Modeling the optimal factors affecting combine harvester header losses

Samira Zareei[1*] , Shamsollah Abdollahpour[2]

(1. Department of Biosystems engineering, University of Kurdistan, Sanandaj, Iran;
2. Department of Agricultural machinery engineering, University of Tabriz, Tabriz, Iran)

Abstract: Combine header loss comprises more than 50% of wheat harvesting losses. Therefore, decline in this part of the loss to the extent allowed amount is an important step in reducing of crop wastes. Combine header is a complex system in which several factors are involved in its work. And, if these factors can be adjusted and controlled to suit the working conditions, to a large extent of crop loss can be prevented during the harvest. In this study, reel index, cutting height of crop and horizontal and vertical distance of reel from cutter bar were selected as the effective factors in header loss. In response surface method, central composite design was used to modeling and finding optimal levels of mentioned factors. The results showed that power model was the best model to describe the dependence of the independent variables and the dependent variable. The optimum conditions for minimum combine header loss (103 kg/ha) were obtained 1.2, 25 and 5 for reel index, cutting height of crop and horizontal and vertical distances of reel from cutter bar, respectively.

Keywords: cutting height, grain loss, header parameters, reel index, wheat

Citation: Zareei, S., and S. Abdollahpour. 2016. Modeling the optimal factors affecting combine harvester header losses. Agricultural Engineering International: CIGR Journal, 18 (2):60-65.

1 Introduction

Wheat, as the most important crop plant, plays a major role in preparing food for people in Iran, but its production has many wastes. The major portion of the wastes of wheat during harvesting that drop in harvest by combine harvesters in Iran is two to three times of the allowed amount. In recent years, considerable researches have been carried out to determine the ratio of loss in crops during harvesting. In this regard, the loss in wheat harvesting by combine in different regions was determined by farm experiments. The results of the investigations introduced the header loss as the highest loss among different parts of combine (Behroozi-lar et al., 1995; Behroozi-lar, 2000). Therefore, decline in this part of the loss to the extent allowed amount is an important step in reducing of product wastes. An important factor in increasing the yield of labor of grain combines and consequently reducing the crop loss is correct adjusting.

Numbers of researchers have been modeling combines header losses in different crop harvesting through linear statistical models as function of the parameters such as the moisture content of grain, reel index, cutter bar speed, cutter bar service life, distance between reel fingers, distance of reel fingers from the cutter bar, radius of reel, reel rotational speed per forward speed of combine harvester (reel index), non-dimensional ratio of the crop height to the height of reel axis at the top of the ground, stem height and other characteristics of the crops (Oduori et al., 2008; Junsiri and Chinsuwan, 2009). Several other studies have focused on the use of intelligent control systems and according to the complexity of modeling the processes of harvesting have used artificial neural networks, fuzzy logic and genetic algorithms to control the factors contributing to the loss of combine and forecast the grain loss (Benson et al.,

Received date: 2016-02-16 **Accepted date:** 2016-03-28
***Corresponding author: Samira Zareei,** Department of Biosystems Engineering, University of Kurdistan, Pasdaran street, Sanandaj, Iran, Postal code : 66177-15177. E-mail: s.zareei@uok.ac.ir

2000; Ma, 2003; Jalaei and Javidi, 2004; Craessaerts et al., 2010; Omid et al., 2010; Zareei et al., 2012).

Response surface method is a collection of mathematical and statistical methods useful for the modeling and analyzing a process and ultimately aims to optimize the process (Myres and Montgomery, 1995). One of the advantages of response surface method is reducing the number of tests. In cases where the number of process variables is high, most information can be obtained from the response with minimum number of experiments using response surface method. Pishgar-Komle et al. (2012) used the response surface methodology to optimize corn grain harvest losses with corn picker-stripper device and investigated the effect of ground speed and forwarding speed on the loss of corn grain. The results of the work showed that the optimal forwarding speed and ground speed to achieve the minimum amount of grain loss were 600 r/min and 3 km/h, respectively.

The main purpose of present study was to investigate the effects of various parameters such as reel index, cutting height of crop and horizontal and vertical distance of reel from cutter bar on the ratio of combine harvester header loss and represent the optimization model using response surface method.

2 Materials and methods

Farm experiments were conducted in the harvest season in 2011. Crops cultivated in the farm were irrigated wheat with the yield of about 6 t/ha. Combine used for the test was manufactured by CLAAS LEXION 510 which was provided by Mechanization Development Center of Agriculture Organization of Fars Province, Iran. In this study farm tests were conducted to measure combines header loss. Combine header losses of grains are seeds coming out with straw and chaff from the bottom of header or as complete clusters or clusters along with the stem from the front of header. To carry out these experiments, first effective factors on header loss and their appropriate levels were found and then loss values were measured in different conditions arising from the change of factors levels. Among the factors influencing the combine harvester header losses, four parameters were selected including reel index, cutting height of crop, horizontal distance of reel from cutter bar and vertical distance of reel from cutter bar, each of them in three levels (Table 1). After entering to the farm, combine harvested at a specific rate about 30 m to reach steady state. Then, wooden frames (50×50 cm^2) were placed at some points from harvested parts which only the header passes from over it and materials got out from the back of combines are not poured into it, to measure of combine header loss and grains and clusters in the frames were collected and weighed.

Table 1 Combine header operating parameters and their corresponding range

Parameter	Range
Reel index	1.0-1.5
Cutting height, cm	25-35
Horizontal distance, cm	0-10
Vertical distance, cm	5-15

Response surface methodology and software Design Expert 8.0.6 (Design Expert 2011) were used to obtain a response surface based on central composite design.

The purpose of response surface method is to find the appropriate amounts of each of these factors to achieve the least amount of combine header loss.

After selecting the appropriate design, the significance of each variable was statistically analysis, model equation was identified and coefficients were predicted.

After the equation coefficients were obtained, response is predicted by solving the equation. Then the model is consistent with experimental data. Capability of general prediction of model is expressed by coefficient of determination (R^2).

3 Results and discussion

The results of the data analysis have been presented in Table 2. By viewing this table we can see that among linear effects, variables had significant effects on the combine header loss, except horizontal distance of reel from cutter bar variable. There were not statistically significant any of interactions and among the quadratic effects, reel index and cutting height had significant impacts.

Table 2 Results of variance analysis of combine header loss using response surface method

Source	Sum of squares	df	Mean square	F value	p- value prob>F
Model	69.18	7	9.88	40.21	<0.0001
A-Reel index	16.15	1	16.15	65.71	<0.0001
B-Cutting height	6.30	1	6.30	25.64	<0.0001
C-Horizontal distance	3.472E-0.003	1	3.472E-0.003	0.014	0.9065
D-Vertical distance	2.61	1	2.61	10.61	0.0036
AC	0.98	1	0.98	3.97	0.0589
A^2	28.30	1	28.30	115.12	<0.0001
B^2	1.38	1	1.38	5.63	0.0268
Resdual	5.41	22	0.25		
Lack of fit	4.17	17	0.25	0.99	
Pure error	1.24	5	0.25		0.5590
Cor total	74.59	29			

Optimized regression model in terms of coded and actual factors is expressed by the exponential form Equation 1 and Equation 2. According to statistical indicators, it can be concluded that regression model well explains the mathematical correlation between the independent variables and the response of process.

$$(\text{Header loss})^{0.62} = 2.20 + 0.3 * A + 0.2 * B + 0.0009 * C + 0.12 * D - 0.068 * AB - 0.080 * AC + 0.97 * A^2 - 0.20 * B^2 \quad (1)$$

$$(\text{Header loss})^{0.62} = 13.755 - 35.56 * \text{Reel index} + 0.5919 * \text{Cutting height} + 0.080 * \text{Horizontal distance} + 0.0244 * \text{Vertical distance} - 0.0545 * \text{Reel index} * \text{Cutting height} - 0.0638 * \text{Reel index} * \text{Horizontal distance} + 15.49 * \text{Reel index}^2 - 8.072 * \text{Cutting height}^2 \quad (2)$$

In Figure 1, Figure 2, Figure 3 and Figure 4 independent variables interactions on the combine header loss have been illustrated using three-dimensional diagrams of response surface. According to these figures, the following results can be achieved:

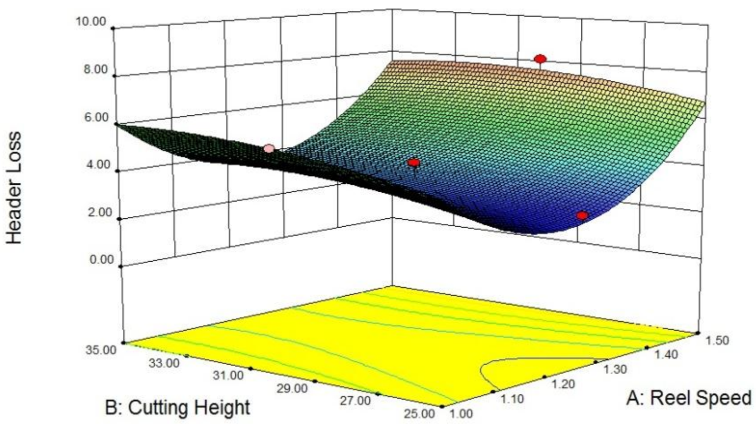

Figure 1 Effect of reel index and cutting height on combine header loss in horizontal distance of 5 cm and vertical distance of 10 cm of reel from cutter bar

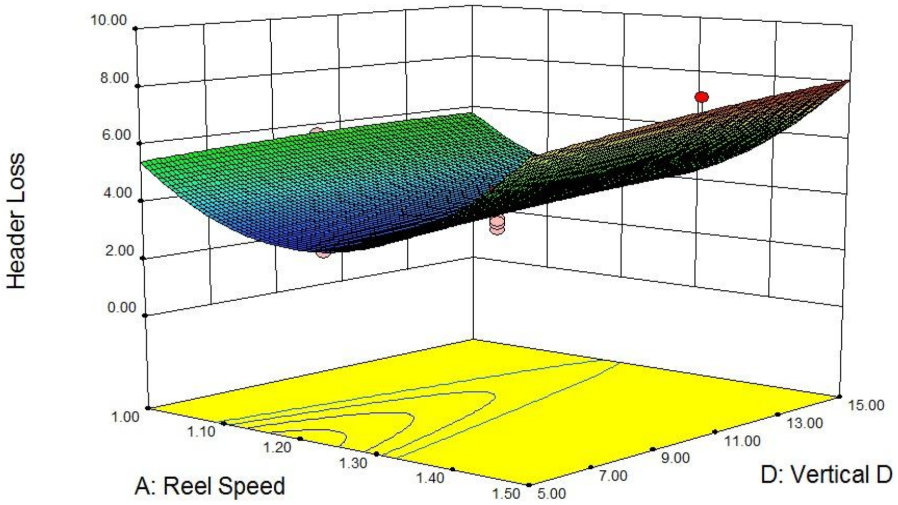

Figure 2 Effect of reel index and vertical distance of reel from cutter bar on combine header loss in horizontal distance of 5 cm and cutting height of 30 cm of reel from cutter bar

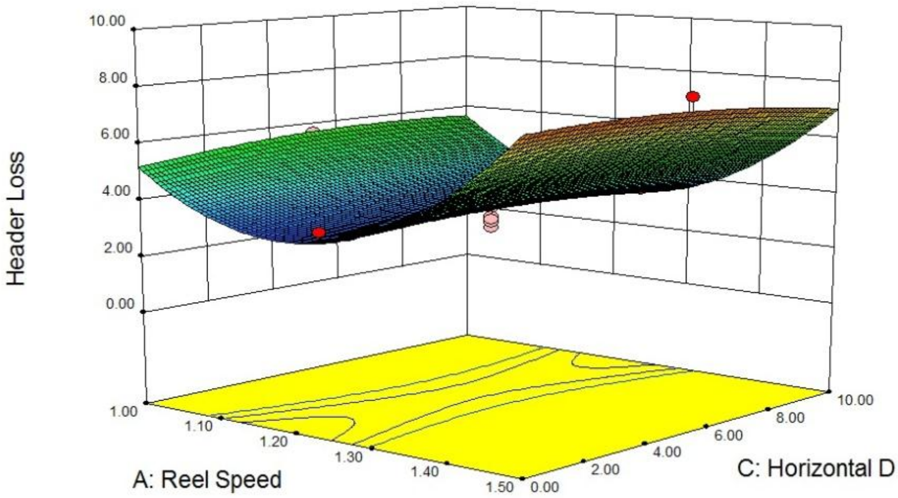

Figure 3 Effect of reel index and horizontal distance on combine header loss in horizontal distance of 5 cm and cutting height of 30 cm of reel from cutter bar

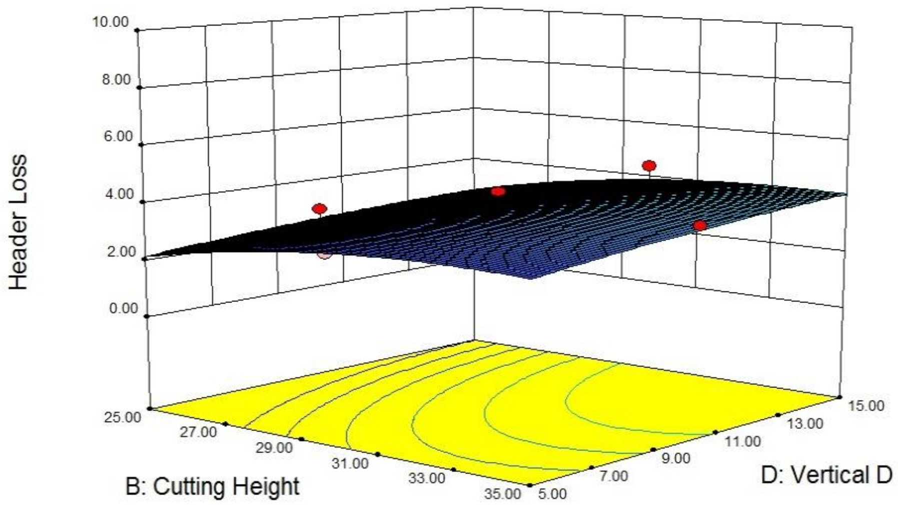

Figure 4 Effect of reel index and vertical distance on combine header loss in horizontal distance of 5 cm and

1. Relationship between reel index and combine header loss is a quadratic curve which has the minimum amount at level two (1.2). In the lower level of reel index (and therefore low reel rotational speed), the fingers cannot collect and direct the crop to the header, hence header loss increases. On the other hand, when reel index is more than level two, by increasing the reel rotational speed fingers strongly hit to cluster and lead to an increase in header loss. This result is consistent with the findings of Junsiri and Chinsuwan (2009); Sangwijit and Chinsuwan (2011).

2. The relationship between cutting height and combine header loss is linear and with the increasing of this height, header loss increases. If the cutting height is too high, header loss increases due to lack of cutting of some shorter spikes. This entry confirms the result of Junsiri and Chinsuwan (2009).

3. The relationship between horizontal distance of reel from cutter bar and combine header loss is linear which the maximum amount is in the first level and by increasing this distance, header loss reduces downward.

4. The relationship between vertical distance of reel from cutter bar and combine header loss is also linear which the minimum amount is in the first level by increasing this distance, header loss increases. Junsiri and Chinsuwan (2009) about the reason for this issue stated that crop stems hardly bend into the cutter bar, resulting in header loss due to effective cutting reduction of total stems.

In Figure 5, the diagram of real values has been given in front of the values predicted by the model. This diagram shows the values of predicted response in front of real values for helping to realize this value or group of values that have not been predicted by models.

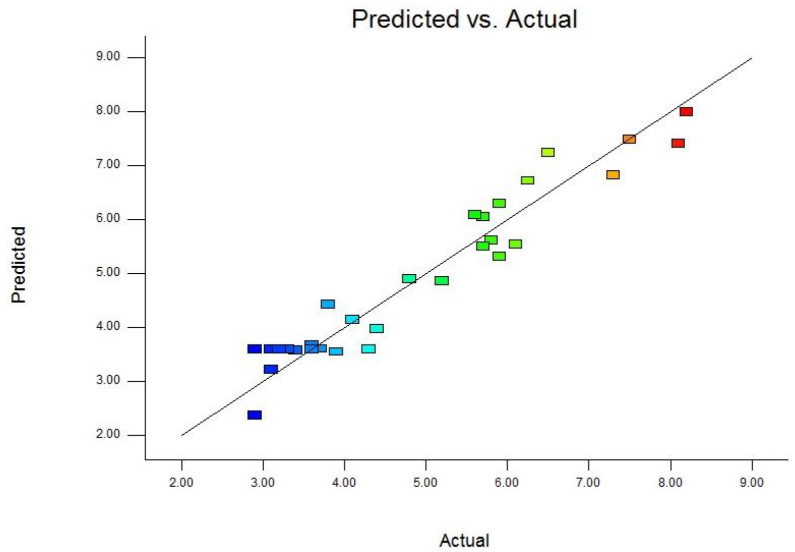

Figure 5 Comparison of real results obtained from test with the values predicted by the model

The results showed that response surface method is well capable to predict data with negligible error and present the proper relationship between the independent variables (reel index, the cutting height of crop, horizontal distance of reel from cutter bar and vertical distance of reel from cutter bar) and combine header loss. Based on the findings of present study, reel index had the greatest impact on combine header loss and horizontal distance of reel from cutter bar had the least impact. According to models test, the fourth model with low error and suitable correlation coefficient was used for modeling of combine header loss on the basis of variables above. The results of the optimization model of header loss revealed that the minimum combine header loss occurred 1.2, 25 and 5 for reel index, cutting height of crop and horizontal and vertical distances of reel from cutter bar, respectively.

4 Conclusion

The optimum conditions for the minimum combine header loss (103 kg/ha) were obtained 1.2, 25, 5 and 5 for reel index, cutting height of crop and horizontal and vertical distances of reel from cutter bar, respectively.

The results showed that response surface method is well capable to predict data with negligible error and present the proper relationship between the independent variables (reel index, the cutting height of crop, horizontal and vertical distance of reel from cutter bar) and combine header loss.

Acknowledgements

The author would like to thank the Fars Organization of Jahad Agriculture and University of Tabriz for the valuable support during this research

References

Behroozi-Lar, M. 2000. Engineering principles of agricultural machinery. Iran: *Azad Islamic University Press*. 702 p (In Persian).

Behroozi-Lar, M., M. Hassanpour, H. Sadeghnejad, A. Asadi, A. Khosravani, and M.Saati. 1995. Final research report: Combine harvesting loss. Agricultural engineering research institute. Karaj, Iran. 116 p (In Persian).

Benson, E. R., J. F. Reid, and Q. Zhang. 2000. Development of an automated combine guidance system. ASAE Paper No. 003137.

Craessaerts, G., J. De Baerdemaeker, B. Missotten, and W. Saeys. 2010. Fuzzy control of the cleaning process on a combine harvester. *Biosystems Engineering*, 106(2): 103-111.

Design Expert. 2011. Version 8.0.6 by Stat-Ease, inc., MN, USA.

Jalaei, A., and M. Javidi. 2004. Investigation of combine cleaning shoe to implementation of a fuzzy logic controller. in The 3th national conference on agricultural machinery and mechanization. Kerman, Iran. (In Persian)

Junsiri, C., and W. Chinsuwan. 2009. Prediction equations for header losses of combine harvesters when harvesting Thai Hom Mali rice. *Songklanakarin Journal of Science and Technology*, 31(6): 613-620.

Ma, X. 2003. Harvester with intelligent hybrid control system in 6553300B2 UPN, ed.

Myres, R. H., and D. C. Montgomery. 1995. Response surface methodology: Process and product optimization using designed experiments. New York: John Wiley & Sons, Inc.

Oduori, M. F., O. T. Mbuya, J. Sakai, and E.Inoue. 2008. Shattered rice grain loss attributable to the combine harvester reel: Model formulation and fitting to field data. *Agricultural Engineering International: the CIGR Journal*. Manuscript PM 06013. Vol. X. March.

Omid, M., M. Lashgari, H. Mobli, R. Alimardani, S. Mohtasebi, and R. Hesamifard. 2010. Design of fuzzy logic control system incorporating human expert knowledge for combine harvester. *Expert Systems with Applications*, 37(10): 7080-7085.

Pishgar- Komleh, Sh, A.Keyhani, M. R. Mostofi-Sarkari, and A. Jafari. 2012. Application of response surface methodology for optimization of picker-husker harvesting losses in corn seed. *Iranica Journal of Energy and Environment*, 3(2): 134-142.

Sangwijit, P., and W. Chinsuwan. 2011. Prediction equations for losses from Thai axial flow rice combine harvesters. *Thai Journal of Agricultural Science*, 44(1): 23-31.

Zareei, S., S. Abdollahpour, M. Moghaddam, and H. Sahrayan. 2012. Optimum setting of combine header for wheat harvesting using Taguchi method. *Research on Crops*, 13(3): 1142-1146.