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Enhancing Wheat Processing Efficiency: Design and Parametric Optimization of a Dehusker Machine for Superior Grain Quality

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Abstract:- Cleaning grain is a critical post-harvest processing step. During harvesting, grains are separated from the plant, but threshing leaves grains mixed with impurities like chaff, leaves, stalks, straws, other seeds, and broken kernels. This study focuses on optimizing a wheat dehusker's performance, a machine designed to remove wheat grain husks. The machine has a hopper for receiving grains, a rotating drum with abrasive surfaces, and outlets for collecting dehusked grains and husks. The Taguchi method was used for Design of Experiments, with process parameters determined through preliminary trials. Factors included rotor speed, output flow, and effective length of the processing drum. Rotor speed was tested at 960, 1152, and 1440 RPM; output flow at 500, 1000, and 1500 kg/hr; and effective drum length at 7, 11, and 15 cm. Experiments used the L9 orthogonal array for systematic parameter exploration. The middle levels—1152 RPM for rotor speed, 1000 kg/hr for output flow, and 11 cm for drum length—yielded optimal performance. The optimized wheat dehusker is compact, energy-efficient, and compatible with domestic electricity, suitable for small-scale industries and Indian farmers. It reduces processing time and labor costs while maintaining high throughput. The dehusked grains can be further cleaned using traditional winnowing or modern grading machines. This study provides an effective solution for wheat grain processing using Taguchi optimization.

Keywords: *Grain, Harvest, Threshing, Chaff, Dehusking machine, Taguchi method, optimization.*

1. Introduction

India is one of the world's largest wheat producers, contributing to global agriculture and national food security (FAO, 2021). Wheat is a staple food for millions of Indians, used in chapatis, bread, parathas, and pasta. It has industrial applications in animal feed, starch products, and biofuels (Kumar et al., 2018). Quality wheat ensures food safety, reduces post-harvest losses, and enhances exports (Singh & Mehta, 2019; Sharma, 2020). In India, wheat is second only to rice as a staple crop. During 2020-2021, India produced approximately 97 million tonnes of wheat (Ministry of Agriculture, 2021). Wheat cultivation covers over 30 million hectares, about 11% of total cropped area, with Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, and Rajasthan as primary producers (ICAR, 2019). This cultivation demonstrates wheat's adaptability to various climates, meeting domestic and international demands (Sharma et al., 2018). India produces bread wheat (Triticum aestivum) and durum wheat (Triticum durum). Bread wheat covers 95% of wheat-cultivated area, used mainly for staple foods (Kumar & Singh, 2020). Durum wheat, covering 4-5% of the area, is used for pasta and semolina production (ICRISAT, 2020). Wheat demand stems from changing dietary habits, urbanization, and population growth, requiring efficient post-harvest management (FAO, 2020). Grain quality and cleanliness affect grade, price, storage life, and processing efficiency (Singh et al., 2017). Wheat cultivation and post-harvest handling involve multiple stages. The process begins with land preparation and planting during rabi season, followed by crop management practices like irrigation, fertilization, and pest control. Wheat is harvested using combine harvesters or manually, followed by threshing to separate grain from chaff and cleaning to remove impurities (Sharma & Gupta, 2018). Despite advanced machinery, post-harvest impurities remain a challenge. Modern combine harvesters have cleaning mechanisms; however, improper drying, uneven threshing, and wheat variety variations can result in residual impurities. Studies show chaff remaining after threshing ranges from less than 1% to over 10% (FAO, 2021). These impurities affect milling efficiency and product quality, highlighting the need for additional cleaning (Kumar et al., 2019). Addressing post-harvest impurity removal is critical for meeting quality wheat demand. By investing in efficient cleaning technologies, India can enhance grain quality and strengthen its position globally. This study emphasizes advanced processing techniques, aligning with agricultural sustainability and economic growth (Sharma et al., 2020). This project was conducted to optimize grain-cleaning system parameters, ensuring highest cleaned grain quality by addressing impurities affecting grain grade and marketability. By optimizing rotor speed, output flow, and cleaning mechanism length, the study aims to minimize impurities while maintaining efficiency. These improvements enhance grain quality, reduce waste, improve storage longevity, and meet rising demands for quality wheat in domestic and international markets (Sharma et al., 2020). Figure 1 shows the wheat grain flow during the grading and cleaning process (Industry) and Figure 2 shows the wheat grain flow chart inside the grading and cleaning equipment.

The current challenge in grain cleaning is the inability to effectively separate grain from chaff. In cleaning systems, oversize and undersize particles are removed initially. The cleaning machine separates chaff containing small wheat grains, while grading ensures size-based segregation.

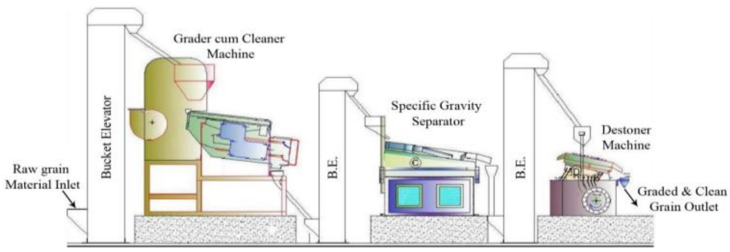

Figure 1. Wheat grain flow during the grading and cleaning process (Industry).

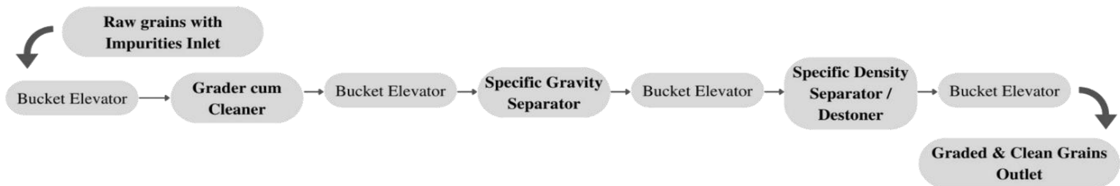

Figure 2. Wheat grain flow chart inside the grading and cleaning equipment

A specific gravity separator and destoner then separate particles by density. However, when significant chaff enters the system with density similar to high-quality wheat grains, the equipment fails to differentiate effectively, leaving residual chaff at the outlet. This issue impacts grain quality and requires a dehusker machine for thorough separation. Chaff in wheat grains causes several problems: It compromises the texture and taste of processed products, reduces shelf life due to natural oils and moisture that promote spoilage, decreases yield efficiency, introduces contamination risks from dirt and microorganisms, and can damage processing machinery. These challenges highlight the importance of removing chaff before processing to enhance product quality, shelf life, and operational efficiency. This project aims to design and analyze the effects of a wheat dehusker machine on grain quality and yield by optimizing process parameters to improve separation efficiency and ensure high-quality wheat products meeting industry standards. This solution not only addresses persistent issues in the current cleaning process but also aligns with the growing demand for efficient and sustainable agricultural practices in wheat processing industries.

The primary goal is to design, analyze and optimize a wheat dehusker machine to improve the efficiency and quality of wheat processing. The objectives are: To analyze current machine performance by evaluating the existing dehusker to identify inefficiencies, particularly in grain-chaff separation, establishing a baseline for improvements. To optimize process parameters like rotor speed, output flow, and effective length for higher separation efficiency between wheat grains and chaff, minimizing residual chaff in processed grain. To enhance wheat quality by developing solutions that minimize contamination and ensure clean grains suitable for milling. To investigate how dehusker optimization affects yield and productivity by assessing improvements in separation process and subsequent milling efficiency. The project aims to enhance operational efficiency and product quality in wheat processing, benefiting both small and large-scale processors while contributing to optimized food production systems in India.

2. Methods and Material

The machine separates husk and impurities from raw grains through multiple components. Raw grain enters through the feeding hopper into the husking region, regulated by a feed control flap. The Electric Motor powers the Roll Shaft for operation. The husking region contains a conical hollow drum with 2 mm perforations and internal nylon rubber belt sections that crush husk and mud balls. The drum's rotation rubs grains against these surfaces for husk removal. A Blower at the outlet creates an upward air current to remove dust and husk. The outlet flow control wheel and flap, connected by a lead screw mechanism, regulate the material exit flow. The dehusker machine operates by crushing grains between two surfaces with spacing. Raw grain enters the hopper and moves to the husking chamber via a feed control flap. Inside, friction between the nylon rubber belt and perforated metal sheet separates the husk from grain. The material then enters an air sifter where lighter particles are removed by upward air stream. The cleaned grains and husk are released through separate chutes. 3.1.2 Various Adjustments available with Machine The dehusker allows adjustments to optimize the dehusking process, with changes in one parameter affecting others.

1. Rotor Speed Higher rotor speed increases friction between rubber belt and perforated drum, improving wheat chaff crushing.
2. Feed Rate A uniform feed rate maintains consistent seed layer inside the conical drum, ensuring even grain processing.
3. Output Flow This parameter controls grain interaction time with rubbing surface, ensuring thorough dehusking and effective grain separation.
4. Effective Gap Between Rolls

The gap between moving rolls and drum surface is crucial, affecting grain pressure and husk removal efficiency. Adjusting this gap allows the machine to process different grains without kernel damage. The dehusker operates through mechanical and airflow actions, with adjustable parameters like rotor speed, feed rate, and roller gap to handle various grains effectively. Figure 3 shows the Dehusker Machine (Left), Hollow Drum (Right Bottom), Roll (Right Top).

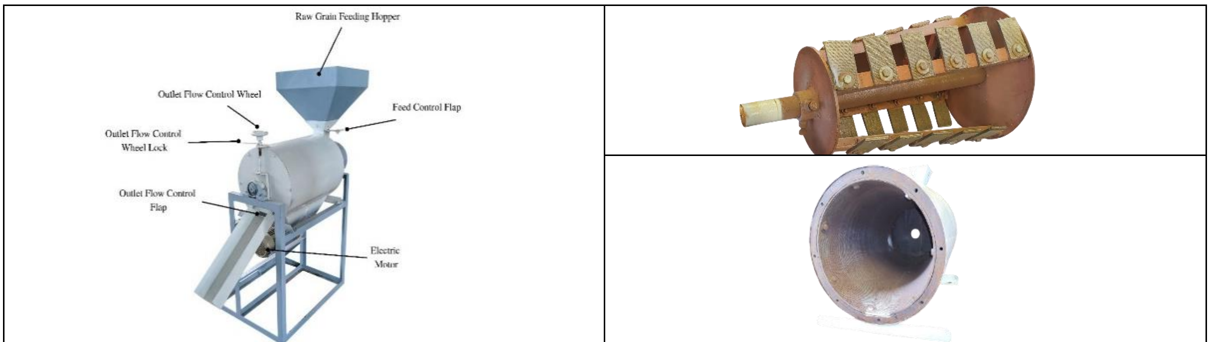

Figure 3. Dehusker Machine (Left), Hollow Drum (Right Bottom), Roll (Right Top)

The experimental setup for the dehusking machine involves a thorough understanding of the machine's key parameters and operation. The dehusker machine, which has an average capacity of 1 ton per hour on a wheat basis, is designed with specific features to facilitate effective dehusking. Below are the key specifications of the machine, as shown in Table 1.

Table 1. Machine Specification

Machine Parameter	Specification
Machine Name	Dehusker Machine
Average Capacity	1 Ton per hour (on wheat basis)
Gross Weight	150 kg

2.1 Methodology

The methodology for the experiment is designed to systematically study the impact of different machine parameters on the dehusking process. The first step in the experimentation process is to identify the key machine parameters that directly influence the quality and efficiency of the dehusking operation. The dehusker machine has several operational factors, but for the purpose of this investigation, the following three parameters as critical to the dehusking process are selected:

1. Rotor Speed: The speed at which the rotor operates can significantly affect the efficiency of husk removal. Higher rotor speeds may lead to faster processing, but they could also result in damaging the grain.
2. Output Flow: The rate at which the grains exit the machine after dehusking influences the interaction time between the grain and the friction surfaces. A proper output flow ensures that each grain undergoes sufficient polishing and husk removal.
3. Effective Length Between Roller and Drum: This distance determines the level of pressure applied to the grain as it passes between the roller and the drum. This factor can influence the effectiveness of the husk removal process.

2.1.1 Taguchi Method

Taguchi has envisaged a method of conducting the DOE, which are based on well-defined guidelines. To study the entire process parameter space with a small number of experiments only, Taguchi's method uses a special design of orthogonal arrays (OA).

Steps involved in Taguchi method:

There are a number of statistical techniques available for engineering and scientific studies. Taguchi has prescribed a standardized way to utilize the DOE technique to enhance the quality of products and processes. In this regard, it is important to understand the philosophy behind the methodology for this, the specified steps involved in Taguchi methods are describe as per the flow chart of Taguchi method as shown in Figure 4.

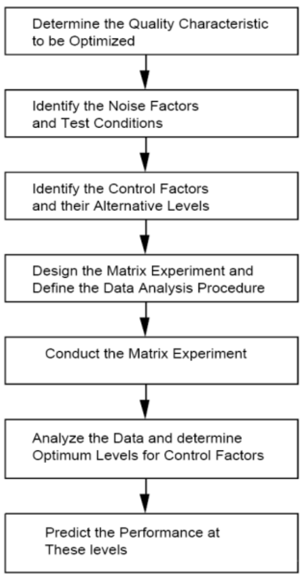

Figure 4. Flow chart of Taguchi method (Dean, 1991)

2.2 Experimentation

During the trial experimentation phase, various parameters of the dehusker machine were carefully observed and recorded. The primary parameters that were observed during the trials included rotor speed, output flow, and the effective gap between the roller and the drum.

In order to explore how changing one parameter while maintaining another's value affects the outcome, samples of each grade are gathered for each setting, and data is logged. Wheat seeds are used in the experiment. The weight of these samples is then determined using a weighing machine using a 39.13 cm^3 volume cup after they have been processed from dehusker. Then a weighing machine measures the weight percent of each grade. Based on the trial experiments the levels of processing paramters are finalised and these are presented in Table 2. By systematically varying these parameters and observing the outcomes, the experiment aims to identify the most effective combination of settings for the dehusker machine using Taguchi analysis.

Table 2. Process Parameters and Levels

Parameter	Lowest	Highest	Level 1	Level 2	Level 3
Rotor Speed (rpm)	950	1800	960	1152	1440
Feed Rate (Kg/hr)	500	1500	500	1000	1500
Effective Length Between Roller & Drum (mm)	7	15	7	11	15

2.2.1 Design of Experimentation using Taguchi analysis

Wheat dehusker machines involve a variety of process variables that significantly impact the quality and quantity of good-grade wheat. During dehusking operations, these parameters are often chosen based on past experiences, but such an approach does not guarantee the optimal set of parameters for specific objectives. To achieve the best results for dehusking characteristics, it is crucial to accurately identify and optimize significant control parameters. The primary objective of this study is to investigate the influence of various operational conditions on the wheat dehusker's performance, using the Taguchi method. To efficiently design the experiments, a mixed-level L_9 (3^4) orthogonal array is selected, which accommodates our three parameters, each with three levels. The experiments were conducted based on the L_9 orthogonal array, where each combination of factors was tested at the specified levels. For each run, the wheat dehusker machine was operated under the conditions outlined, and data were collected on the performance of the machine, focusing on the quality of dehusking and the quantity of good-grade wheat. The results of the experiments were converted into S/N ratios using the higher-the-better criterion. This approach helps identify the optimal combination of process parameters that maximize the yield of good-grade wheat while minimizing the deviation from the desired quality. The Table 3 shows the measured response with the calculated S/n ratio for each experimental rum. This data is then analysed with the Minitab software and the results of optimization are presented in next chapter.

Table 3. DoE with L_9 OA and Measured Responses

Expt. No.	Speed of Rotor (rpm)	Output Flow (Kg/hr)	Effective Length (mm)	Wt% of Good Grade wheat at Outlet Hopper	S/N ratio
1	960	500	7	92.23	39.29
2	960	1000	11	96.66	39.70
3	960	1500	15	80.73	38.14
4	1152	500	11	96.42	39.68
5	1152	1000	15	96.42	39.68
6	1152	1500	7	83.51	38.43
7	1440	500	15	86.3	38.72

8	1440	1000	7	83.51	38.43
9	1440	1500	11	86.3	38.72

3. Result and Discussion

The results of the experiments conducted on the wheat dehusker machine were analyzed using both General Linear Model (GLM) and Taguchi methods to evaluate the impact of three key process parameters i.e rotor speed (rpm), output flow (Kg/hr), and effective length (mm) on the percentage of good-grade wheat at the outlet using Minitab software and the detailed results are summarised as follows;

3.1 Analysis of variance (ANOVA)

The ANOVA results show that all three factors—rotor speed, output flow, and effective length—had a statistically significant effect on the dehusking quality, as indicated by their very low p-values (less than 0.05). The analysis of variance (ANOVA) Table 4 and 5 reveals the following insights:

- Speed of Rotor (A): The rotor speed significantly impacts the dehusking quality, with an F-value of 1568.89 and a p-value of 0.001, suggesting that rotor speed variations lead to substantial changes in the percentage of good-grade wheat.
- Output Flow (B): The output flow also showed a significant effect, with an F-value of 3151.62 and a p-value of 0.000. This indicates that the throughput, or the rate at which wheat is processed, plays a critical role in determining the quality of the dehusking operation.
- Effective Length (C): The gap between the roller and the drum is another influential factor, with an F-value of 1779.17 and a p-value of 0.001. This result suggests that changes in the effective length directly affect the husk removal efficiency and grain quality.

The model summary indicates that the regression model fits the data very well, with an R-squared value of 99.98%, suggesting that nearly all of the variation in the percentage of good-grade wheat is explained by the model. The high R-squared value and low standard error (S = 0.150111) suggest that the experimental setup and parameter selections were appropriate for this analysis.

Table 4. Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Speed of rotor (A) rpm	2	70.705	35.3524	1568.89	0.001
Output flow (B) Kg/hr	2	142.033	71.0164	3151.62	0.000
Effective length (C) mm	2	80.181	40.0906	1779.17	0.001
Error	2	0.045	0.0225		
Total	8	292.964			

Table 5. ANOVA Summary

S	R-sq	R-sq (adj)	R-sq (pred)
0.150111	99.98%	99.94%	99.69%

3.2 Taguchi Analysis

The Taguchi analysis, specifically the response table for signal-to-noise (S/N) ratios, confirms the findings from the GLM analysis. The S/N ratio analysis aims to determine the optimal settings that maximize the dehusking quality. Table 6 shows the response Means and Table 7 shows responses for S/N ratio, Figure 5 and 6 shows the main effects plot for mean and S/n ration, based on this the results show the following trends:

- Output Flow (B): This parameter has the highest delta (difference between the highest and lowest S/N ratios), with a delta of 0.84, indicating it has the most significant impact on the dehusking quality. The optimal output flow for maximum good-grade wheat is at Level 2 (1000 kg/hr).
- Effective Length (C): The effective length also shows a significant impact, with a delta of 0.65, ranking second in importance. The best dehusking quality is achieved with an effective length of 11 mm (Level 2).

- Speed of Rotor (A): Rotor speed, while important, has the smallest delta (0.64), indicating that it has a relatively lower impact compared to the other two factors. The optimal rotor speed for the best quality is at Level 2 (1152 RPM).

The mean response table for the dehusking quality (wt% of good-grade wheat) further supports the above conclusions. The optimal parameter settings for maximizing good-grade wheat are a rotor speed of 1152 RPM, an output flow of 1000 kg/hr, and an effective length of 11 mm. These settings are associated with the highest mean values for good-grade wheat at 92.13%, 92.11%, and 93.25%, respectively.

Table 6. Response Table for Means

Level	Speed of Rotor (A)	Output Flow (B) Kg/hr	Effective Length (C) mm
1	89.80	91.71	86.36
2	92.13	92.11	93.25
3	85.37	83.49	87.69
Delta	6.76	8.62	6.89
Rank	3	1	2

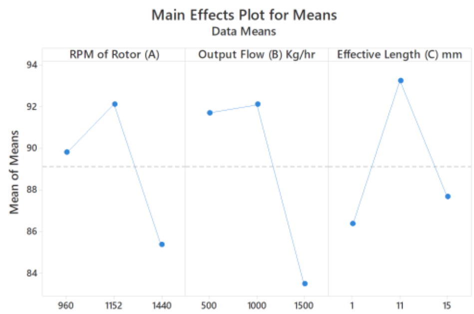

Figure 5. Main effects plot for Mean

Table 7. Response for Signal to Noise Ratios

Level	Speed of Rotor (A)	Output Flow (B) Kg/hr	Effective Length (C) mm
1	39.05	39.23	38.72
2	39.27	39.27	39.37
3	38.63	38.43	38.85
Delta	0.64	0.84	0.65
Rank	3	1	2

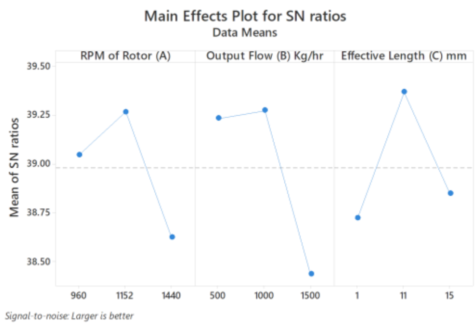

Figure 6. Main effects plot for S/N ratio

The Table 8 summarised the optimized results based on the analysis:

Table 8. Summary of the optimized results

Parameter	Level 1	Level 2	Level 3	Optimized Level
Speed of Rotor (rpm)	960	1152	1440	**1152**

Output Flow (Kg/hr)	500	1000	1500	**1000**
Effective Length (mm)	7	11	15	**11**
Wt% of Good Grade at Outlet (%)	89.80	92.13	85.37	**92.13**

5. Conclusions

From the results, it was evident that rotor speed, output flow, and effective length significantly influence the quality of the dehusked wheat. Specifically, the findings revealed that maintaining a rotor speed of 1152 RPM, an output flow rate of 1000 Kg/hr, and an effective length of 11 mm maximized the percentage of good-grade wheat at the outlet, achieving an optimal value of 92.13%. These settings were shown to strike the best balance between processing time and dehusking quality, thereby reducing waste and improving the throughput of the machine.

The use of the Taguchi method allowed for a structured analysis of the factors affecting dehusking, providing valuable insights into the most influential parameters. The statistical tools, including Analysis of Variance (ANOVA) and signal-to-noise ratio (S/N) analysis, confirmed that output flow (B) had the highest influence on the dehusking quality, followed by effective length (C), and rotor speed (A). The experimental results showed that while the rotor speed and effective length played important roles, the output flow had the most significant impact on the percentage of good-grade wheat, with an optimal setting of 1000 Kg/hr.

In terms of practical implications, this study demonstrates that the wheat dehusker machine, when optimized with these settings, not only improves the quality of dehusked wheat but also contributes to reducing operational costs. The optimized process parameters ensure that the dehusking operation is efficient, consistent, and capable of producing high-quality wheat, which is essential for the production of wheat flour—a staple ingredient in various food products. This approach reduces reliance on manual labor, minimizes waste, and increases the overall productivity of wheat processing operations.

In conclusion, the findings of this study provide a scientifically grounded, efficient, and cost-effective method for optimizing the dehusking process. The application of the Taguchi method and the insights gained from the analysis can serve as a valuable reference for improving wheat dehusking machines and other similar agricultural processing equipment, ensuring higher-quality products and better resource utilization.

References

1) Abdulkadir, S. A., Ibrahim, V., & Joshua, R. M. (2023). Optimization of groundnut decorticating machine parameters using response surface methodology. *Savannah Journal of Science and Engineering Technology*, *1*(4), 223-230.

2) Acherjee B., Kuar S., Mitra S., Misra D. (2012). “Experimental investigation on laser transmission welding of PMMA to ABS via response surface modeling.” International Journal of Optics and Laser Technology 44:1372–1383

3) Ankita, S., Sahoo, P. K., Prajakta, P., Behera, D., & Barik, P. K. (2022). Performance Evaluation of a Mobile Solar Powered Maize Dehusker Cum Sheller. *The Pharma Innovation Journal*, *11*(5), 2040-2048.

4) Antony J. (2001). “Simultaneous optimization of multiple quality characteristics in manufacturing processes using Taguchi’s quality loss function.” International Journal of Advanced Manufacturing Technology 17:134–138

5) Antony J. (2003). “Design of experiments for engineers and scientists.” Elsevier.

6) Asilturk I., Akkus H. (2011). “Determining the effect of cutting parameters on surface roughness in hard turning using the Taguchi method.” Journal of the International Measurement Confederation 44:1697–1704.

7) Aslan E., Camuscu N., Birgoren B. (2007). “Design optimization of cutting parameters when turning hardened AISI 4140 Steel (63 HRC) with Al2O3 + Tin mixed ceramic tool.” International Journal of Materials and Design 28:1618–1622.

8) Balappa, B. U., Dayananda, B. S., Dinesh, P. A., & Suresh, R. (2024). Thresher-Dehusker Farm Machinery: Review of current situation and future needs in Indian context and development of prototype unit. *Agriculture and Natural Resources*, *58*(2).

9) Balasubramanian V., Lakshminarayanan A., Varahamoorthy R., Babu S. (2009). "Application of response surface methodology to prediction of dilution in plasma transferred arc hardfacing of stainless steel on carbon steel." International Journal of Iron and Steel Research 16 (1):44–53.
10) Cavazutti M. (2013). "Optimization methods from theory to design." Springer link.
11) Chandel, R., & Thakur, S. S. (2022). Optimizing field performance of axial flow rotary combine with single rotor and snap roll header for maize harvesting. *Journal of Agricultural Science*, *14*(3), 211.
12) Chilur, R., & SUSHILENDRA, S. (2017). Performance assessment and optimization of maize dehusker cum sheller-A technology for Northern Transition Zone of Karnataka. *The Indian Journal of Agricultural Sciences*, *87*(11), 1535-1542.
13) Datta S., Bandyopadhyay A., Pal P. (2008). "Application of Taguchi philosophy for parametric optimization of bead geometry and HAZ width in submerged arc welding using a mixture of fresh flux and fused flux." International Journal of Advanced Manufacturing Technology 36:689–698.
14) Dean E. (1991). "Overview of Taguchi method." Presented at the 1991 annual conference of the International Society of Parametric Analysts 1–10.
15) Dehghani K., Nekahi A., Mirzaie M.A.M. (2010). "Optimizing the bake hardening behavior of Al 7075 using response surface methodology." International Journal of Materials and Design 31(4):1768–1775.
16) Dingal S., Pradhan T., Sundar JKS, Choudhury A., Roy S. (2008). "The application of Taguchi's method in the experimental investigation of the laser sintering process." International Journal of Advanced Manufacturing Technology 38:904–914.
17) Dubey A., Yadava V. (2008). "Robust parameter design and multi-objective optimization of laser beam cutting for aluminium alloy sheet." International Journal of Advanced Manufacturing Technology 38:268–277.
18) Dubourg L. St-Georges L. (2006). "Optimization of laser cladding process using Taguchi and EM methods for MMC coating production." International Journal of Thermal Spray Technology 15:790–795
19) Durairaj M., Sudharsun D., Swamynathan N. (2013). "Analysis of process parameters in wire EDM with stainless steel using single objective Taguchi method and multi objective grey relational grade." Procedia Engineering 64:868–877
20) FAO. (2021). *Global Wheat Statistics*. Food and Agriculture Organization.