DEVELOPMENT AND TESTING OF A SEMI-AUTOMATIC MACHINE FOR MAKING NOODLES

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Abstract:
As part of the research, a shaft for cutting flat noodles of 4 mm and 2 mm for a semi-automatic portable noodle-making machine was developed and tested. The main diameter of these shafts was 14 mm. The theoretical analysis observed the von Mises stress flat noodle-cutting shaft and the effective stress of the noodle-cutting shaft of 4 mm. In a numerical analysis using FEA, the von Mises stress and effective stress of the shaft were observed for cutting 4 mm flat noodles. According to the results, the maximum percentage errors between the theoretical and numerical FEA results were 13.7% and 16.8%, respectively. In the experimental part, the capacity and efficiency of the semi-automatic machine for making noodles were analyzed. The average capacity and efficiency of the 4 mm flat noodle machine was 71 kg/h, while the average capacity and efficiency of the 2 mm flat noodle machine was 73 kg/h. The research results showed that the 2 mm flat noodle machine has a higher capacity than the 4 mm flat noodle machine, but their efficiency is the same at 93%.

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1. INTRODUCTION

Most people like noodles and think they are a nice, nutritious, quick food option. Essentially a compound of flour, grains, salt, and water, noodles are a staple food consumed by people from many countries. Noodles can also be classified as starch noodles, rice noodles, pasta, Chinese-type wheat noodles, Japanese-type wheat noodles, buckwheat noodles (Soba), and Korean-type noodles, depending on the including of raw materials and ingredients [1]. The amount of fat, calories, fiber, protein, and vitamins in noodles is negligible. These days, machines are used to make noodles instead of hands. Noodles are produced using a variety of sizes and cooking techniques [2]. Noodle-making machines come in various forms, although the most common ones are semiautomatic and fully automatic [3]. Small and family-owned enterprises use semiautomatic noodles-making machines. A portable noodles-making device with a compact design can be operated by one person [4]. The motor, pulley, noodles cutting shafts, noodles rollers, roller gears, and noodles cutter gears are essential components of portable noodle-making machines [5].

This machine includes two sets of cutting shafts and rollers. Because the rollers are hollow and set in pairs, they can support a small weight. Two revolving rollers of the same diameter sheet the dough [6]. There are two cutting shafts, a driving shaft and a driven shaft. These two shafts are fastened to a sliding bush with a frame providing support [7]. Spur pinions and gears in this machine are used to attain a particular speed and output capacity.

Nikam et al. [2] proposed the design and production method of a machine for making axial noodles. This machine uses a simple mechanism compared to other machines, cheaper parts, an easy-to-detach device, and a portable design. In the coming period, these authors are planning research on reducing the size, weight and increasing the functionality of the machine.

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Eze [4] designed a household instant noodle-making machine. Two v-belt pulley systems, two pairs of rollers, and four gears were used in his work. The total torque required of the machine, the mass of dough per roll revolution, the maximum bending moment, the maximum stress in shear, and the shaft's standard diameter were described when designing their machine.

Olatunji et al. [6] modified the existing design of a domestic chinchin cutting machine using Pro/Engineer Wildfire 5.0 software. The authors analyzed three different types of cutting shafts, 20 mm, 30 mm, and 60 mm, with 3, 2, and 1 cutting blades, respectively.

Cipto et al. [8] designed the meat-cutting shaft with a capacity of 5 kg. The analysis was performed using the finite element analysis method with Autodesk software. The research concluded that the greater the load, the greater the value of von-Mises stresses and deformations [8]. The deformation analysis of the forward-turning and reverse-turning methods was proposed using Finite element analysis for the slender shaft [9].

Jakubowski and Dounar [10] presented the finite element analysis of a large machined rotor fastened into a heavy, precise lathe. The research mentioned above provided different shafts for noodles, meat, etc. In a noodles-making machine, very high stress is created at the end near the frictionless support of the noodles cutting shaft when the two gears come into drive it. Designing the noodle's cutting shaft is important because it can lead to fatigue and shaft failure. This paper proposed the design and stress analysis for the noodles' cutting shaft to solve this problem using FEA.

As part of this research, an experiment was conducted with shafts for cutting flat noodles of 2 mm and 4 mm. The performance of the proposed design was evaluated in terms of capacity and efficiency for two different shaft types.

2. MATERIAL AND METHOD

2.1 Design of Noodles Cutting Shaft

This entire machine, which is the research subject, was driven by an induction motor with a capacitor of 180 W that has 1330 rpm. The noodles roller has a 50 mm diameter and 147 mm length. The mass of dough was 27.34g per revolution of the roller. This machine used a V belt with a length of 955.7 mm. The masses of the 4 mm and 2 mm flat noodles cutting shafts were 0.5593 kg and 0.56 kg, respectively. The rotational speed of the cutting shafts (n) was 69 rpm. There are transmission, idler, roller, and cutting shaft gears. The specifications of these pinions and gears are shown in Table 1. The gear train of the noodles-making machine is shown in Fig. 1.

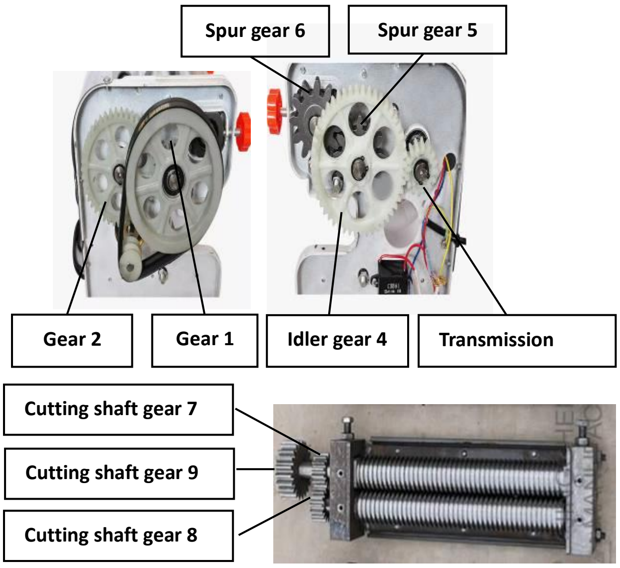


Fig. 1. Cutting shafts and compound gear train of portable noodles-making machine

Table 1. Specifications of spur pinions and gears

Types of gear	Pitch diameter (mm)	Module (mm)	Speed (rpm)
Gear 1	30	3	379
Gear 2	115	3	97
Transmission gear 3	35	3.5	97
Idler gear 4	112	3.5	30
Spur gear 5	50	5	30
Spur gear 6	50	5	30
Cutting shaft gear 7	25	2.5	69
Cutting shaft gear 8	25	2.5	69
Cutting shaft gear 9	49	3.5	69

The noodle's cutting shaft is the main component, which must be designed carefully for the efficient working of the machine [11]. The length of the noodle's cutting shaft is 220 mm, which includes a span length for grooves and cutters of L_{gc} = 154 mm. The widths and spaces of grooves and cutters for the noodles cutting shaft are w_g = w_c = 4 mm.

The number of cutters for the 4 mm flat noodles cutting shaft is:

$$N_a = \frac{L_{gc}}{w_g + w_c} = 19.25 \approx 19 \qquad (1)$$

The number of cutters for 2 mm flat noodles cutting shaft is:

$$N_b = \frac{L_{gc}}{w_g + w_c} = 38.5 \approx 39 \qquad (2)$$

2.1.1. Calculation of Shear Force and Bending Moment

As shown in Fig. 2, the cutting shaft is supported by two plain bearings of the same size and carries two gears.

R_C and R_D were the reactions at bearings *C* and *D*, W_A, W_B and W_C were loads from the gears and the uniformly distributed load.

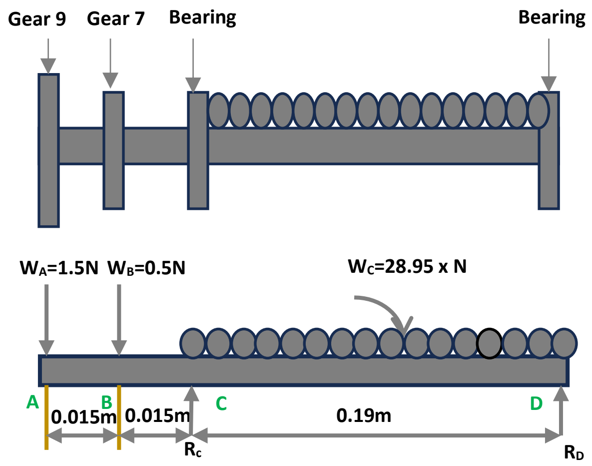


Fig. 2. Loading diagram of noodles cutting shaft

Bending moments about *D* [12] is:

$$\sum M_D = 0$$

$$190R_C - 220W_A - 205W_B - 95W_C = 0 \quad (3)$$

Reaction forces at *C* and *D* respectively [12] are:

$$\sum F_Y = 0$$

$$R_C + R_D - W_A - W_B - W_C = 0 \quad (4)$$

Fig. 3 described the span of point *A* to *B*. The span of point *A* to *C* is shown in Fig. 4.

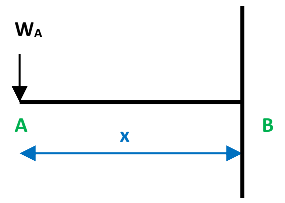


Fig. 3. Span AB (0 < x < 0.015 m)

Shear force at span *AB* is:

$$SF_{AB} = -W_A \quad (5)$$

The bending moment at *A* and *B* is:

$$BM_{A,B} = -W_A x \quad (6)$$

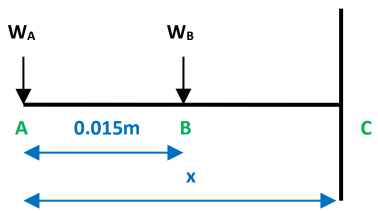


Fig. 4. Span BC (0 < x < 0.015 m)

Shear force at span *AC* is:

$$SF_{AC} = -W_A - W_B \quad (7)$$

The bending moment at *B* and *C* is:

$$BM_{B,C} = -W_A x - W_B(x - 0.015) \quad (8)$$

The span of point *D* to *C* is shown in Fig. 5.

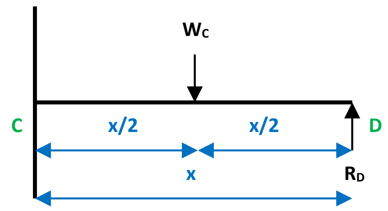


Fig. 5. Span DC (0 < x < 0.19 m)

Shear force at span *DC* is:

$$SF_{DC} = -R_D + 28.95x \quad (9)$$

The bending moment at *D* and *C* is:

$$BM_{D,C} = R_D x - 28.95x(\tfrac{x}{2}) \quad (10)$$

The shear forces and bending moments of the noodles cutting shaft are shown in Table 2 and Fig. 6.

Table 2. Result for shear force and bending moment

Parameter	Symbol	Value
Reactin force at C	R_C	5.026 N
Reactin force at D	R_D	2.474 N
Shear force at span AB	SF_{AB}	-1.5 N
Shear force at span BC	SF_{BC}	-2 N
Shear force at C	SF_C	3.02 N
Shear force at D	SF_D	-2.47 N
Bending moment at A	BM_A	0 Nm
Bending moment at B	BM_B	-0.0225 Nm
Bending moment at C	BM_C	-0.052 Nm
Bending moment at D	BM_D	0 Nm

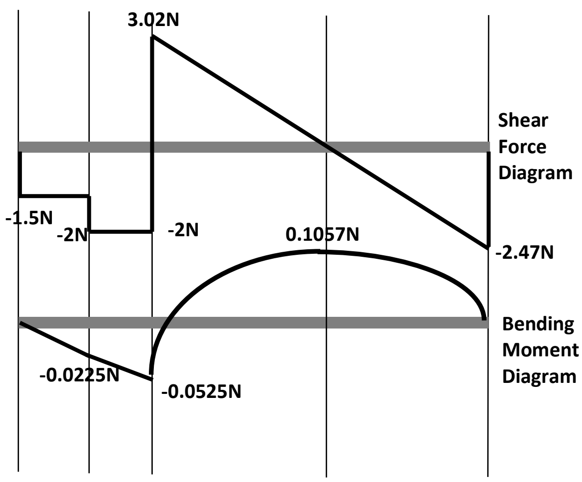


Fig. 6. Shearing force and bending moment diagrams

2.1.2 Calculation of Main Diameter for Cutting Shaft

AISI 1020 carbon steel has been used to design the noodles cutting shaft. This material has high corrosion resistance and good wearing properties [13]. The mechanical properties of this material are shown in Table 3 [14]. The maximum permissible shear stress (S_s) for AISI 1020 carbon steel was described in the following Equations 11 and 12.

The maximum permissible shear stress (S_s) is [14]:

$$S_s = 0.75 \times 0.18 S_{ut} = 56.7\ MPa \qquad (11)$$

or

$$S_s = 0.75 \times 0.3 S_y = 79.2\ Mpa \qquad (12)$$

A smaller value is chosen for further analysis 56.7 MPa [14]

Table 3. Material properties of noodles cutting shaft [14]

Material	AISI 1020 Carbon steel
Density (ρ)	7680 kg/m^3
Yield Strength (S_y)	352 MPa
Tensile Strength (S_{ut})	420 MPa
Young's Modulus (E)	207 GPa
Poisson's ratio (υ)	0.27

Combined shock and fatigue factor applied to bending moment - K_b =1.5 and combined shock and fatigue factor applied to torsional moment - K_t =*1.*

Maximum bending moment - M_b = 0.1057 *Nm and* maximum torsional moment - M_t is:

$$M_t = \frac{P \cdot 60}{2\pi N} = 24.911\ Nm \qquad (13)$$

where are:

P - motor power (W),

N - speed of noodles cutting shaft (rpm).

ASME Code equation for the solid shaft is [15]:

$$d^3 = \frac{16}{\pi S_s}\sqrt{(K_b M_b)^2 + (K_t M_t)^2} \qquad (14)$$

$$d = 13.1\ mm$$

Therefore, the standard shaft diameter is 14 mm for 4 mm and 2 mm flat noodles cutting shafts. The cutter ring diameters are 24 mm and 28 mm, and the groove depths are 3 mm and 5 mm, respectively. The detailed data can be seen in Fig. 7 to Fig. 10. The geometries were created by AutoCAD software.

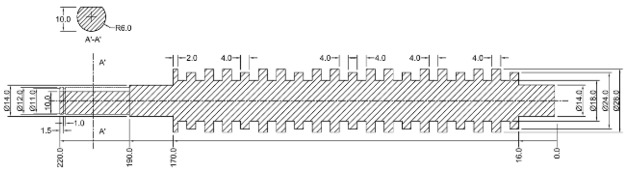


Fig. 7. Sectional view of the 4 mm flat noodles cutting shaft

Fig. 8. Isometric view of the 4 mm flat noodles cutting shaft

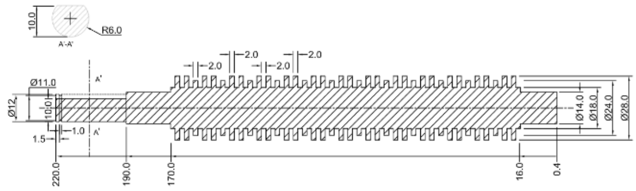


Fig. 9. Sectional view of the 2 mm flat noodles cutting shaft

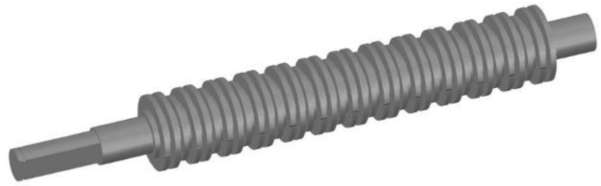


Fig. 10. Isometric view of the 2 mm flat noodles cutting shaft

2.1.3 Calculation of Capacity and Efficiency

The capacity (*C*) and the efficiency (*η*) of the semiautomatic noodles-making machine are calculated as follows:

$$C = \frac{W \cdot 10^{-3} \cdot 3600}{T}, \qquad (15)$$

$$\eta = \frac{w \cdot 100}{W_d}, \qquad (16)$$

where are:

W - weight of noodles after boiling (g),

T - noodles cutting time (sec),

W_d - weight of dough (g),

The weight of dough is calculated as follows:

$$W_d = w + W_b \qquad (17)$$

where are:

w - the weight of noodles before boiling (g),

W_b - the weight of broken noodles (g).

2.2 Analysis of the Structural Behavior of the Noodles-Cutting Shaft.

The first step was to analyze the theoretical and FEM analysis of the noodles cutting shaft. In the theoretical approach, the cutting shaft's effective stress and strain are calculated using von-Mises criteria and the effective strain equation. In the numerical approach, the structural behaviors of the cutting shaft are analyzed using ANSYS software. The second step was the fabrication of the noodles-making machine, and the third step was the performance evaluation of the noodles-making machine.

2.2.1 Theoretical and FEM Analysis of Noodles Cutting Shaft

Finite element analysis is a method of structural analysis that uses mathematical processes. In research [16,17], FEM analysis is used to determine the stress state and strain of the noodles cutting shaft for the material. Static analysis of the structure using FEA aims to verify and check the calculation of analytical stresses [18,19].

2.2.2 Theoretical Approach by Using Principal Stress and Strain

The basic types of stress are torsional shear stress and bending stress. The stresses acting on the noodles cutting shaft can be obtained by using the following equations, and the results are shown in Table 4.

Bending stress (σ_b) of cutting shaft is [15]:

$$\sigma_b = \frac{32M_b}{\pi d^3} \quad (18)$$

Shear stress (τ_{xy}) of cutting shaft is:

$$\tau_{xy} = \frac{16M_t}{\pi d^3} \quad (19)$$

Principal stresses ($\sigma_{1,2}$) are:

$$\sigma_{1,2} = \frac{1}{2}(\sigma_x + \sigma_y) \pm \frac{1}{2}\sqrt{(\sigma_x + \sigma_y)^2 + 4\tau_{xy}{}^2} \quad (20)$$

According to the von-Mises Criteria, von-Mises stress or effective stress ($\bar{\sigma}$) is:

$$\bar{\sigma} = \frac{1}{\sqrt{2}}[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2]^{\frac{1}{2}} \quad (21)$$

where are:

σ_1 - first principal stress (MPa),

σ_2- second principal stress (MPa),

σ_3 - third principal stress (MPa).

The first principal strain (ε_1):

$$\varepsilon_1 = \frac{1}{E}[\sigma_1 - \upsilon(\sigma_2 + \sigma_3)]. \quad (22)$$

The second principal strain (ε_2):

$$\varepsilon_2 = \frac{1}{E}[\sigma_2 - \upsilon(\sigma_1 + \sigma_3)]. \quad (23)$$

The third principal strain (ε_3):

$$\varepsilon_3 = \frac{1}{E}[\sigma_3 - \upsilon(\sigma_1 + \sigma_2)]. \quad (24)$$

Effective strain ($\bar{\varepsilon}$):

$$\bar{\varepsilon} = [\frac{2}{3}(\varepsilon_1^2 + \varepsilon_2^2 + \varepsilon_3^2)]^{\frac{1}{2}}. \quad (25)$$

Table 4. Theoretical result of von-Mises stress and effective strain of noodles cutting shaft

Parameter	Symbol	Value
Bending stress	σ_b	0.392 MPa
Shear stress	τ_{xy}	46.23 MPa
First Principal stress	σ_1	46.43 MPa
Second Principal stress	σ_2	-46.03 MPa
von-Mises stress	$\bar{\sigma}$	80.07 MPa
First principal strain	ε_1	$2.843 \cdot 10^{-4}$
Second principal strain	ε_2	$2.829 \cdot 10^{-4}$
Third principal strain	ε_3	$-5.217 \cdot 10^{-7}$
Effective strain	$\bar{\varepsilon}$	$3.275 \cdot 10^{-4}$

2.2.3. Numerical Approach by Using FEM

In the numerical approach, the structural behaviors of the noodles cutting shaft were analyzed using the FEA method. Static structural analysis as a part of FEA was conducted using ANSYS. It was used to determine the stresses, strains, displacements, and forces in the shaft of structures caused by loads that do not induce significant inertia and damping effects [20].

The following steps were conducted to model and analyze the static behavior of the cutting shaft [21,22]:

- ✓ modelling the noodles cutting shaft;
- ✓ dividing up the geometric model using the network of finite elements;
- ✓ defining the load and boundary conditions;
- ✓ processing and solving the set mathematical model; and
- ✓ presenting the computation results in numerical and graphical form.

The noodles cutting shaft is drawn using SolidWorks software. The geometry is meshing with a maximum of 5 layers. This geometry is divided into a small number of elements or parts in the form of lines connected by nodes throughout the geometry of objects [23]. The number of elements is 4899, and the number of node points is 22956. The mesh is generated in a fine position to obtain a good-quality mesh.

The boundary conditions and loads applied to the noodles cutting shaft during the FEA were described as follows and shown in Fig. 11:

- ✓ the forces of 1.5 N at point *A*,

- ✓ the forces of 0.5 N at point *B*,
- ✓ the frictionless support at points *C* and *D*,
- ✓ the forces of 5.5 N at point *E*,
- ✓ the moment of 24.911 Nm at point *F*.

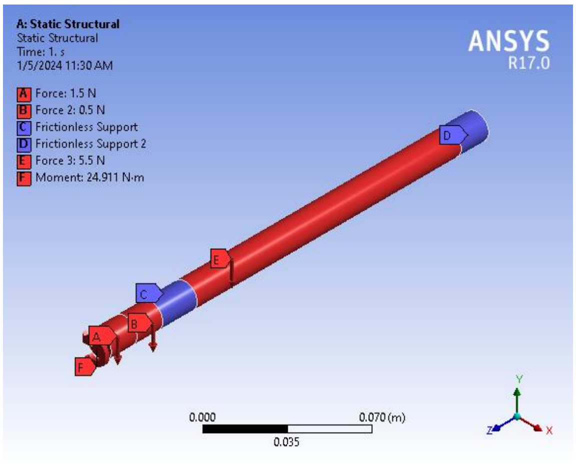


Fig. 11. Boundary condition of cutting shaft

By FEA, the maximum stress values occur at the cross section near bearing support *C*, which is called the critical cross-section. According to Fig. 12, the maximum equivalent (von-Mises) stress on the shaft is 69.069 MPa, and the minimum equivalent (von-Mises) stress is 0.1412 kPa. The von-Mises stress value is much less than the allowable stress, so it can be concluded that there is no risk of indications on the cutting shaft due to static load. According to Fig. 13, the maximum effective strain on the cutting shaft is $3.935{\cdot}10^{-4}$.

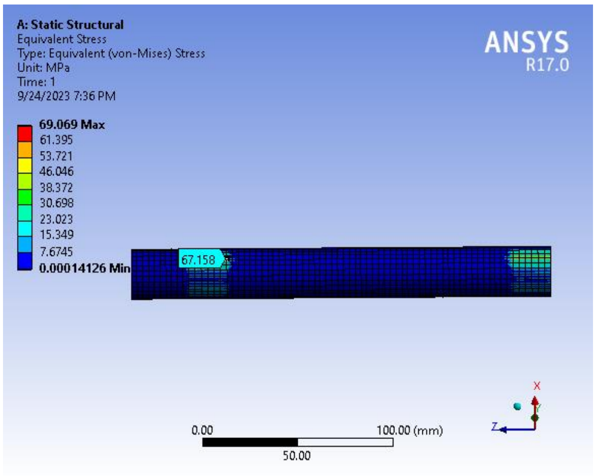


Fig. 12. von-Mises stress of cutting shaft (AISI 1020 carbon steel)

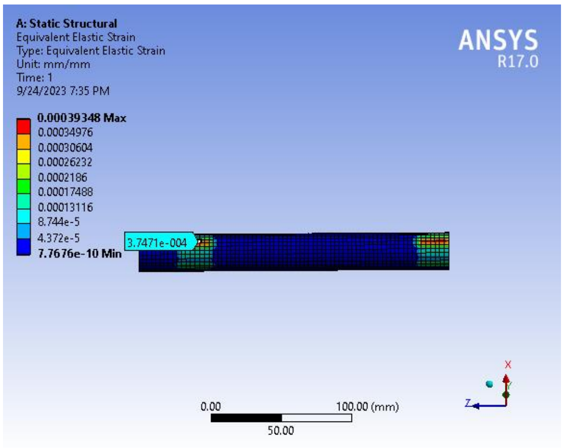
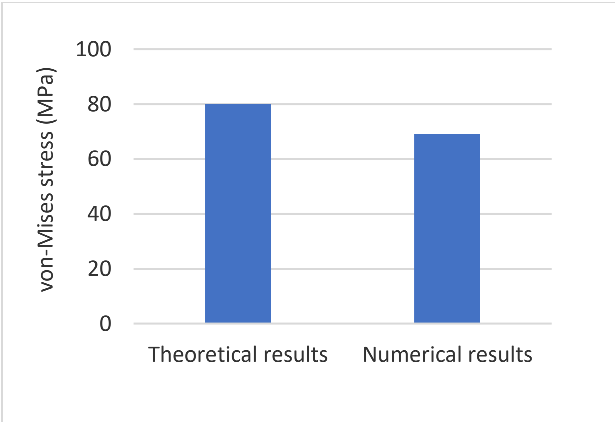


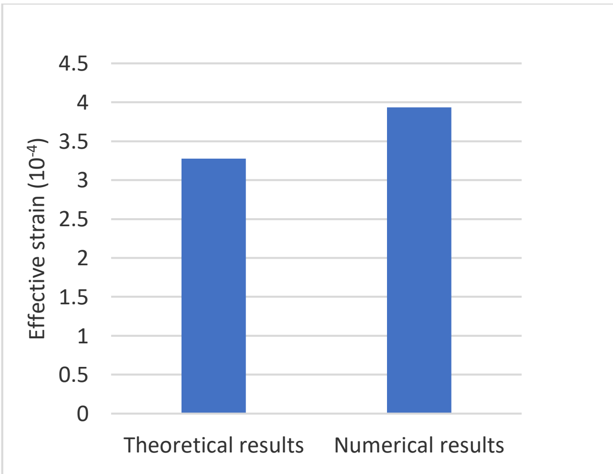
Fig. 13. Effective strain of cutting shaft (AISI 1020 carbon steel)

2.2.4 Comparison of Theoretical and Numerical Approaches

The comparisons of theoretical and numerical approaches are shown in Fig. 14 and Table 5



a)



b)

Fig. 14. a) Comparison of theoretical and numerical von-Mises stress (MPa) and b) Comparison of theoretical and numerical effective strain (10^{-4})

Table 5. Comparison of theoretical and numerical von-Mises stress and strain

Parameters to compare	Theoretical results	Numerical results	Percent Deviation (%)
von-Mises stress (MPa)	80.07	69.069	13.7
Effective strain	3.275×10^{-4}	3.935×10^{-4}	16.8

Figures 14 (a) and 14 (b) compare analytical and numerical von-Mises stress and effective strain. The theoretical and numerical results are nearly the same. The stress obtained from theoretical and numerical values is smaller than the yield stress. Therefore, the AISI 1020 carbon steel is suitable, and the design of the noodles cutting shaft is safe [24].

2.3 Fabrication of Noodles-making Machine

Semiautomatic noodles-making machines are used to reduce human power and improve production. The spur pinion and gears should be strong enough to resist the tooth loads; hence, they have been made of the strong material AISI 1020 carbon steel. The dough rollers and noodles cutting shafts should also be produced with AISI 1020 carbon steel because they are directly in contact with the dough. The cutter ring diameters are 24 mm and 28 mm, and the groove depths are 3 mm and 5 mm in the design of the 4 mm and 2 mm flat noodles cutting shafts. They have 19 and 35 cutters, respectively. The primary diameter of the 4 mm flat and 2 mm flat noodles cutting shafts is 14 mm. The conventional lathe machine is used to produce the noodles' cutting shafts. The components of the noodles-making machine are shown in Fig. 15.

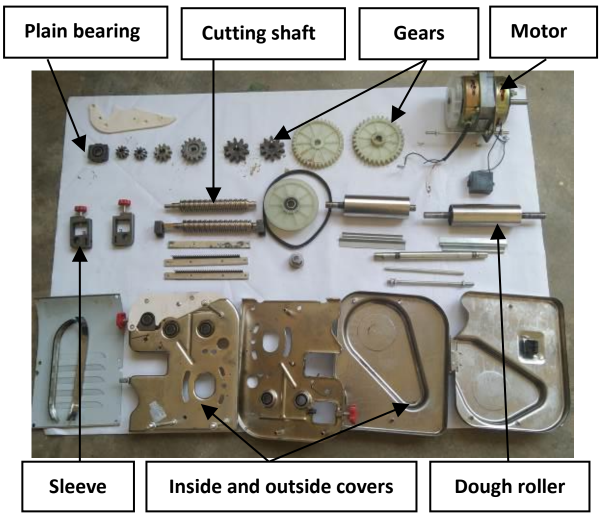


Fig. 15. Components of noodles-making machine

Firstly, the 180 W induction motor with capacitor start was installed, with pulley 1 passing through the frame. A V-belt with a length of 955.7 mm was used to connect pulleys 1 and 2. Then, the spur gears and pinions on the left and right sides were connected to the two dough rollers. The noodles' cutting shafts were also connected with the pinions and gears. Fig. 16 shows the assembly of a semiautomatic noodles-making machine with pulleys, a gear train, rollers, and the cutting shaft. Fig. 17 shows the speed measurement of all pinions and gears.

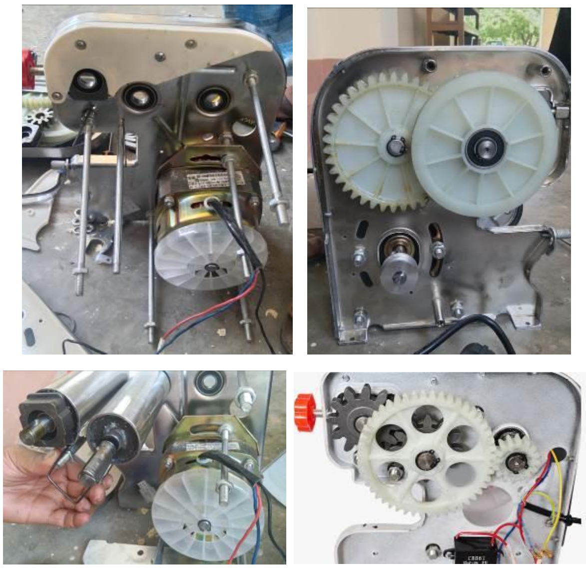


Fig. 16. The assembly of a noodles-making machine

Fig. 17. Measurement of the pinion and gear speeds with a tachometer

2.3.1 Performance Evaluation of Noodles-Making Machine

Generally, the noodle-making process involves many steps: dough mixing, dough compounding, dough sheeting, cutting, and drying [25]. The wheat flour, salt, and water were mixed in a container. Then, it needed to wait about 30 minutes at room temperature, and 500 g of dough was sheeted by the rollers (30 rpm) for about 20 minutes. It was sheeted from 20 mm of dough to 3 mm for 5 minutes. Then, the dough was returned to its initial thickness of 20 mm and sheeted to 2.5 mm for 5 minutes. Finally, the dough was returned to its original thickness of 20 mm and sheeted to 2 mm for 10 minutes. The roll gap can be adjusted by using roller modulators. The final sheeting was into a 2 mm-thick dough, as seen in Fig. 18.

Fig. 18. Dough before and after rolling

The noodles are cut into 4 mm in width when the necessary thickness is reached during sheeting. The cutting device consisted of two noodles cutting shafts with slots or grooves the same width. The cutting shafts are used to determine the strand width of noodles. The cutting shafts are set up in a linear pattern, with the front cutting shaft rotating counter-clockwise and the back cutting shaft rotating clockwise at the same speed (69 rpm). The length of the noodles string is cut to the desired length of 25 cm to 30 cm. After cutting the noodles, the 4 mm flat noodles can be seen in Fig. 19.

Fig. 19. Procedure cutting flat noodles from 4 mm

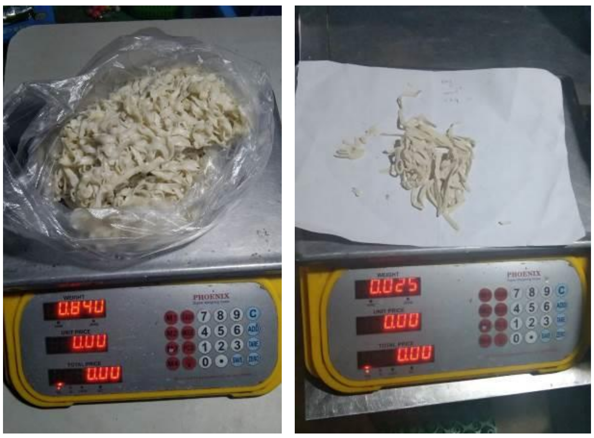
The important factors in the noodle cooking process are the time taken and the amount of water. The amount of boiling water must be greater than the amount of the noodles. If the amount of water is insufficient, more time is needed for the cooking process.

In the experiment, 500 g of dough was added to the noodles five times per day for a total of three days. After the noodles were cut, the weights of the noodles before and after boiling were 475 g and 873 g, respectively, in the process of manufacturing 4 mm flat noodles. It took 48 seconds to chop the noodles. Fig. 20 shows the weights of the dough and noodles before and after boiling. The three days's experimental results for 4 mm flat noodles can be seen in Tables 6-8.

Additionally, 2 mm flat noodles are made once more. The 500 g of dough for 2 mm flat noodles is also manufactured three days in advance, five times a day. The three-day experimental results for 2 mm flat noodles can be seen in Tables 9-11.

The noodles can be dried and kept if boiling is not desired. Moisture must be removed from the noodles, generally for storage purposes. Compared to thicker noodles, thinner noodles will dry out more quickly during the drying process. Higher-thickness noodles may not crack as easily in storage.

a)



b)

Fig. 20. Display of dough and noodles: a) before boiling and b) after boiling

Table 6. Performance of noodles-making machine with 4 mm flat noodles cutting shaft (Day 1)

No	Weight of dough W_d, (g)	Weight of noodles before boiling w, (g)	Weight of noodles after boiling W, (g)	Weight of broken noodle W_b, (g)	Cutting time T, (s)	Capacity C, (kg/hr)	Efficiency η, (%)
1	500	475	840	25	48	63	95
2	500	460	833	40	47	63.8	92
3	500	455	821	45	38	77.8	91
4	500	462	845	38	45	67.6	92
5	500	480	861	20	42	73.8	94
Average Value		466	840	34	44	69	93

Table 7. Performance of noodles-making machine with 4 mm flat noodles cutting shaft (Day 2)

No	Weight of dough W_d, (g)	Weight of noodles before boiling w, (g)	Weight of noodles after boiling W, (g)	Weight of broken noodle W_b, (g)	Cutting time T, (s)	Capacity C, (kg/hr)	Efficiency η, (%)
1	500	450	820	50	39	75.7	90
2	500	467	845	33	48	63.4	93
3	500	471	870	29	50	62.6	94
4	500	458	836	42	42	71.7	92
5	500	461	840	39	46	65.7	92
Average Value		461	842	39	45	67	92

Table 8. Performance of noodles-making machine with 4 mm flat noodles cutting shaft (Day 3)

No	Weight of dough W_d, (g)	Weight of noodles before boiling w, (g)	Weight of noodles after boiling W, (g)	Weight of broken noodle W_b, (g)	Cutting time T, (s)	Capacity C, (kg/hr)	Efficiency η, (%)
1	500	480	880	20	45	70.4	96
2	500	470	863	30	42	74	94
3	500	462	848	38	35	87.2	92
4	500	474	867	26	41	76.1	95
5	500	477	877	23	39	81	95
Average Value		473	867	27	40	78	94

Table 9. Performance of noodles-making machine with 2 mm flat noodles cutting shaft (Day 1)

No	Weight of dough W_d, (g)	Weight of noodles before boiling w, (g)	Weight of noodles after boiling W, (g)	Weight of broken noodle W_b, (g)	Cutting time T, (s)	Capacity C, (kg/hr)	Efficiency η, (%)
1	500	460	857	40	45	68.6	92
2	500	446	871	54	39	80.4	89
3	500	450	884	50	42	75.8	90
4	500	468	879	32	47	67.3	94
5	500	474	881	26	50	63.4	95
Average Value		468	874	32	45	71	92

Table 10. Performance of noodles-making machine with 2 mm flat noodles cutting shaft (Day 2)

No	Weight of dough W_d, (g)	Weight of noodles before boiling w, (g)	Weight of noodles after boiling W, (g)	Weight of broken noodle W_b, (g)	Cutting time T, (s)	Capacity C, (kg/hr)	Efficiency η, (%)
1	500	465	870	35	42	74.6	93
2	500	460	867	40	38	82.1	92
3	500	470	875	30	45	70	94
4	500	475	889	25	46	69.6	95
5	500	468	869	32	41	76.3	94
Average Value		468	874	32	42	75	94

Table 11. Performance of noodles-making machine with 2 mm flat noodles cutting shaft (Day 3)

No	Weight of dough W_d, (g)	Weight of noodles before boiling w, (g)	Weight of noodles after boiling W, (g)	Weight of broken noodle W_b, (g)	Cutting time T, (s)	Capacity C, (kg/hr)	Efficiency η, (%)
1	500	455	860	45	36	83.7	91
2	500	468	873	32	48	65.5	94
3	500	473	868	27	40	78.1	95
4	500	462	872	38	49	64.1	92
5	500	472	885	28	42	75.9	94
Average Value		466	872	34	43	73	93

3. RESULTS AND DISCUSSION

In this study, a semiautomatic noodles-making machine was fabricated to produce the two sets of noodles-cutting shafts. The primary shaft diameter for cutting 4 mm and 2 mm flat noodles was 14 mm. The experimental tests were performed by running the machine for three days, five times daily. Fig. 21 shows the comparison of experimental results for capacities.

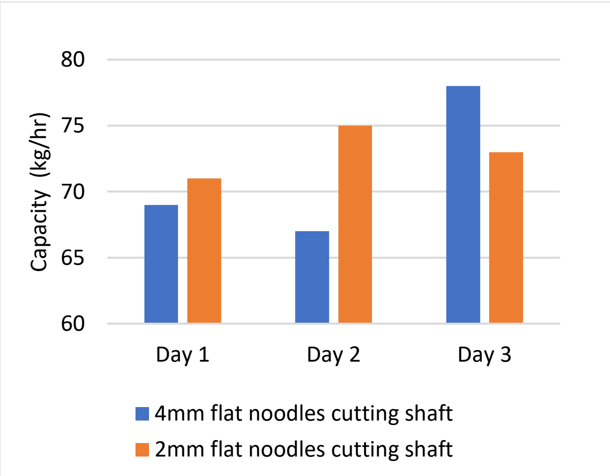


Fig. 21. Comparison capacities (for the first, second, and third days) for 4 mm and 2 mm flat noodles-making machines

The capacities of the 4 mm flat noodles-making machine for the first, second, and third days were 69 kg/hr, 67 kg/hr, and 78 kg/hr. Therefore, the average capacity of the 4 mm flat noodle-making machine was 71 kg/hr. The capacities of the 2 mm flat noodles-making machine for the first, second, and third days were 71 kg/hr, 75 kg/hr, and 73 kg/hr. Therefore, the average capacity of the 2 mm flat noodle-making machine was 73 kg/hr.

According to the experimental results, the efficiencies of the 4 mm flat noodles-making machine for days (for the first, second, and third days) were 93%, 92%, and 94%, respectively. Therefore, the average efficiency of the 4 mm flat noodles-making machine was 93%. The efficiencies of the 2 mm flat noodles-making machine (for the first, second, and third days) were 92%, 94%, and 93%, respectively. Therefore, the average value of the efficiency of the 2 mm flat noodles-making machine was 93%. The result shows that the average efficiency of both machines is the same. Fig. 22 compares experimental results for 4 mm and 2 mm flat noodles-making machines.

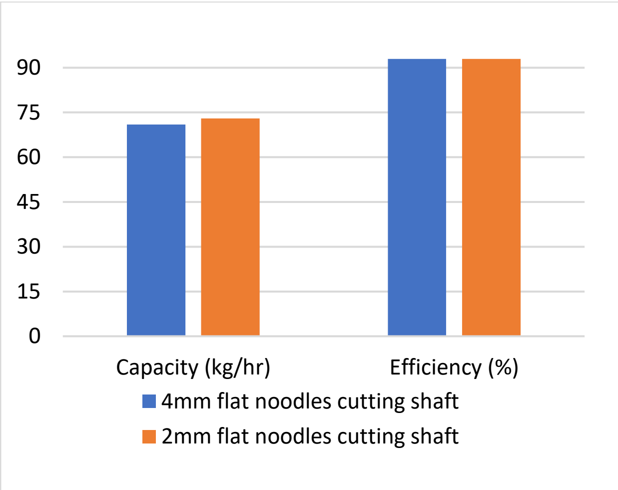


Fig. 22. Comparison of experimental results for 4 mm and 2 mm flat noodles-making machines

4. CONCLUSION

As part of the research, a shaft for cutting flat noodles of 4 mm and 2 mm for a semiautomatic portable noodle-making machine was developed and tested. The main diameter of these shafts was 14 mm. The number of cutters for 4 mm and 2 mm flat noodles cutting shafts were 19 and 39.

In the theoretical analysis, the von Mises stress of the 4 mm and 2 mm flat noodles cutting shafts was 80.07 MPa, and the effective strain of the noodles cutting shafts was $3.275 \cdot 10^{-4}$. In the numerical analysis using FEA, the von Mises stress and effective strain of the 4 mm flat noodles cutting shaft were 69.069 MPa and $3.935 \cdot 10^{-4}$. According to the results, the maximum percentage errors between the theoretical and numerical FEA results are about 13.7% and 16.8%, respectively. The stress values obtained from the theoretical and numerical results are smaller than their yield stress. Consequently, it can be concluded that the noodles cutting shaft's design is safe in working conditions.

In the experiment, the capacity and efficiency of the semiautomatic noodles-making machine are analyzed, for three days, five times per day. The average capacity and efficiency of the 4 mm flat noodles-making machine are 71 kg/hr and 93%, respectively. Moreover, the average capacity and efficiency of the 2 mm flat noodles-making machine are 73 kg/hr and 93%, respectively. It can be concluded that the 2 mm flat noodles-making machine has more capacitance than the 4 mm flat noodles-making machine, but their efficiencies are the same.

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Conflicts of Interest

The authors declare no conflict of interest.

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