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Analysis of The Frame Design of Cracker Sheet Printing and Cutting Machine Using Finite Element Method Simulation

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ABSTRACT

The food industry continues to evolve and faces challenges in enhancing production efficiency. One product that has garnered significant attention is crackers, which have high global demand. Manual processes involved in printing and cutting cracker sheets result in time and labor wastage, leading to production limitations and reducing the industry's competitiveness. Therefore, this research aims to analyze the design framework of a cracker sheet printing and cutting machine using finite element method simulation. The research methodology involves 3D modeling of the machine framework, selection of appropriate materials, and configuration of finite element method simulation to understand the structural behavior of the machine. The research findings identify critical areas requiring design improvements to enhance machine reliability and operational efficiency. By leveraging automatic cutting technology, this research is expected to enhance cracker production efficiency, reduce production costs, and improve the competitiveness of local food industries in the global market. Using cracker sheet printing and cutting machines, cracker production can be significantly enhanced compared to manual processes. These findings make a significant contribution to improving production efficiency and the competitiveness of the food industry.

Keywords: crackers, printing machine, cutting machine, finite element method simulation, production efficiency.

ABSTRAK

Industri makanan terus berkembang dan menghadapi tantangan untuk meningkatkan efisiensi produksi. Salah satu produk yang menjadi fokus adalah kerupuk, yang memiliki permintaan yang tinggi secara global. Proses manual dalam pencetakan dan pemotongan lontongan kerupuk menghasilkan pemborosan waktu dan tenaga kerja manusia, menyebabkan pembatasan dalam tingkat produksi dan mengurangi daya saing industri. Oleh karena itu, penelitian ini bertujuan untuk menganalisis desain rangka mesin pencetak dan pemotong lontongan kerupuk dengan menggunakan simulasi metode elemen hingga. Metode penelitian melibatkan pemodelan 3D rangka mesin, pemilihan material yang tepat, dan pengaturan simulasi metode elemen hingga untuk memahami perilaku struktural mesin. Hasil penelitian mengidentifikasi daerah-daerah kritis yang memerlukan perbaikan desain guna meningkatkan keandalan dan efisiensi operasional mesin. Dengan memanfaatkan teknologi pemotong otomatis, diharapkan penelitian ini dapat meningkatkan efisiensi produksi kerupuk, mengurangi biaya produksi, dan meningkatkan daya saing industri makanan lokal di pasar global. Dengan menggunakan mesin pencetak dan pemotong lontongan kerupuk, produksi kerupuk dapat ditingkatkan secara signifikan dibandingkan dengan proses manual. Temuan ini memberikan kontribusi penting dalam rangka meningkatkan efisiensi produksi dan daya saing industri makanan.

Kata kunci*: kerupuk, mesin pencetak, mesin pemotong, simulasi metode elemen hingga, efisiensi produksi.*

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1. Introduction

The food industry is a continuously growing sector and plays a vital role in the global economy [1-3]. In this context, snack products like crackers have become favorites among consumers both domestically and internationally [4-6]. The high demand for crackers places pressure on the industry to enhance production efficiency to meet the increasing demand [7,8]. One of the main challenges in cracker production processes is the printing and cutting of cracker sheets, which are still predominantly done manually [9,10].

The manual process of printing and cutting cracker sheets results in time and labor wastage [11]. This limitation has the potential to hinder production rates and reduce the competitiveness of the cracker industry in the highly competitive global market [12,13]. Although the food industry has witnessed significant technological advancements, including the use of automatic machines in various production stages, there is still room for the development of specialized machines for the cracker industry [14-16]. In modern engineering industries, the Finite Element Method (FEM) has become a crucial foundation in the analysis and design of complex mechanical structures [17-19]. This method is utilized to model and analyze the structural behavior of a system by dividing the structure into small elements that can be analyzed separately [20-25].

In this context, the aim of this research is to conduct a design analysis of the framework of a cracker sheet printing and cutting machine using finite element method simulation. Through this research, the goal is to develop a printing and cutting machine that is optimized in design, allowing for effective and efficient implementation in the cracker production industry. By leveraging automatic cutting technology, it is expected that this research will make a positive contribution to enhancing cracker production efficiency, reducing production costs, and creating opportunities to improve the competitiveness of local food industries in the global market. In the upcoming upgrade of the equipment we are developing, the primary focus is on the cutting system of the cracker sheet printing machine. When the cracker sheets produced reach a length of 17.6 cm, they will automatically be cut into 4 pieces with a diameter of 4 cm each. This additional feature is designed to expedite the production process and enhance the consistency of cracker size, ultimately expected to improve product efficiency and quality. Thus, the development of this cracker sheet printing and cutting machine has the potential to address several limitations inherent in manual processes and enhance the overall competitiveness of the cracker industry.

2. Methods

The first step in this research is to perform 3D modeling of the machine framework using solid works software. The model must accurately represent the geometry and structure of the machine framework as a whole. The design of the tool and cracker sheet printing machine framework is depicted in figures 2.1 and 2.2.

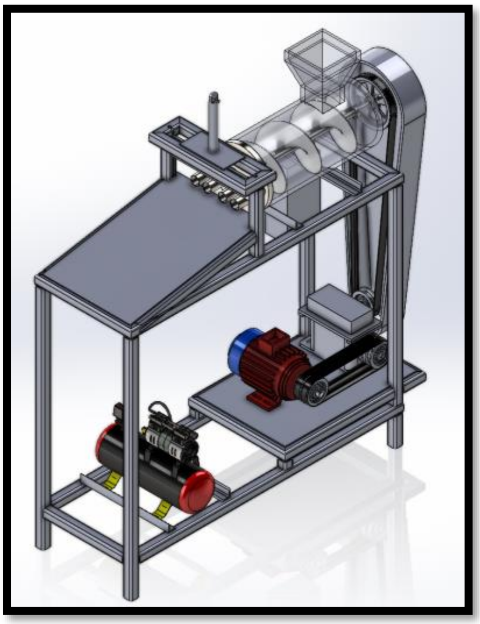

Figure 2.1 Design of the cracker sheet printing machine.

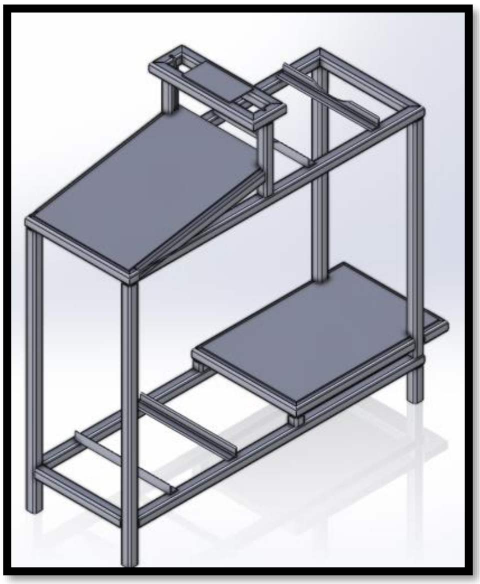

Figure 2.2 Design of the cracker sheet printing machine framework.

Once the modeling is complete, the selection of the appropriate material is based on strength and safety requirements. Material property data such as tensile strength, compressive strength, and modulus of elasticity are obtained from literature sources or relevant material testing.

Table 2.1 Modulus of Elasticity Values for Materials (E)

No.	Material	E (GPa)
1.	Steel and nickel	200 – 202
2.	Wrought iron	190 – 200
3.	Cash iron	100 – 160
4.	Copper	90 – 110
5.	Brass	80 – 90
6.	Alumunium	60 – 80
7.	Timber	10

The tools and materials used to create the cracker sheet printing machine are:

- Computer
- SolidWorks software
- Air compressor
- Pneumatics
- Electric motor
- Hollow steel
- Gearbox
- Lathe machine
- Welding machine
- Grinder machine

The finite element method simulation configuration is performed by inputting the geometric model of the machine framework, relevant boundary conditions, and loading conditions that reflect the operational conditions of the machine. Simulation parameters such as element types and convergence criteria are set according to accepted simulation standards. The simulation results are analyzed using simulation software to examine stress, deformation, and safety factors on the machine framework. Evaluation includes identifying areas with high stress or deformation for further design improvements.

Validation of the simulation method is conducted by comparing the simulation results with available experimental data or previously published studies. This ensures the accuracy and reliability of the simulation results. Ethical and safety considerations are not relevant in this research as it is conducted virtually through computer simulation. In-depth analysis of the simulation data is conducted to understand the structural behavior of the machine framework. Interpretation of the results involves explaining the influence of factors such as stress distribution and deformation on the machine's performance. The limitations of the study include assumptions made in the simulation model and constraints in applying the simulation results to different operational conditions without additional testing.

3. Results and Discussion

The results of the finite element method simulation yield a comprehensive structural analysis of the cracker sheet printing and cutting machine framework. The observed stress distribution and deformation provide valuable insights into the machine's performance under operational loads. Identifying critical areas within the machine framework is a crucial focal point of this research. Findings indicate that several parts of the framework structure experience high stress or deformation, signaling potential risks of structural failure under operational conditions.

The interpretation of the results confirms that high stress and significant deformation can threaten the reliability and safety of the machine. Therefore, design improvement steps in these areas are crucial to enhance the overall performance of the machine. In the stress analysis results of the frame, as shown in Figure 3.1, the highest stress is indicated by the red color, with a value of 8,358 + 10^6 N/m². The yield strength, marked by the red arrow, is at a value of 2,449 x 10^4 N/m².

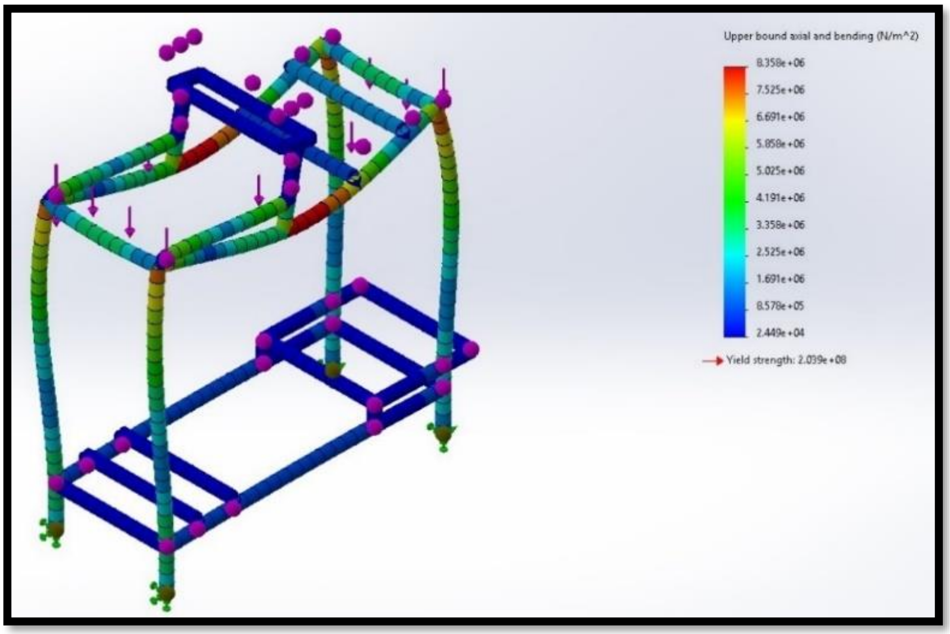

Figure 31. Stress analysis on the frame

In Figure 3.2, the most curved (deformed) part of the cracker sheet printing machine framework is the region highlighted in the deepest red color, measuring 1.59 mm, on the central cross-section beam shown in red.

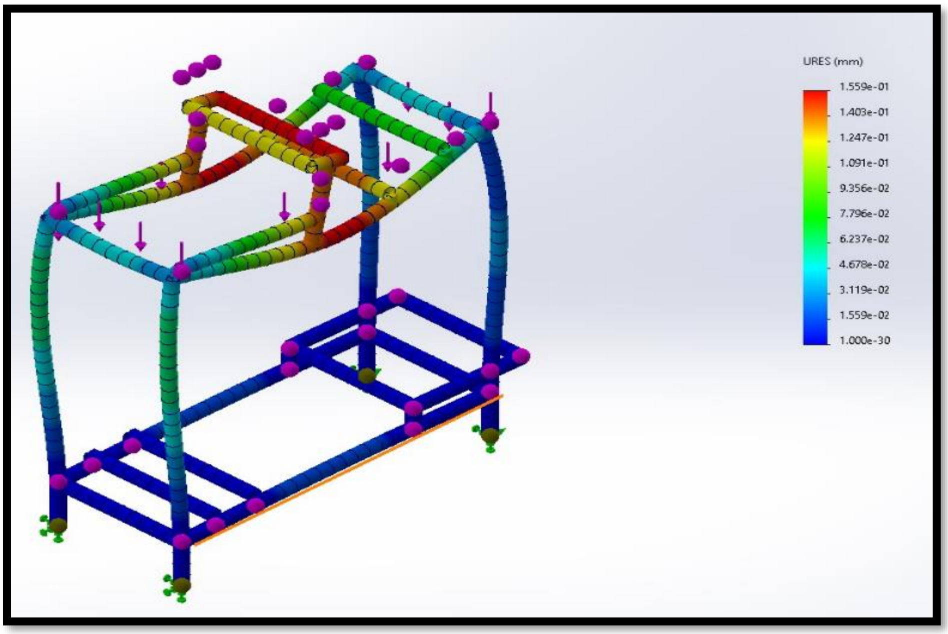

Figure 3.2 Deformation analysis on the frame

The results of the maximum and minimum safety factors are depicted in Figure 3.3, where the highest safety factor is indicated by the value of 8.328e+03, and the lowest safety factor is indicated by the value of 2.440e+01.

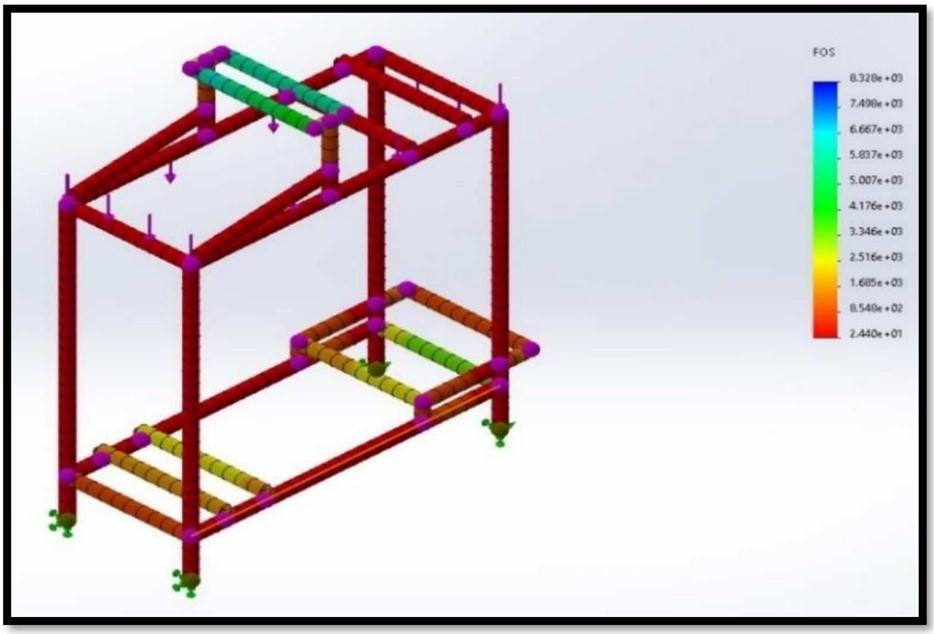

Figure 3.3 Frame safety factor analysis

Directly aligned with the research objective, the analysis results provide a profound understanding of design weaknesses that can be addressed to enhance the efficiency and reliability of the machine. By identifying areas requiring improvement, this research makes a significant contribution to the technological advancement in the food industry. Although there hasn't been specific prior research in this context, the findings of this study can be viewed as a significant step towards a better understanding of structural analysis in industrial machinery. Comparisons with previous studies can provide additional insights into the progress made and the unique contribution of this research.

Meanwhile, the limitations of the study, such as assumptions in the simulation and uncertainties in the results, need to be acknowledged. This indicates that the findings of this research represent an initial step towards a deeper understanding of the design of cracker sheet printing and cutting machines. By presenting comprehensive analysis results and discussions, this research provides valuable insights for the food industry, laying the groundwork for the improvement of more efficient and reliable machine designs in the future.

4. Conclusions

This study yields a comprehensive structural analysis of the cracker sheet printing and cutting machine framework through finite element method simulation. The identification of critical areas and interpretation of the results highlight crucial design improvements that can enhance the reliability of the machine. The stress, deformation, and safety factor analysis of the framework provide a profound understanding of the machine's performance. These findings are significant for the development of food industry technology, although this research represents an initial step that needs to be followed by further validation. Recommendations for further research include further validation through field testing or experimental trials to strengthen the reliability of the results. These steps will broaden the understanding of machine design and enhance cracker production efficiency overall.

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