RESEARCH ARTICLE

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A Comprehensive Analysis of Control Frequency in Self-Propelled Combine Harvesters Operating in Chhattisgarh

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Abstract

The increased utilization of combine harvesters in India, including the state of Chhattisgarh, has sparked concerns regarding operator discomfort stemming from subpar ergonomics. Particularly during the peak harvesting season, operators are compelled to work for extended durations, resulting in repetitive different control movements that exert excessive strain on them. To address this issue, a study was undertaken in Chhattisgarh to evaluate the operational frequencies of controls on self-propelled combine harvesters and categorize them as either frequently or infrequently used. 13 available combine harvesters of diverse makes and models were selected for this investigation, during which the operational frequency of 10 controls was scrutinized while harvesting paddy crops. The findings unveiled those controls such as the header assembly control lever, ground speed control lever, engine speed control lever, gear shift lever, clutch pedal, and brake pedal were frequently operated, with frequencies ranging from 315 to 655, 55 to 247, 5 to 13, 66 to 156, 58 to 256, and 49 to 152 actions per hour, respectively. Conversely, controls that were infrequently operated, namely the threshing control lever, whole assembly control lever, grain unloading control lever, and header engagement control lever, exhibited lower operational frequencies, varying from 3 to 9, 4 to 11, 2 to 5, and 4 to 9 actions per hour, respectively. In order to enhance efficiency and user-friendliness, it is recommended that frequently used controls be positioned within the close reach for maximum operator's population, while controls with lower usage rates can be placed within the maximum reach of the operators. This strategic optimization of control placement is poised to enhance the overall performance of self-propelled combine harvesters in Chhattisgarh.

Major Findings: 1. The incorporation of control frequency will provide will provide guidance for further improvement in degree of deployment of combine harvester for Chhattisgarh user. **2.** This paper gives insight of control frequency for of various control lever which engage their most frequent controls are Header assembly control lever, clutch pedal, ground speed control lever, gear shift lever and brake pedal. **3.** The incorporation of controls in new combine harvesters will reduce the drudgery and provide better comfort for both combine operators as well as farming community.

Keywords: Combine Harvester, Ergonomics, Frequency, Self-Propelled, User's Population

1. Introduction

In the year 2020, India had a recorded total of 40,000 combine harvesters, which accounted for 1% of the overall farm equipment availability, measured at 2.761 kWha[1]. India boasts over 50 manufacturers primarily located in Punjab and Haryana, collectively producing an annual quantity of 4,500 to 5,000 units[2-3]. In this market, self-propelled combine harvesters hold a commanding position, comprising 60% of the market share and representing a value of USD 96 million in 2018. Projections indicate that the Indian combine harvester market is anticipated to experience a Compound Annual Growth Rate (CAGR) of 5.60% from 2023 to 2028[4]. On a regional

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scale, Chhattisgarh state recorded a total of 93 combine harvesters available during the 2022-2023 as Chhattisgarh Plains, Bastar Plateaus and Northern hills zones, occupies 51.0 %, 28.0 % and 21.0% of the geographical area, respectively[5]. It was found that, out of total Chhattisgarh plains covered a major share of mechanization followed by Northern hills as and Bastar plateau[6].

Initially, combine harvesters were not widely adopted for crop harvesting across the country, with notable exceptions in states like Haryana and Punjab. However, their prevalence has grown nationwide due to factors such as a decline in agricultural workers, timeliness of harvesting and threshing operation and challenging climatic conditions.

Harvesting operations using combine harvesters involve the operation of about 10 controls, which imposes a significant physical workload on the operators. However, operators must not only fit spatially in a man machine task system but also be able to move and function dynamically[7]. The location of controls may vary depending on the make and model of combine harvesters. To achieve higher output and improve the quality of work performed by combine harvester operators, it is essential for them to efficiently operate these controls. The strain on the tractor operators during operation of varies for different controls[8]. Thus, it can be seen that after several years of mechanization, the problem of such fatalities has not gone away[9]. Dimensions for seat pan and back rest were measured and analyzed, according to BIS recommendations. The results highlighted that seat pan width was found 10.9% less, seat height was found 15.3% in excess, no vertical adjustments and backrest width was also found 20.4% less[10]. Neglecting the importance of proper interaction between humans and machines can result in a poor focus on the health and safety of the operators of combine harvester. This, in turn, increases the risk of injuries, musculoskeletal disorder and accidents over time[11]. Therefore, it is crucial to prioritize the well-being of the operators to ensure safe and effective harvesting operations. Operator controls within the workplace should be conveniently and logically located, and the workplace should fit both tall and short operators[12]. The primary variables influencing the work-space designs of a system are the forces to be applied, the kind and frequency of motions, and the position and displacement of the operational control aspects of the human body[13-14].

During the peak harvesting season in Chhattisgarh, combine harvesters from neighboring states like Madhya Pradesh, Punjab and Haryana enter the region. These states experience a non- harvesting season during this time. As a result, harvester operators often work extended hours, sometimes exceeding 15 hours a day, without adequate consideration for their health. Harvesting is done through custom hiring arrangements, leading to year-round profits for the harvester owners. These harvesters come with varying cutter bar widths and engine powers. Notable manufacturers of self-propelled combine harvesters in India include Dashmesh Group, Preet Agro Industries, Kartar Agro, Vishal Agriculture Works, John Deere, and Class, all of which have a significant presence in the market[15].

However, it has been observed that most of the harvester operators who come from their respective states are skilled, whereas local operators in Chhattisgarh are unskilled. The local operators often find it challenging to reach the controls within the workplace and easily experience fatigue. Significant difference has been recorded in the anthropometry of Chhattisgarh state comparatively to other parts of country[16]. It is learned that there is a mismatch of body dimension which is responsible for back pain and other discomfort[17]. Also, anthropometric survey has been compared from Chhattisgarh region to other such that 300 male workers were taken and 9 done dimensions were compared, it was found that workers of northern India have higher body weight (61.8 kg) and stature (1685 mm) as compared to other regions[18].

This occurs due to the disparity between the local operators and the combine harvester's workplace. This mismatch between the local user population and the harvester workplace presents certain challenges. Therefore, understanding the operational frequencies of these controls becomes crucial.

2. Materials and Methods

The experiment was in Chhattisgarh, specifically in seven districts namely Raipur, Bemetara, Balodobazar, Bhatapara, Mungeli, Mahasamund and Durg chosen from out of 33. These districts are situated in the Chhattisgarh plain region, which is known for its relatively higher level of mechanization compared to other agro- climatic zones[19]. The weather conditions during the experiment

were characterized by hot and dry conditions. In the state of Chhattisgarh, the farm power availability for the year 2022-2023 was recorded at 1.57 kW/ha, which is lower than the national average of 2.76 kW/ha for the year 2021-2022[20]. However, despite this, Chhattisgarh holds the distinction of being known as the "Rice Bowl" of India, with 2.60 lakh hectares dedicated to Kharif rice production, contributing significantly to the overall rice crop area in the country.

2.1 Selection of Combine Harvesters

The study included a total of 13 self-propelled combine harvesters, each representing different makes and models. These combine harvesters were employed for the purpose of harvesting paddy crops within the designated study area. The majority of the selected combine harvesters were brought in from North Indian states. There were seven harvesters from Haryana, five from Punjab, and two from Madhya Pradesh. Table 1 provides a detailed specification overview of the selected combine.

Permission was obtained from the owner of the combine harvesters and their respective landowners prior to conducting the experiment. Briefing of the task was given to operators of the combine harvester and asked to do harvesting as per their routine job. Harvesting was done for crop paddy from every self-propelled combine harvester. While doing normal harvesting through video was recorded with the use of 30 mega pixel camera. And further it was calculated by counting when played in slow-motion of the originally recorded video[10]. Video was taken closely for both left and right-side controls respectively. The frequency of operation of controls of combine harvesters vary based on various factors like field condition, land topography, crop density, crop moisture content. Prior to commencing the observations, it was ensured that the operators were in good physical and mental health and free from any physical or psychological abnormalities.

Operation having actuation interval of less than 5 minute during their normal harvesting operation are considered as frequently operated controls on the other hand controls having more than five minutes of interval considered as non-frequently operated controls as per, stated that control shaving less than 12 actions per hour said as non-frequent controls and vice versa[9,13]. Frequency of operation of controls was reserved into actions.h^{-1}.

Analysis of frequency was done to observe time and efficiency required by the operator to operate the controls. To know the gap between operator's capability of doing work and frequency requirement for reaching accuracy in operation. Ranking of controls was given using statistical tool descriptive analysis.

3. Results and Discussions

The operation of a combine harvester demands significant physical and mental exertion during movement. These machines incorporate numerous controls, all of which perform identical functions across the selected self-propelled combine harvesters, ensuring uniformity in their operation. Controls available in selected self-propelled combine harvesters are listed in Table 2. Similar placements have been seen all the harvesters[12]. Five controls observed on the left side of the operator, eight controls are on the right side of the operator, steering wheel placed in front and center of the combine harvester's workplace.

Table 1. Specifications of all selected self-propelled combine harvesters

Parameter	Selected Combines												
Nomenclature	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
Manufacturing year	2019	2016	2016	2019	2016	2019	2016	2013	2010	200	2019	2020	2016
Rated engine, rpm	2200	2200	2200	2200	2100	2200	2200	2200	2200	2200	2200	2200	2200
Maximum power, kW	101	101	101	101	110	101	101	101	94	105	102	101	110
Specific fuel consumption, kg.kW/h	0.260	0.271	0.266	0.265	0.260	0.245	0.245	0.266	0.250	-	0.260	0.260	-
No. ofcylinders	6	6	6	6	6	6	6	6	6	6	6	6	6
No. of forward gears or reverse gears	3/1	4/1	3/1	3/1	3/1	3/1	3/1	3/1	3/1	3/1	3/1	3/1	3/1
Cutter bar width, mm	4300	3962	4230	4423	4255	4300	4265	4230	4245	4267	4245	4300	4267

Table 2. Name and placement of control

Name of Control	Placement Side
Steering wheel	Center
Grain unloading control lever	L.H. S
Whole assembly control lever	L.H. S
Header engagement lever	L.H. S
Threshing control lever	L.H. S
Clutch pedal	L.H. S
Header assembly reel control lever (up/down)	R.H. S
Ground Speed Control lever	R.H. S
Gear shift lever control (1/2/3/4)	R.H. S
Gear speed lever control (low/high)	R.H. S
Brake pedal	R.H. S
Engine Speed Control	R.H. S
Horn	R.H. S
Reel position control lever	R.H. S

Range of the operational frequency of controls for all the 13 existing self-propelled combine harvesters are shown in Table 3 for ten controls and it was observed that controls like header assembly control lever, ground speed control lever, engine speed variation lever, gear shift lever, clutch pedal, brake pedal have more than 12 frequencies per hour having range of 315-655, 55-247, 5-13, 66-156, 58-256, 49-152 actions.h^{-1} respectively. Non-frequently operated controls ranged between 3-9, 4-11, 2-5, 4-9 actions.h^{-1}(less than 12 actions.h^{-1}) for controls threshing control lever, whole assembly control lever, grain unloading control lever, header engagement control lever respectively. The highest frequency influenced by the diverse land topography and the presence of lodged crops, which also relied on the skill of the operator.

It has been observed that the infrequently used controls were located on the left side of the operator's seat. All of these controls are operated by hand. Among the six controls that are frequently operated, four of them

Table 3. Range of frequency of controls

Particulars	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	Range
Steering wheel	539	1023	784	708	721	984	759	1271	1300	799	714	609	799	**539-1300**
Header assembly control lever	315	446	548	624	485	521	492	365	655	654	428	365	506	**315-655**
Ground speed control lever	55	69	73	189	208	217	72	109	247	247	428	365	506	**55-247**
Engine speed variation lever	5	7	9	7	6	11	8	5	13	13	109	75	109	**5-13**
Gear shift lever	71	92	117	103	86	117	83	66	156	156	5	4	9	**66-156**
Threshing control lever	3	5	8	9	5	7	6	4	3	8	3	5	4	**3-9**
Whole assembly control lever	4	6	7	11	7	5	5	6	9	2	5	6	8	**4-11**
Grain unloading control lever	4	2	2	4	2	2	3	2	5	5	2	4	6	**2-5**
Header engagement control lever	4	4	8	8	6	5	6	4	9	5	7	4	6	**4-9**
Brake pedal	68	52	96	148	72	77	86	49	152	162	69	72	59	**49-152**
Clutch pedal	119	90	123	230	18	202	162	126	256	213	202	153	143	**18-256**

Table 4. Placement of controls

Placement of Controls	Hand Operated Controls	Leg Operated Controls
Dashboard	Start key Horn Hand accelerator Header assembly lever Reel position control lever Gound speed control lever (high/low) Light switches	
Driving controls	Steering wheel, Gear lever- high/low, Gear shift lever	Clutch pedal Brake pedal Foot accelerator
On-farm working controls	Header assembly lever Reel position control lever Gound speed control lever (high/low) Whole assembly control lever Threshing control lever Grain unlading control lever Header engagement lever	

are hand-operated, and two are leg operated i.e., clutch and brake pedal. Clutch pedal present in left side of the operator and rest of them in right side of the operators' seat. Except these controls one most important driving control is steering wheel. Operators used to constantly hold this control throughout the work either in field or on -road. It used to in both directions clockwise, anticlockwise, full rotation, half rotation. Operators also used it as resting option for hand. It was observed that steering wheel frequency was 539-1300 action.h^{-1}.

It was seen that maximum number of operational frequencies was found in C9 was working. It was due to irregular shape of the field, lodged crop. Frequency of controls highly depend upon operator's skill, experience. All these controls are interrelated therefore simultaneous operation and its frequencies was observed for combines. Controls was classified as on farm and driving which is shown in Table 4. According to task, controls of combine harvesters are classified as i) driving controls, ii) on-farm controls. Driving controls include steering wheel, brake pedal, clutch pedal, gear shift levers, engine speed control levers. On farm controls include header assembly control lever, ground speed control lever, threshing control lever, whole assembly control lever, header engagement control lever and grain unloading control lever.

3.1 Ranking of Controls

Ranking of controls was given based on mean frequency of use of controls per hour. Descriptive analysis was used to know the ranking of controls based on that rank was given to the controls. Detailed of ranking are shown in Table 5. From table it was observed that highest rank is given to header assembly control lever of mean operational frequency value 495 actions.h^{-1} followed by clutch pedal of value mean operational frequency value 147 actions.h^{-1}, ground speed control lever means operational frequency value 137 actions.h^{-1}. Lowest rank was given to grain unloading control lever.

Table 5. Ranked frequency of controls

Name of Control	Mean (actions.h^{-1})	Rank
Header assembly control lever	495	1
Clutch pedal	147	2
Ground speed control lever	137	3
Gear shift lever	99	4
Brake pedal	89	5
Horn	8	6
Engine speed variation lever	8	7
Whole assembly control lever	7	8
Threshing control lever	6	9
Header engagement control lever	6	10
Grain unloading control lever	3	11

4. Conclusions

The analysis of control operational frequencies of self-propelled combine harvester of various makes and models led to the following outcomes: Out of the 10 controls observed, 6 controls were frequently operated, including the header assembly control lever (315-655 actions.h-1), ground speed control lever (55-247 actions.h-1), engine speed control lever (5-13 actions.h-1), gear shift lever (66-156 actions.h-1), clutch pedal (58-256 actions.h-1), and brake pedal (49-152 actions.h-1). On the other hand, 4 controls were found to be non-frequently operated, namely the threshing control lever (3-9 actions.h-1), whole assembly control lever (4- 11 actions.h-1), grain unloading control lever (2-5 actions.h-1), and header engagement control lever (4-9 actions.h-1). Header assembly control lever found to be the mot frequent control out of all.

5. Future Scope of the Study

The study could be conducted on larger scale to assess the effect of operational frequency of controls on operators of combines. Such study may also conduct in areas where mechanization level is limited to accept the technologies at higher pace.

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