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ROTARY POTATO GRADER OPTIMIZATION. PART II

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Abstract

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Maximum of gradation precision and reasonable damage is conceivable at optimum speed and feed. Response surface statistical model was applied in MINITAB software for machine optimization and achieving suitable quantities. Thus, factorial design based on completely randomized design was done with two factors of speed and feed at three repeats. Speed and feed levels were selected respectively 9, 14, 20 RPM and 0.1094, 0.2188, 0.6565 kg/s. Precision was measured as correct graded mass divided by total mass at a specific grade. Results of statistical data analysis indicated 99% significant difference between factors and their interactions. In addition, optimum speed and feed respectively was obtained at 9 RPM and 0.1094 kg/s. System included precision of 70.45% for Morfana variety and 68.33% for Agria. Damages were under 5% in these conditions. Two series experiments were done at angle of 20° for machine. Mean precision respectively was acquired 69.8% and 65.31% for Morfana and Agria.

Key words: Optimization, gradation precision, rotational speed, feed, response surface statistical model
Abbreviations: P- Precision, m- Mass, f- Feed, s- Speed

Introduction

Natural processes and practical designs have very complexity. Thus, their analysis always have included with approximation and estimation. Agricultural machinery design has abundant practical aspect, because of close relevance with problems of agriculture. Therefore, supplemental and experimental methods always have been adviser for design and optimization and a device for reducing intricacies and difficulties.

A grader machine will have different efficiency by selection of different values for effective variables to its operation. Thus, researchers have applied various methods for optimization and suitable conditions selection.

Garvie (1966) indicated operation conditions for achieving maximum efficiency of particles passage through the perforated screen sake grains cleaning and grading.

Feller (1975) analyzed oscillating motion effect on the particles passage through the perforated screen, until choice and decision possibility prepared for obtaining better conditions and results.

Peleg et al. (1975) researched on the optimal grading of citrus. In addition, he (1985) attempted to reduce grading error with a definition series of quantitative indexes and finally, reported that optimal site of different grades separation lines positioned at intersection of product distribution curves in any grade.

Harrison et al. (1983) measured particle velocity on oscillating screen, using digital computer and then, graphed particle and screen velocity versus independent variables. Finally, he recommended quick return mechanism for oscillating screen with considering limit velocity and optimal gradation.

Shyam (1990) applied oscillating sieves for potato gradation. He tested various combinations of velocity,

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motion amplitude and sieves slope for achieving optimal grading based on mass and selected best conditions.

Khojastapour (1996) designed a system for potato gradation using oscillating screen. He wrote a computational program for selection of suitable conditions and he calculated optimal combination, position and amount of different effective variables on the oscillating screen operation.

Ghanbarian et al. (2010) presented potato grader machine, made with lacy helix. Three parameters of motor speed, feed quantity and tension of net elements controlled the gradation precision in this system. Response surface method was used for optimal selection of parameters, based on mass gradation. Thus, Behnken design and quadratic multiple regression model was applied. Optimal values were estimated after analysis and precision equation versus variables was discovered.

Any of researchers have applied a type of optimization according to conditions, facilities and operation manner until, system works at the best possible state and with maximum efficiency. Herein, various methods have been used such as statistical, computational, analytical, experimental, trial and error and so on. Because in this design, incipient computational and experimental analyses have been done, statistical methods and software help the design completion and optimization.

The research objectives consist of appendix items deliberation:

- Have rotational speed and input feed quantity, significant effect on the gradation precision?
- If response of first question is positive, what measure of rotational speed and input feed present maximum gradation precision (based on mass) and reasonable damages exerted by machine?

Materials and Methods

Experimental design

Two factors of rotational speed and feed were considered. Gradation precision of system was measured. Damages finally were checked.

Relevant design is factorial based on completely randomized design, because effects of two factors of speed and feed are noteworthy and system fixes in all treatments. Any of factors were executed at three levels for this design. Thus, 3^2 treatments appeared that 27 experiments totally were done with three repeats.

Variation of system rotational speed accomplished with increase and decrease of engine rotational speed in the tractor. Speed was measured by non-contact digital tachometer.

Duration of feeding products into the machine increased and reduced for change of input feed. Therefore, variable feed was obtained with constant input mass at different times.

Precision was measured as correct graded mass divided by total mass in the specific grade. For example with three grades of one, two and three Precision of grade 2 equals:

$$P_2 = \frac{\sum_{i=1}^{n} m_{2i}}{\sum_{i=1}^{p} m_{1i} + \sum_{i=1}^{N} m_{2i} + \sum_{i=1}^{q} m_{3i}} \times 100 \quad (1)$$

Grade two (50-80 g) was selected as activity criteria, because potato gradation goal is concentrated on this mass range. In addition, precision was better at the other grades according to measured data, thus grades of one and three enjoy more improvement with optimization of grade two.

Maximum value of 20 RPM was suggested, based on analyses of Part I. Minimum rotational speed that made with tractor was 9 RPM. Of course, selection of less speed is not desirable because of transfer volume reduction. Accordingly, three rotational speed levels of 9, 14 and 20 RPM were chosen for experimental design based on conditions.

Thirty potatoes were opted from any mass range and distinguished with red, blue and black colors.

These potatoes (90 numbers) with the weight of 6565 g were fed to machine at 10, 30 and 60 seconds. Corresponding value of these numbers are 2.4 Ton/h, 788 and 394 kg/h. These feed quantities were applied for design considering maximum feed about 3 t/h (mentioned at part I) and minimum limit approximately 400 kg/s.

Optimization

Data were transmitted to Minitab software after achievement of 27 experiments and calculation of precision. First, design of 3^2 was defined at response surface part. Then, data analyses were done. Probable region was recognized at overlaid contour plot section and finally, desirable variables deals were estimated with aid of response optimizer portion.

Results and Discussion

Data analysis

Analysis of data variance was performed at Minitab software. Table 1 shows this information. As it is clean cut, differences between speed, feed and their interactions is significant at 0.01 confidence level. This point confirmed presented themes at Part I and it was probable.

Optimization

As regards, speed and feed have significant effect on the precision; optimization stages were done. Figures 1 and 2 respectively present 3D graph and contour plot of precision versus rotational speed and input feed.

Precision equation was reported based on speed and feed by Minitab software with determination coefficient of $R^2 = 81.1\%$:

$$P = 121.621 - 4.127s - 229.594f + 0.0996s^2 + 258.572f^2 - 0.0750sf \quad (2)$$

P: precision (percentage)
f: feed, kg/s
s: rotational speed (RPM)

It seemed that it could be searched for optimal reign at low speed and feed. Figure (3) shows zone that precision was between 60-100 %. Therefore, these zones could be scrutinized for activating of software optimizer and maximum precision search.

Figure 4 displays the yield of software attempt for optimization. Maximum precision was 70.45% at speed of 9 RPM and feed of 0.1094 kg/s in these conditions. Desirability was 99% for estimation of optimal amounts at software.

Optimal speed and feed suggested by software were minimum data for experimental design execution. Therefore, more indagation was necessary at lower speed and feed. Nevertheless, more reduction of speed and feed was not advantageous and lessened the operation and efficiency. Thus, this was best situation.

Similar manner was done for Agria variety. Two experiments were executed at optimum condition (9 RPM and 0.1049 kg/s). Precision of 65.9 and 68.2 with mean of 67.05% was obtained. Because, dimensions of Agria variety potato were smaller than Morfana, separation plates were closer. Therefore, precision is reduced than Morfana.

Tow series experiments were done at angle of 20° than horizon on system, one for Morfana and other

Table 1
Analysis of data variance

Source	DF	SS	MS	F	$F_{1\%}$
Speed	2	902.46	451.23	32.22**	6.01
Feed	2	730.13	865.07	61.76**	6.01
Speed*Feed	4	362.04	90.51	6.46**	4.58
Error	18	252.11	14.01		
Total	26	3246.74			

**P < 0.01

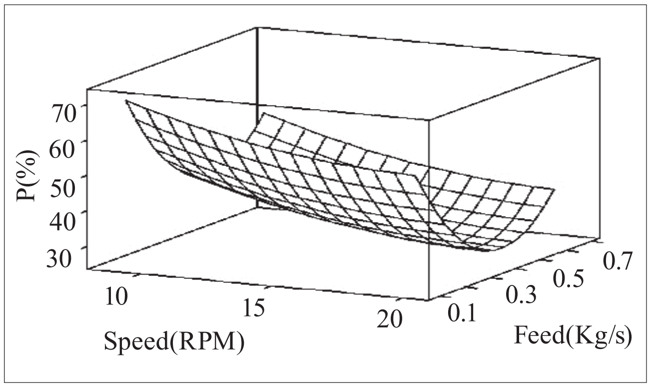

Fig. 1. Precision graph versus speed and feed

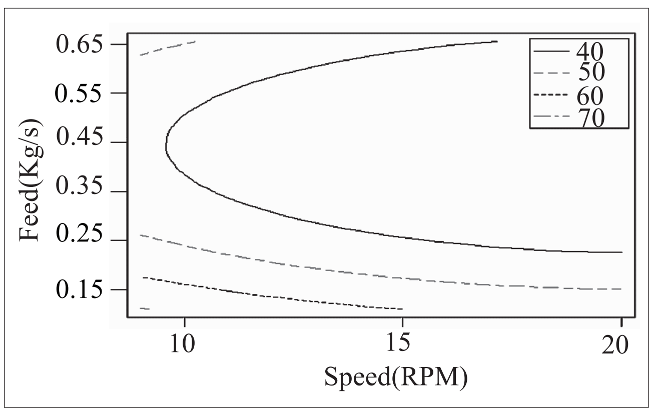

Fig. 2. Precision contour plot versus speed and feed

Agria. Angel of 20° is conventional in potato harvesting machines (Kanafoiski et al., 1976). Two series experiments were accomplished for each group. Results for Morfana have negligible downfall. Obtained amounts are 69.9 and 69.6%. Similar operation was observed for Agria. Measured numbers were 66.27 and 64.35%. It is necessary to mention that separation plates supplanted with system declining until slope effect was exerted on the separators distance. According to measurements, external damages do not exceed 5% at optimal speed and feed for total states.

Mentioned subjects for system inclined state were a start point and it corroborated the machine power for working in this condition. Hence, distinct research should accomplish for new conditions with a suitable potato harvesting blade and finalization of design in slope state.

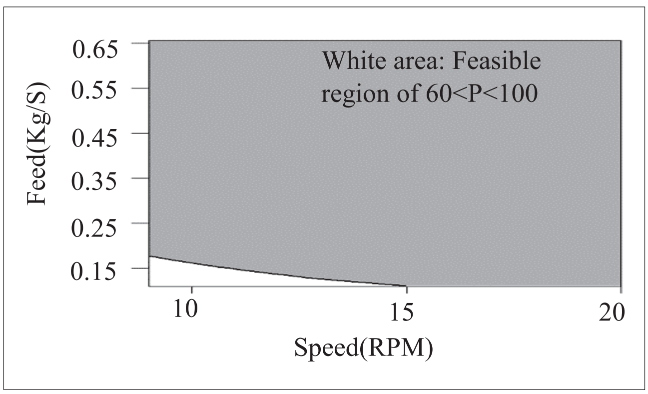

Fig. 3. White area shows precision between 60-100%

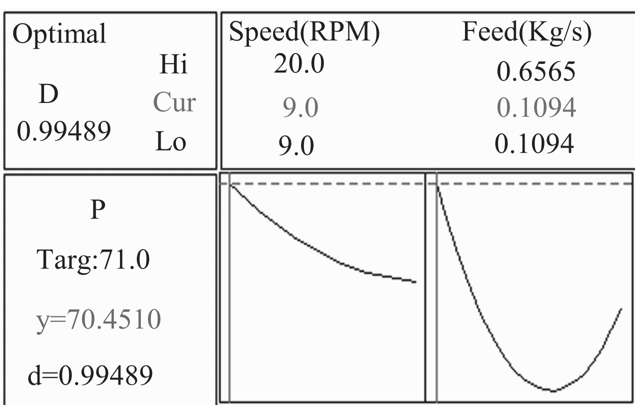

Fig. 4. Optimal speed and feed presented by software for achieving maximum precision.

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Conclusion

- Rotational speed and input feed have significant effect on the gradation precision.
- Optimal speed of 9 RPM and input feed of 0.1094 Kg/s begot maximum precision of 70.45 and 67.05% respectively for Morfana and Agria variety.
- Machine made mean precision of 69.7 and 65.3% respectively for Morfana and Agria variety at angel of 20° than horizon.
- Damages do not exceed 5% at total states.

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