MICROCLIMATE CONDITIONS AND STRESS FACTORS EFFECTING FARM MACHINE OPERATORS DURING HARVEST

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Abstract. Agricultural machinery operators are exposed to unfavourable working weather conditions, which eventually may lead to their health problem. Beside extreme cold winter and heat in summer, operators often encounter heavy and predominant workload primarily during the summer harvest time. Due consideration is not given enough to resolve the problem of prolonged static exertion and its effect. This research finding specifies the stress caused by microclimate influence on farm machine operators. Farm machine operators basically drive over rough agricultural terrain and perform plentiful activities in short-distances. These manipulations lead to fatigue related stress by the actual workload on farm fields. This paper presents the outcome of the stress factors affecting the observed engagements carried out by two different farm machinery operators; i.e. the tractor and combine harvester in their respective working processes. Data on operators' heart rate variation and thermal variation in the drivers' cabin were carefully collected throughout the course of harvest and transport performance. The significance of farm field segments, operators' extra manipulations activity as well as obstacles occurred while performing the harvest and transportation were the substantial data. The core finding of this research is the presumption of the cause of the changes of heart rate variation.

Keywords: combine harvester, driver, terrain, tractor, workload.

Introduction

Heart rate variability describes the variations between consecutive heartbeats.Human factors research shows that the driver stress is associated with workload and fatigue, and is a construct that can have an impact on overall driver safety. Microclimate composition rate is an important index factor affecting contentment of drivers in the cabin. Recommended values of microclimate in the cabin of the car according to [1] are: air temperature 18-22 ºC; relative humidity 40-60 %; air velocity 0.1 $m \cdot s^{-1}$ at 18 ºC and 0.4 $m \cdot s^{-1}$ at 24 ºC; air exchange per person (clean air) 25-50 $m^3 \cdot h^{-1}$ of fresh air; maximum concentration of pollutants 0.17 % of CO_2, 0.01 % of CO and 1 $mg \cdot m^{-3}$ of dust. Furthermore, a heart rate variability analysis was particularly applicable for this study as it is a strong indicator of mental stress or workload caused by driving tasks [2]. Numerous researchers used different measurements to assess the driver workload under diverse driving conditions. The conclusions made by monitoring physiological based measures support an objective and continuous analysis in a dynamically changing situation [3]. Researchers [4; 5] came to a conclusion that the relationship between the safety and stress depends on the route conditions and work load. Furthermore, measurements of the heart are most practical for application in the driving domain as it least interferes with the driving performance [6]. Specific research has not yet well expended to ensure the mental and physical workload and its impact on farm machine operators. The objective of the finding is to examine operators engaged on rural, bumpy, uneven, rough pavements, dusty, muddy and stubble farm fields. Frequent steering, reducing speed, monitoring various operations of different devices while driving in short intervals, long working hours denote a significant degrade in driver performance. Due to all these performances, farm machine operators are exposed to whole body vibration which leads to swift fatigue compared to acceptable and normal operating conditions, surfaces and pavements. Further examination on physiological and psychological changes in truck drivers based on heart rate variability has come to a conclusion that the smoother the route, the more enjoyable the ride [7].

In order to fully understand the complexity of the relationship between the surface characteristics and driver behaviours, this paper closely examines various yet realistic uneven, rough, up and down drives, turns, breaking and accelerating and other working related conditions, influences of driving behaviours, physical strength of the operators playing a leading role on dimensions of stress. Generally, crashes are correlated to impaired driver cognition due to fatigue, stress, or mental workload [8]. Therefore, by evaluating stress as a form of distraction, this paper addresses the safety impacts of farm field and roadway surface conditions. Furthermore, other researcher [9] has hypothesized about the traits established in the Driving Behaviour Inventory and their probable consequences, based on cognitive stress processes.

The findings related to stress associated and dislike of driving were related to lateral positional variability and control errors, but reduced risk taking; aggression was strongly related to speed and frequency of high-risk overtaking tasks, but unrelated to performance on the open-road; high cognitive alertness resulted in quicker hazard detection [10]. Measurements of driver stress can be objectively captured using physiological measures. Physiological measurements can be used to quantify the changes in the body state [11]. These measurements can include skin conductivity, cardiac, neurological, muscle, and respiratory activity. Observation also concluded that heart data were less expensive, invasive, and more portable to collect; specifically compared to brain mapping (electroencephalogram or EEG) and muscle activity (electromyography or EMG) [12]. Many studies have concluded that during periods of increased stress, there tends to also be an increase in the values of heart rate and low to high frequency ratio [13-15; 17].

Similar research findings published [16] show that the impacts of the microclimate conditions in the driver cabin play a significant role in stress and changes in heart rate variability. A suitable microclimate is necessary and the systems must ensure a suitable microclimate as it is one of the most important safety features of the vehicles. The driver cabin features a large flat glass, a small volume of air inside and relatively low heat insulation, resulting in a greater degree of influence on the operating conditions.

Materials and methods

The authors performed the research on farm machine operators of a combine harvester and tractor. Both farm machineries are properties of an agricultural enterprise at eastern Bohemia farming on an area of 2500 ha. The combine harvester Claas 450 is a German brand, widely used in Europe and as well a large number is used in Czech agriculture. The tractor Zetor 7711 is a Czech brand widely used in the country. The authors selected these farm machinery operators of ten year different ages. Their weight, height, oxygen content in their blood before and after their operation performance were registered. The age and the number of years spent working as farm machine operators are classified accordingly. In July 2015 there happened to be continuous fluctuation in the climatic conditions. For the selected climate condition, which was extremely hot summer, two machinery operators were available for the research performance. Although, the research was confidential, we took into consideration the life background of both operators. The combine harvester operator is forty-eight years old and 115 kg of weight. He has his license as a combine harvester operator for twelve years and handled the job for ten continuous harvest seasons. The second farm machine, tractor operator is fifty-eight years old and 130 kg of weight. He has thirty-two years of working experience as an operator. The data collection was performed in the hot summer period of July 2015, from 13:06 to 17:37 hrs.

For the actual heart rate measurement, the authors used the polar measuring sensors package. The operators put on a sensor (Polar RS800CX) around the body and computer device on the wrist of the driver to record the heart rate variability (HRV). The package of the measuring instrument consists of four parts of Polar brand. The Polar RS800CX is a computer which displays and records the heart rate and other data like the position and velocity during the driving examination; Polar wear link W. I. N. D. transmitter sends the heart rate signal to the computer. It includes the connector and strap; CD-ROM which includes software and a complete user manual for the RS800CX computer.

Data detected (heart rate of the driver of the farm machinery) are stored in Polar RS800CX are transformed through infra port to a personal computer for further processing and analysis.The Czech government health protection regulation determines the conditions for the protection of health related to light manual work such as driving under normal operating conditions. Under this regulation, for particular metabolic energy output 81-105 $W \cdot m^{-2}$, the recommended operating temperature is 20 ± 2 ºC and relative humidity to be 30-70 %. Thermal state of the internal environment can be described by applying the index of temperature and humidity (THI). This index is widely used to describe the heat stress, and it is also a key indicator of the environmental conditions of stress.

Data on the microclimate conditions in the farm machinery operator cabin were collected from the measurement devices, which are installed on the dashboard of the respective farm machinery. The thermal comfort in the space was continuously measured by globe temperature (measured by globe thermometer FPA 805 GTS with operative range from -50 to +200 ºC with accuracy ±0.01 K and diameter of 0.15 m) together with temperature and humidity of surrounding air measured by the sensor FH A646-21 including the temperature sensor NTC type N with operative range from –30 to +100 ºC with accuracy ±0.01 K, and air humidity by capacitive sensors with operative range from 5 to 98 % with accuracy ±2 %. The concentration of CO_2 was measured by the sensor FY A600 with operative range 0-0.5 % and accuracy ±0.01 %. All data were measured continuously and stored at intervals of one minute to the measuring instrument ALMEMO 2690-8 during the measurement.

Results and discussion

Principal measurement results of temperature differences in the internal drivers' cabin of the conducted vehicles are evaluated and summarized on Fig. 1 for the combine harvester and Fig. 2 for the tractor Zetor 7711, respectively. Fig. 3 indicates the results of the combination ofboth farm machine operators' average heart rates at the monitored reference points, for nine selected variables. The mean values including standard deviation were calculated from the results of measurements for each of the parameters.

The obtained results of measurements were processed by Excel software and verified by statistical software Statistica 2013. Table 1 and Table 2 represent the average values including standard deviation which were calculated from the results of measurements for each of the external and microclimatic parameters: external temperature t_e, external relative humidity RHe, internal temperature t_i, internal globe temperature t_g, internal relative humidity RH_i, THI, BGHI and concentration of CO_2. The results of the measurement microclimate in the combine harvesters' cabin during the job performance are presented in Table 1 and in the tractor operator's cabin in Table 2.

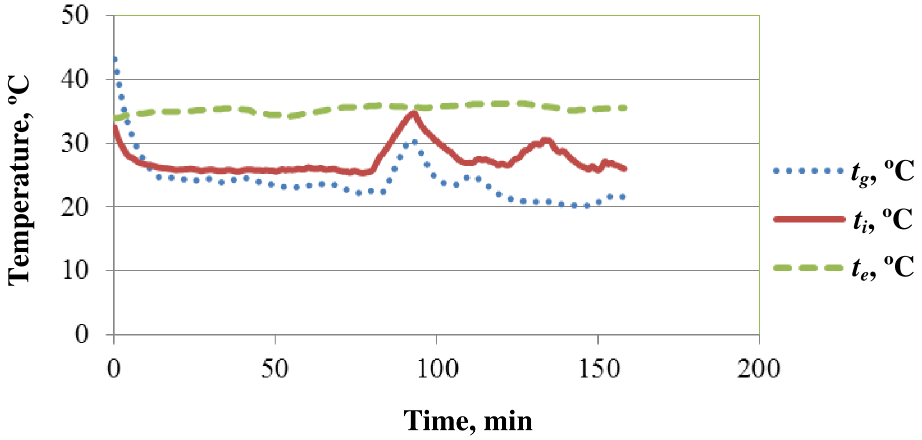

Fig.1. **Temperature in combine harvester operator driving cabin**

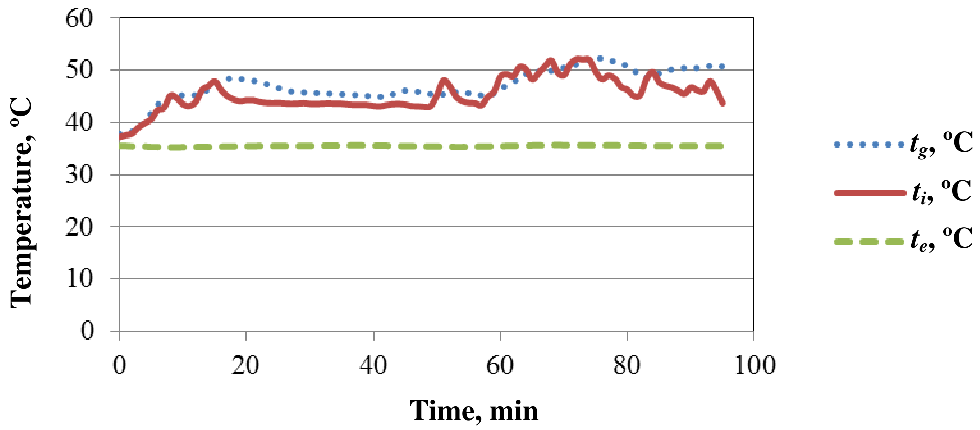

Fig. 2. **Temperature in tractor operatordriving cabin**

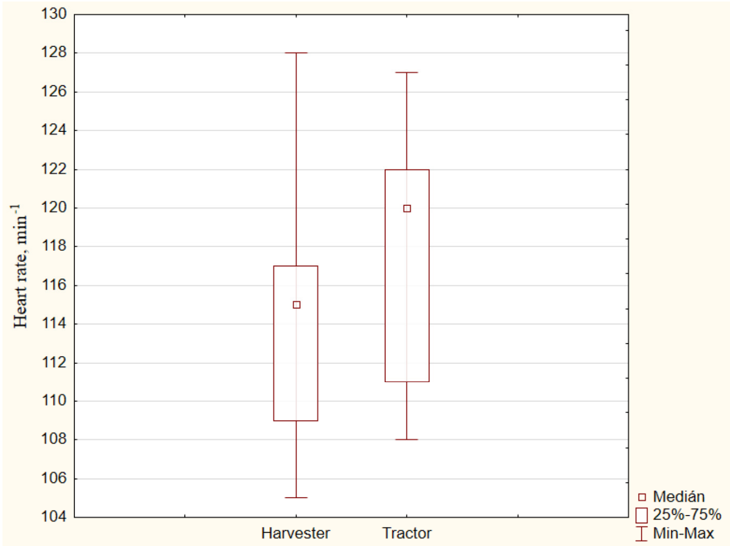

Fig. 3. **Box and Whisker plot of combine harvester and tractor operator heart rate**

Table 1

Indoor parameters in cabin of combine harvester

Parameter	t_e	RH_e	t_i	t_g	RH_i	THI	BGHI	CO_2
Units	ºC	%	ºC	ºC	%	-	-	%
Mean value	35.32	21.9	27.38	24.05	33.8	72.7	68.9	0.121
Standard d.	0.57	1.3	2.14	3.47	3.4	3.42	3.10	0.048
Minimum	33.90	19.8	25.31	20.23	24.9	69.4	64.0	0.035
Maximum	36.20	25.1	34.67	43.10	41.0	82.4	92.6	0.184
Median	35.40	21.9	26.53	23.57	34.3	71.8	68.4	0.128

Table 2

Indoor parameters in cabin of tractor Zetor 7711

Parameter	t_e	RH_e	t_i	t_g	RH_i	THI	BGHI	CO_2
Units	ºC	%	ºC	ºC	%	-	-	%
Mean value	35.48	21.05	45.38	47.08	21.20	89.3	91.0	0.037
Standard d.	0.12	0.70	3.12	3.11	2.6	4.9	4.2	0.005
Minimum	35.20	20.00	37.19	37.80	16.3	79.9	80.5	0.035
Maximum	35.70	22.30	52.16	52.39	29.9	89.5	99.7	0.050
Median	35.50	21.18	44.15	46.31	21.5	88.0	90.3	0.033

Conclusions

The results of the research demonstrate the changes in heart rate variability on both farm machine operators depending on the feature of the farm field and their actual performance. Significant increase of heart rate was observed at downhill drive and farm field drives for both operators. The highest heart rate increase of the combine harvester operator was registered on drum clugg and a cell phone call from the dispatcher related to the defect (128 %). Frequent turns during harvest performance had significant influence to heart rate fluctuations with the increase of 125 % for the combine harvester operator. A profound increase in heart rate was observed while transporting the harvester on third category route on braking performance due to deceleration (130 %).The tractor operator has demonstrated the increase in heart rate during sudden leak of the cooling system from the radiator caused by mal function of the thermostat (125 %).The harvester operator seems to be in a better physical condition compared to the tractor operator. This could be explained by worse health disposition of the tractor operator with his extra weight (130 kg).

Tinted glass of the windshield of the combine harvester had a noticeable influence in reducing the radiation. Strong radiation effect has been observed and measured by globe thermometers on uphill drive of the combine harvester due to direct appearance to the sun shine; i.e. t_g = 43.10 ºC. Based on the results of the measurements in the combine harvester cabin higher temperatures have occurred; for example, global temperature t_g from 20.23 ºC to 43.10 ºC. The internal temperature t_i rose from 25.30 ºC to 34.67 ºC. The result of the measurement in the tractor operator cabin indicates extreme increase. Internal temperature t_i has increased from 34.19 ºC to 52.16 ºC and the globe temperature t_g increased from 37.80 ºC to 52.39 ºC. This indicates that the influence of solar radiation has increased rapidly compared to the internal temperature t_i, which is against the regulation in relation to the directive on the health supervisor (Government Regulation 361/2007 of Czech Republic, 2007).

Measurement evaluation applying the THI and BGHI indexes also reveals the major influence of radiation. E.g., the mean value of the THI is 72.7 and the BGHI mean value 68.9 for the combine harvester THI is 89.3 and BGHI is 91.0. The inner temperatures can reduce the influence of solar radiation by adequate ventilation of the operators' driving cabin. To maintain the recommended air temperature inside the cabin, operators are recommended to use air conditioning and frequent ventilation.

Drivers are recommended to ventilate sufficiently even in colder outdoor conditions to let in fresh air (O_2) and exhaust the polluted air (CO_2 and odours). Based on the results of the measurement, a higher concentration pollutantCO_2 (0.184 % = 1850 ppm) has been observed in the harvester operator cabin, which is air conditioned. This result denotes that there is insufficient ventilation in the driver cabin and the value measured is slightly more than the maximum tolerance [1].Slight increase in CO_2 (0.050 % = 500 ppm) pollutant has occurred in the tractor cabin, which is not air conditioned. Based on the recommendation (0.035 % = 350 ppm), the value has slightly increased. This can be explained by frequent ventilation due to extreme external temperature. From the values measured, the authors strongly recommend ventilation in the driver cabin even if the farm machineries are equipped with air conditioning.

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