickly fabricate a scale model of a physical part or assembly using three-dimensional computer aided design (CAD) data. Construction of the part or assembly is usually done using 3D printing technology. The first techniques for rapid prototyping were used to produce models and prototype parts [http://www.efunda.com. Accessed on December 2012]. Today, they are used for a wide range of applications and are used to manufacture production-quality parts in relatively small numbers if desired without the typical unfavorable short-run economics.

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Fig. 6: Assembled Model.

Design Review Package:

In this section, the initial stages of the documentation required for realization of this project is indicated for reviewing by client. The details of project as a whole package compiling by unit part and cost of raw material shared to facilitate the manufacturing process [K. McGarvey et al., 2009]. The preliminary costing expected price is gained at the end of this stage. This document is for reviewing by manufacturer before further pricing complete with manufacturing cost, labour cost and etcetera.

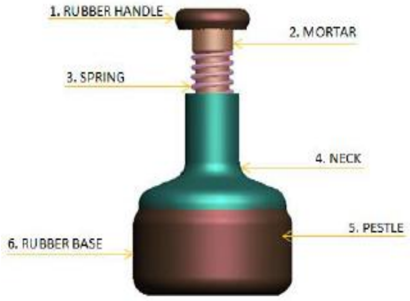

Fig. 7: Part List.

Table 7: Material List.

ITEM	PART NAME	MATERIAL	STATUS	QUANTITY
1	Rubber handle	Chloroprene rubber	Common	1
2	Mortar	Stainless steel 430	Unique	1
3	Spring	Stainless Steel 316	Standard	1
4	Neck	Stainless steel 304	Unique	1
5	Pestle	Stainless steel 304	Unique	1
6	Rubber base	Chloroprene rubber	Common	1

Table 8: Cost of Material.

DESCRIPTION	**PART NAME**	**MORTAR**
ROD	MATERIAL TYPE	SS 430
ø30	FINISHING	SAND BLASTED
ø36	PRICE/KG (RM)	3.7/KG
ø60	MIN ORDER 1 TON	3,700/TON
	PART WEIGHT (KG)	1.2
	UNIT PRICE (RM)	4.44/UNIT
DESCRIPTION	**PART NAME**	**PESTLE**
SHEET	MATERIAL TYPE	SS 304
5MM	PRICE/KG (RM)	1.4/KG
	MIN ORDER 1 TON	1,400/TON
	PART WEIGHT (KG)	0.56
	UNIT PRICE (RM)	0.784/UNIT
DESCRIPTION	**PART NAME**	**NECK**
SHEET	MATERIAL TYPE	SS 304
5MM	PRICE/KG (RM)	1.4/KG
	MIN ORDER 1 TON	1,400/TON
	PART WEIGHT (KG)	0.49
	UNIT PRICE (RM)	0.686/UNIT
DESCRIPTION	**PART NAME**	**PRICE (RM)**
OTHER	RUBBER HANDLE	0.12
	RUBBER BASE	0.30
	SPRING	0.80

Roughly estimate raw material price per unit for 850 units production. The price only covers the raw material part.

Table 9: Total Price.

PART	MORTAR	PESTLE	NECK	RUBBER HANDLE	RUBBER BASE	SPRING
UNIT PRICE (RM)	4.44	7.84	6.86	0.12	0.30	0.80
TOTAL	20.36					

Conclusion:

The use of mortar and pestle as a tool to crush onion synonyms with multi-cultural and cross-border race users. Although there are many other modern equipment declared as the best substitute to mortar and pestle, but it fails to meet the requirements of users who captured by the taste and aroma of crushed ingredients produced by this tool. Many attempts have been made by culinary experts to create a tool like this, but nothing ever goes beyond the use of mortar and pestle which so close to the users.

This project is trying to exploit this rave tool to study the operating process and introduce the upgraded tool with the same quality of output. The invention of onion crusher as per this design aim to benefit to facilitate in food preparation task and at the same time enhancing the quantity as well as saving time without marginalize traditional touches that comforting users.

Design does not end when the model has been produced, despite the completion of designing stage open room for improvement by feedback, in this case by analysis. In searching of an ultimate design that meets customer needs in term of efficiency, quantity, quality and safety, continuous improvements shall be made.

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