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## Investigating common grain harvester header losses in Divandareh county and modeling the ferris wheel using Abaqus software

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### ABSTRACT

Wheat is the most important cereal crop in Iran, and its annual production is about 14 million tons annually. Part of the harvested product is wasted due to wear and tear and poor adjustment, and the heavy weight of the John Deere combine harvester. It is one of the most important factors that affect harvest loss. Therefore, the stress and strain of the ferris wheel and helix are determined according to the ferris wheel rotating speed using Abaqus software, the combine harvester weight is reduced, and finally, an optimal system is designed. Therefore, the forces acting on the ferris wheel and helix modeling for the optimization and better design of the combine head will help to reduce wheat loss to increase the useful life of the ferris wheel components and combine helix, in addition to harvesting. The results showed that as much as the humidity of the crop increases, the header loss decreases to a great extent. The natural loss was reported at 6.57% with 11% humidity, while there is no significant difference between 14% and 17% humidity. The effect of the kinematic index was significant in low humidities, but the effect of the kinematic index on platform collapse was not significant in high humidities. The maximum header loss on the platform occurred in the kinematic index of 1.4 and humidity of 11% of wheat, and the minimum header loss occurred in the kinematic index of 1.1 and humidity of 17%. As a result, total combine harvester header loss includes the natural loss in the field, loss on the platform, and loss at the end of the combine harvester. In general, the effect of the kinematic index on harvest loss is insignificant, especially in the humidity of 11 and 12.5 percent. As the crop humidity increases, its loss decreases noticeably, but its efficiency increases with 17% humidity due to the increase of header loss from the end. Minimum loss occurs at and kinematic index with 14% humidity. In general, the effect of the kinematic index on crop shedding is negligible, especially in 11 and 12.5 percent humidity. As a result, crop moisture is 14%, and the kinematic index is 1.3. It is the best condition for harvesting by John Deere 1055 Combine harvesters in the Divandareh region (Kurdistan province).

**Keywords:** Stress, Moisture, Loss, Kinematic index, Strain, Modeling

### INTRODUCTION

The combine harvester is a machine that harvests the crop and obtains the seeds, performing five main operations: cutting and feeding (harvesting the upright product), threshing (separating the grain from the straw and stubble), separating (cleaning the grain from straw fragments), cleaning (cleaning the grain from straw fragments and plant residues), moving (transferring clean grain).

The losses of chickpeas to harvesting machines occur in two parts of the header. Based on the results of the harvesting project of chickpeas, the losses increased up to 68% (Ebrahimi et al., 2009).

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Based on the authors' knowledge, just a few types of research has been performed on the design and construction and even how to change the mechanisms for harvesting chickpeas. Miller et al. (1990) presented a type of reel with a triangular structure with the same angles instead of a fixed type on the harvesting machine. The results showed that the use of this mechanism increases the performance of the machine.

Zarei et al. (2014) presented an adaptive fuzzy system based on an artificial neural network to optimize settings and combine head settings to reduce loss. According to the field results and statistical analysis, it was found that the kinetic energy index of the carousel is the most important factor affecting loss on the harvester platform.

The analysis of the effect of applying static loads and the resulting vibrations on the rear axle of John Deere 1055 Combine was to investigate the stresses and strains in it. A 1.28 stress was obtained in the center of the axle with a maximum static load of 3000 kg applied. The safety factor in static loading was calculated for loads of 500, 1000, 1500, 200, 2500, and 3000 kg using von Mises theory from the maximum von Mises stress and allowable stress, which was obtained from 1/3 for 3000 kg loads to 1/8 for 500 g loads in strain sensitive points. Results: At the highest natural frequency of axel, there is the highest stress and strain and deformation. In general, stress and strain in vibrational conditions are less than in static and linear conditions (Azam Rezaei et al., 2016). In Iran, losses were relatively high in common combines, which can be mentioned in John Deere 955 or 1055 combine losses, which do not have advanced technology. In recent years, crop shedding has been one of the basic defects of this combined model, as well as newer models that have been used, and the need to fix this defect is noticeable. In this regard, during the research carried out in Kurdistan province to check the quality of harvesting using combine harvesters, the percentage of broken seeds and harvest losses in New Holland TC56 and Jandir 955 combines were higher than the permissible limit (Golpira, 2011). Several factors affect the combined loss. The performance of the combine cutting machine is the most important factor that affects the front and rear combined losses. In the present study, peripheral speed and advance were studied based on the kinematic index (the ratio of the peripheral speed of the carousel to the forward speed) and the effect of the height of the Ferris wheel axis on the nasal drop of the combine. The results showed that the effects of height and kinematic index are significant in the total nasal drop of the 1% level header. The maximum drop related to the highest kinematic index was 3.83 and about 3.8%. The main effects of height and kinematic index on cluster drop and their mutual effect are significant at the 1% level in relation to the total cluster drop. The results showed that the main effects were significant at the level significance of 1% and the interaction effect was significant only on the left side of the nose and total harvesting loss according to the harvesting loss (Jalali et al., 2021).

Explaining that the proper operation of the cutting mechanism is due to the speed of advance, reel circumference, cutting height, product moisture and type, the kinematic index of the ratio of reel speed to forward speed and the effect of cutting height on the nose of the combine were studied. In a research project, Golpira et al. (2021) presented a mathematical model to optimize the chickpea harvester reel. The trochoid trajectory of the chickpea harvester reel based on the kinematic index, chickpea plant height and spacing between the plants was considered for the optimization process. The results showed that the best performance of the reel was obtained (harvesting efficiency > 0.7) with a height of 40 cm and a kinematic index of 2.4.



In another study, the data-driven simulator was used to redesign different prototypes of chickpea harvester reels. Five headers were considered for the test, and ten years of trials were applied in a fuzzy logic model. The aim of the model was to reduce harvesting loss. The obtained model predicted the reel structure within an acceptable range (Gopira and Sola-Guirado, 2022). As mentioned earlier, a high percentage of product loss is related to the nose, which is situated in the front of the combine. This drop is mainly related to the Ferris wheel. On the one hand, lifting the crop in front of the cutting machine when the crop is completely standing and vertical; on the other hand, if the product is not upright or if it is lying horizontally on the field, it should be lifted and moved to the cutting unit so that it can be harvested easily. Research has shown that Nosal losses depend on the rotating speed of the ferris wheel and combined speed as well as the performance of the cutting blade. Meanwhile, the rotational speed of the ferris wheel and the movement speed of the combine have a significant effect. Losses include 0.5% to 2% of the total yield (Jalali and Abdi, 2013a). Losses include 0.5% to 2% of the total yield (Jalali and Abdi, 2013a). The ferris wheel should be placed at the height of 15-25 cm above the cutting edge, and in addition, the speed of the carousel should be set at 1.5-1.25 times the combined speed. (Niyazi et al., 2020). The crop shedding and the grain damages in two parts of the harvesting and cutting unit were measured on the agricultural lands in John Deere and New Holland combined. The results showed that the effect of a kinematic index on platform collapse is not significant in high humidity.

(2014) Jalali and Abdi reported that the proper performance of the cutting mechanism was obtained according to the vehicle speed, reel tangential speed, cutting height, product moisture and product type. They studied the effect of the kinematic index and cutting height on the header of the combine. The results showed that the largest decrease is related to the highest kinematic index.

Hirai et al. (2004) analyzed the grain harvest using the force systems from the combined reel. They investigated the horizontal and vertical forces in both laboratory and simulated modes by flexural analysis and dynamic response of the crop stem. In the case of bending, the maximum horizontal reaction force of each wheat plant was 3.1 N, and its maximum value in the vertical direction was 0.8 N.

The ferris wheel design and modeling of the chickpea harvesting machine were done to reduce the seed drop, and the amount of strain and stress changes under the effect of the rotating speed of the carousel according to the thickness of the blades and rods was evaluated using Abaqus software.

The results showed that the aforementioned factors did not have a significant effect on the amount of harvest, drop and remaining chickpeas (Niyazi, 2019). Jahantigh (2012) claimed by calculating and analyzing the force applied to the ferris wheel rods, helices and fingers in the ANSYS software, using a six-bar ferris wheel is better for achieving ferris wheel optimal performance. In this case, crop harvesting is also done better, in addition to reducing the tension on the rods and fingers.

The reel of the header also designed the pod of the chickpea machine. This researcher uses a mechanism in which the fixed fingers of the header penetrate into the standing product at a height tangential to the ground, and at the same time as the machine proceeds into the crop carcasses under the pressure of torsional springs. The chickpea machine is guided by a cutter,



and a movement is applied to the plant to prevent the crop from slipping into the cutter. The reel sweeps the plucked pods inward, and at the end of the cutting cycle, where the contact between the blade and the platform is about high, the energy stored in the blade torsion springs is instantly accelerated. The data product undergoes a transfer process at the same time as the cutter (Mahmoudi, 2015).

In examining the losses of the grain harvesting machine, it was found that the maximum loss is related to the nose. Zendieh et al. (2016) designed and implemented a closed-loop rotary speed control system to reduce the loss of the combined nose and reduce harvest loss.

In the monitoring system of grain yield in Iran, control and detection of nose drop has become one of the basic problems of farmers. Therefore, in the present study, an automatic system was designed and built to measure the nose drop of the grain combine head. The built system consists of a collection, transfer, weighing and display section. In order to systematically evaluate the performance of the monitoring system, it was made. Its results were compared with conventional methods. In order to evaluate the amount of grain combine head loss, the effect of the forward speed of the carousel and the peripheral speed of the carousel (in other words, the carousel was examined on the amount of head loss). The results showed that there was a significant difference in the average head loss in the installed system at the probability level of 5%. The comparison of the loss measurement by the two mentioned methods showed that the difference between these two measurements was not significant, but the biggest difference was in the index of 1.9. and 0.78 was observed, which indicates that the accuracy of the device has decreased significantly in these two indicators. The range of the forward speed and the peripheral speed of the flywheel are 2.05 km/h, respectively. 2-5 meters per second. And the optimal levels for the flywheel index were estimated to be 1.44, 1.152, 1.02, and 0.96.

These crudities, in conjunction with the inappropriate design of conventional grain headers for the mechanical harvesting of chickpeas, cause high shattering losses and manually harvesting of the crop by laborers in some developing countries. (Niazi, A.; Golpira, H.; Akhijahani2021).

## **Materials and methods**

### **a. Grain sampling method at harvest stage**

At this stage, the sampling plan was implemented by moving on the road between the fields and finding combines during wheat harvest. This plan was carried out in Divandara city, 100 kilometers from Sanandaj, with the participation of Agri Jahad of this county. The farm and land characteristics (the technical test card of the combine, the technical examination form of the fall and loss of the combine) were checked in the losses of different parts of the combine by plotting in this field during wheat harvesting by combine and questionnaires from the farmer and combine driver. Factors affecting wheat yield include the familiarity of the farmer with a combine, the life of the combine, the rotating speed of the wheel, the height of the cutting shoulder and driver skill, combine harvesting health and newness of the combine, and the adjustments and timely service and appropriate crop performance level and type of farming and planting, which play a significant role in combine losses.



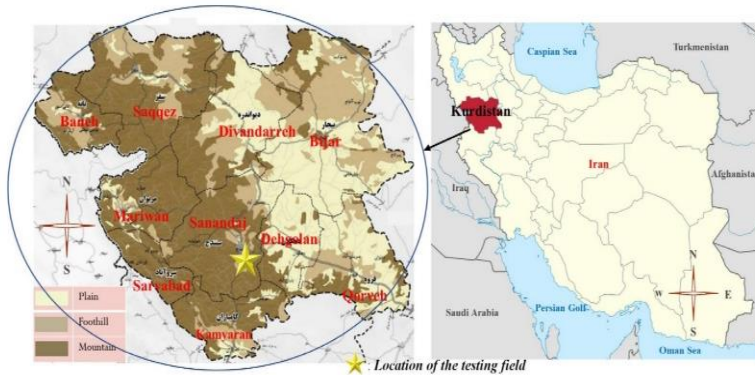


Figure 1. Location of the testing fields in the Dooshan farm of the University of Kurdistan



Figure 2: Harvesting of wheat crop and sampling plan (technical examination card for loss and fall of the combine harvest)

**b- Losses of dormant wheat in the field before harvest.**

By dropping a 1 x 1 m wooden frame at five points of the field randomly and collecting the seeds and clusters in it, and weighing the resulting seeds, no values were observed from different parts of the field before the combine entered the field, and there is no natural loss.



Figure 3: How to measure the metal frame to measure the natural loss of wheat

**c. Losses of the cutting nose of the John Deere 1055 Combine**



The losses of the cutting nose of the combine were measured by embedding a wooden frame of 1 meter per point from different parts of the harvested land (that the material removed from the back of the combine was not dumped there) and by collecting the seeds and clusters in the frame and weighing the seeds obtained from them after the combine harvests a surface of the field.



Figure 4: How to install the wooden and metal frame in the center of the rear wheels of the combine perpendicular to the direction of motion



Figure 5: Wooden frame of the end of the combine loss- the metal frame of the John Deere 1055i combines platform

#### d. Quality losses of wheat crop

The chopped seeds were separated from the healthy ones and weighed according to the weight percentage of the chopped seeds as well; the seeds of weeds, and straw, were separated, and their weight percentage was obtained by sampling the wheat in the combine grain tank. Then, the quality loss of the wheat crop was determined.



Figure 6: Quality loss of wheat crop in the combine grain tank



**Table 1: John Deere Specifications of Jandir 1055i combine specifications**

|   |                           |
|---|---------------------------|
| Horsepower (hp)                                   | 105 horsepower at 2500 pm |
| Effective working width                           | 2/4 meter                 |
| The variable speed of the Straw Chopper propeller | 21-55 rpm                 |
| Spiral speed inside the platform                  | 52-196 rpm                |
| cylinder speeds of the thresher                   | 470-1160 rpm              |
| Straw Choppers number                             | 4                         |
| Speed of Wind tank capacity                       | 325-1080 rpm              |
| Sieve of straw and grain area                     | 2.1-65.1 meter            |
| Wind propeller speed                              | 325-1080 rpm              |
| The length of the combined nose                   | cm4                       |

**Table 2: Tests with the John Deere 1055i combine in the agricultural lands of Kurdistan (Divandre) in 2020**

|  |                                |
|--|--------------------------------|
| Fall of the end of the combine+the fall of Harvesting unit+ relative performance= absolute performance | <i>KG/HR</i> 86<br>1408/       |
| natural fall + absolute fall = real performance  | <i>1387/52</i><br><i>KG/HR</i> |
| natural fall   | 2.5%                           |
| Fall of cutting shoulder   |                                |
| Fall of the end of the combine   | 7.09%                          |

### **e Designing a combine harvesting machine**

Optimum design and modeling of the combine harvester can greatly reduce the fall of the nose in wheat crop shedding. In the combine harvesting machine, nose fingers have a difference of 90 degrees, and it is obtained in a way that is proportional to the height of the product stem and with changes in the height of the combine carousel.

Another limitation can be the correct design of the fingers mechanism in terms of optimally directing the product towards the carousel into the helix, which increased its maneuverability significantly by choosing a suitable material for making the fingers used in the combine



harvesting machine, in addition to reducing the economic cost, crop shedding and nose drop, and the of crop harvesting power. In this study, the combine harvesting machine is designed using Solidworks 2021 software, and modeling will be done with Abaqus 2022 software. Therefore, the ferris wheel speed of the combine is higher than the speed of advance, and harvesting is done in tall wheat with 1st Gear and short-backed wheat with the 2nd Gear.

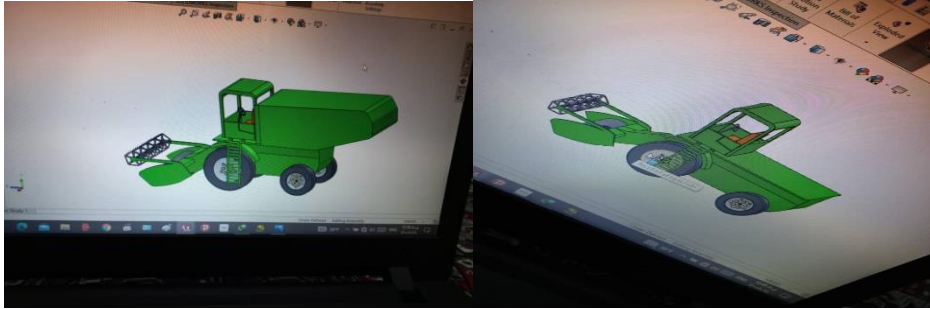


Figure 7: Modeling of the combine harvesting machine using Abaqus 2022 software

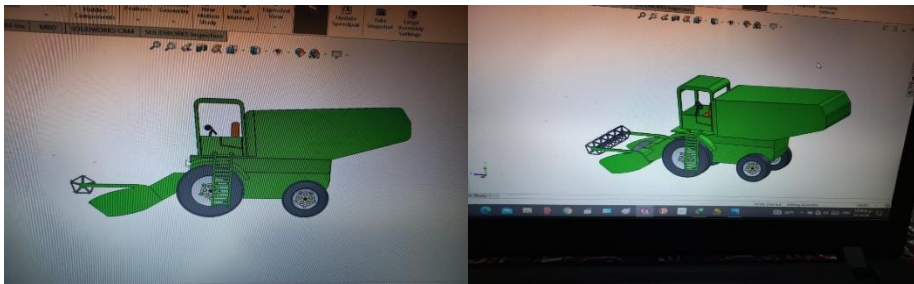


Figure 8: Design of the combine harvester using 2022 solid-works software

#### f. Modeling the ferris wheel of the combine harvesting machine

For the analysis of helix and ferris wheel of combine harvester machine in dynamic and static mode after meshing and helix components, on both sides of the tie, Gravitational acceleration is considered in all analyzes (Figure 8). Therefore, the design implemented for the helix combine era in order to simplify, considering the importance of stress and strain and the deformation of the combine ferris wheel, has been effective in the stress in combine helix.

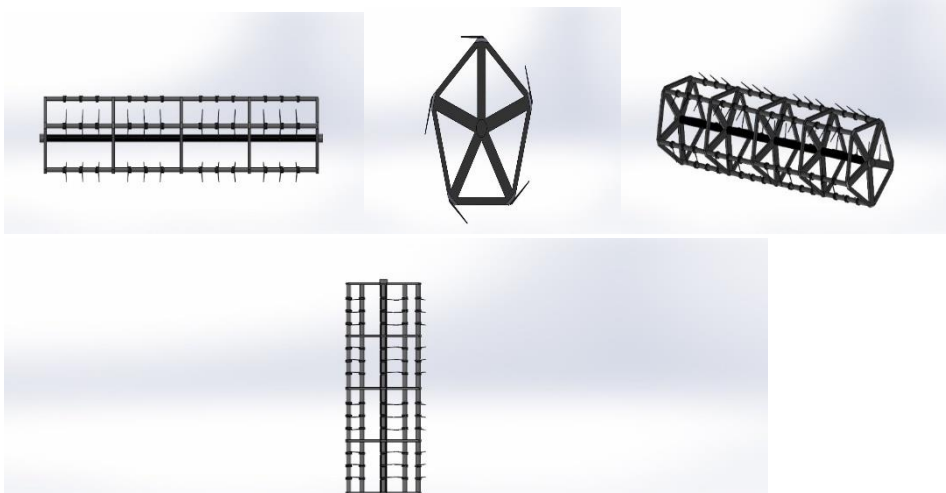


Figure 8: Modeling the 1055I John Deere combine harvester ferris wheel using 2022 solid-works software

g. Design of the combine harvester Helix

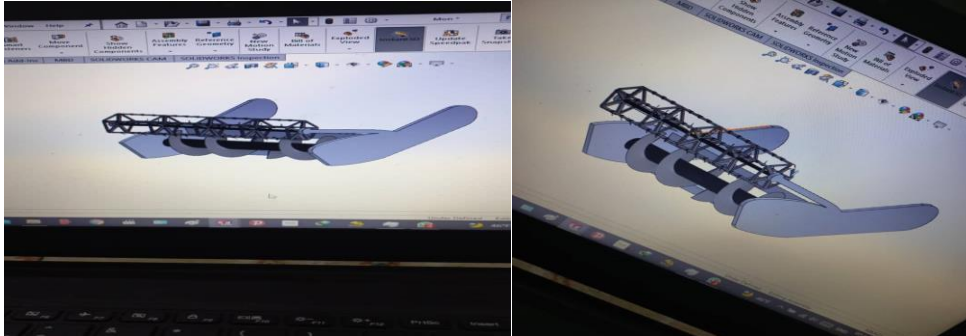


Figure 9: Modeling of Helix of 1055I John Deere combine harvester using Abaqus 2022 software

### Results and discussion

The results of wheat loss are analyzed and described during harvesting in different parts of the combine. The figure shows the moisture effect of wheat on natural falls in the field. As much as the crop humidity increases, the shedding greatly decreases. The natural shedding was 6% normal in 11%/57 humidity, while there is no significant difference between 14% and 17% humidity. It can be said that crop shedding due to natural factors is more than unnatural factors in some cases.

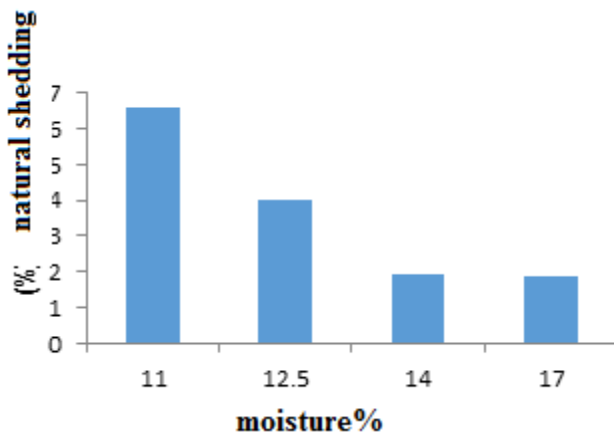


Figure 9: Natural shedding of wheat with changes in crop moisture

Shedding on the platform is one of the most important factors that unnaturally leads to crop shedding in the field. The highest amount of shedding, in this case, is also caused by crop moisture. As the crop humidity increases, the shedding decreases significantly. The effect of the kinematic index was high in low moisture, but the kinematic index effect on the collapse of the platform was not significant in high moisture. The highest shedding on the platform was in the 1.4 kinematic index, and 11% humidity in wheat, and the lowest was in the 1.1 kinematic index and 17% humidity. An increase in moisture increases the dependence of the seed on the



spike, and therefore, the possibility of the seed slipping or falling decreases with each shake (figure 10).

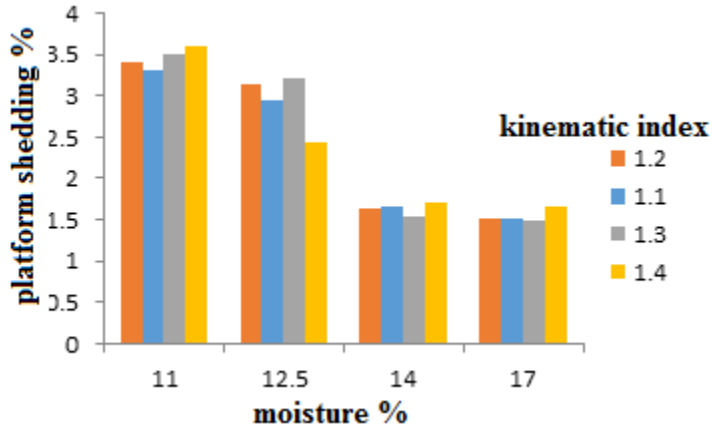


Figure 10: Platform shedding changes with changes in crop moisture and combine kinematic index

In figure 10, the fluctuations of shedding at the end of the combine are shown with changes in crop moisture and combine kinematic index. Accordingly, increase some of the product is removed from the threshing cycle and thrown out from the end of the combine because of the crop moisture and improper threshing of the crop. In addition, with the increase of the kinematic index, due to the large volume of the crop being entered into the combine and the lack of enough time to thresh crop, it is wasted some amount of the crop. However, the kinematic index effect is less than the effect of humidity on the efficiency of the internal sieves of the combine.

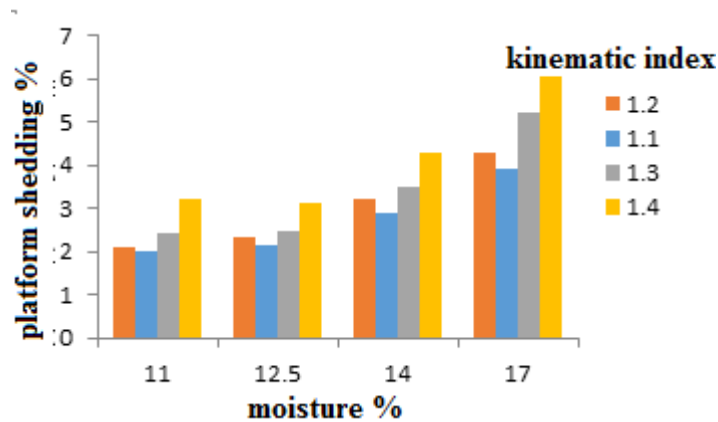


figure 11: Shedding fluctuations at the end of the combine due to changes in moisture and kinematic index

Figure 11 display the results of the shedding of the combine, including the natural shedding of the field, the shedding on the platform, and the shedding at the end of the combine. In general, the kinematic index effect on the amount of crop shedding is insignificant, especially in the humidity of 11-12.5%. But its effect is more noticeable in high humidity. As the humidity of the

product increases, the amount of shedding decreases significantly. However, at 17% humidity, its value increases due to the increase of shedding in the end. Minimum shedding was at 14% humidity and kinematic index. It can be said that the crop moisture is 14%, and the kinematic index is 1.3 is the best condition for harvesting by John Deere 1055i combine harvester in the Divandara region due to the non-significance of changes in the total shedding in the kinematic indexes 1.2 and 1.3. Therefore, the results of modeling and stress analysis in the ferris wheel of the combine harvester are discussed, and the results of the dynamic analysis of the Abaqus 2022 software are presented. The dynamic analysis of the ferris wheel of the combine harvesting machine led to the optimization of the shedding minimum.

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**Ethical statements: None**

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