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BRAKE FORCE TESTING IN ERGONOMICALLY ADJUSTED CRANE CABINS

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Abstract: Crane operators' job is extremely demanding. They work long hours in constrained workspaces in awkward posture. Their neck extension, trunk flexion and repetitive arm movement are associated with an increased risk of developing neck and shoulder pain that leads to reduced working capacity, quality and safety. The comfortable operator posture could not be achieved without considering the anthropometric criteria to analyze aspects of seat comfort, visual displays locations, pedal controls, reaches etc. When proposing novel, anthropometrically assessed and adjusted seat solutions, it is important to analyze pedal brake force exerted. In this paper 68 crane operators participated in survey, with task to test novel seat solution and corresponding exerted pedal brake force. Mark 10 EK3 200 ergonomic test kit was used to measure pedal brake force. Examined variables included: height and weight (body mass index), pedal brake force average value, deviation of each three measurements from average value and absolute measurement error. After descriptive statistics, Spearman's correlations are calculated. Besides proving novel solution, there also has been found statistically significant correlation between body mass index and mean value of force, as well as between BMI and absolute measurement error. It is recommended, in future research to enlarge sample and repeat statistical testing.

Keywords: Pedal brake force, BMI, crane operator, descriptive statistics, absolute measurement error

1. INTRODUCTION

The comfortable operator posture could not be achieved without considering the anthropometric criteria to analyze aspects of seat comfort, visual displays locations, pedal controls, reaches etc. Previous studies show that there is a need to optimize the interior space and to enhance the safety and comfort of multi-users.

Crane operators job is very demanding since remain in cabins during almost the whole shift (Fung, et al., 2016; and Bongers, et al., 1988). Kushwaha & Kane (2016) and Kuijt-Evers (2003)

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based on data collected through questionnaire conclude that more than half operators rated crane cabin comfort as “average/poor” with special attention on seat design.

The aim of this paper is to test brake force which participants are able to exert when using anthropometrically adapted crane cabin with novel seat. After introduction, literature review is done, then follow methodology description and results of statistical examinations, and finally conclusions are given.

2. LITERATURE REVIEW

A possible explanation for the improper crane cabin adequacy for the operator may be found in the fact that today’s available standards and manufacturers rely on the anthropometric data of the general instead of crane operators` population (Zunjic et al., 2015).

Contemporary anthropometric characteristics (including variation in anthropometric measurements, gender, and operator fitness) and the orientation and layout of the cabin should be considered as contributing factors in designing a crane cabin of high quality in order to ensure the safety and comfort of the operator and his environment (Spasojević, Brkic, et al., 2014). Brkić, VK Spasojević et al. (2015) also point out to operators’ biomechanical and visual problems and propose novel cabin design based drawing-board mannequins and kinematic modeling. Essdai et al. (2016) use multivariate anthropometric models, spanning 95% of the population on the basis of a set of 8 anthropometric dimensions to obtain dimensions of the interior space, necessary for the accommodation of the crane operator.

Wang et al. (2000) use sample of French crane cabin operators and computerized human model MAN3D in the ergonomic evaluation of a container crane workplace (Figure 1). Large number of authors emphasize seat and foot problems of operators (Wang et al., 2000; Spasojevic Brkic et al.,2015; Zunjic et al., 2015). Despite today's’ the risk awareness, incidents in crane’s operations have not substantially decreased. Proposed design enables the operator’s fatigue and stress reductions due to ergonomic adjustments, together with increasing the productivity of the crane and safety and security while decreasing production and insurance costs.

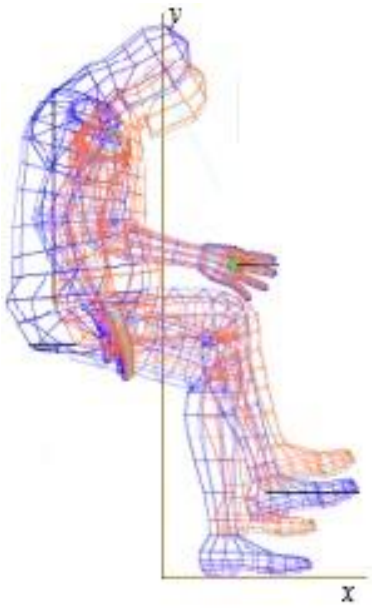

Figure 1. Crane operator workstation (adapted from Wang et al. 2000)

On other side, Vogt et al. (2005) define a concept for an interior layout process in terms of the ergonomic posture of the human body and comfort angles for the human skeleton (Figure 2).

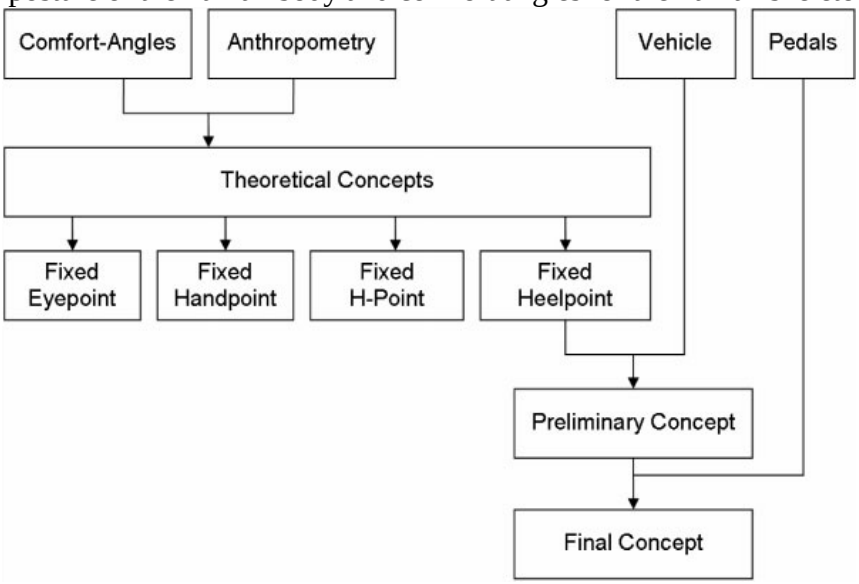

Figure 2. Interior vehicle layout concept (Vogt et al., 2005)

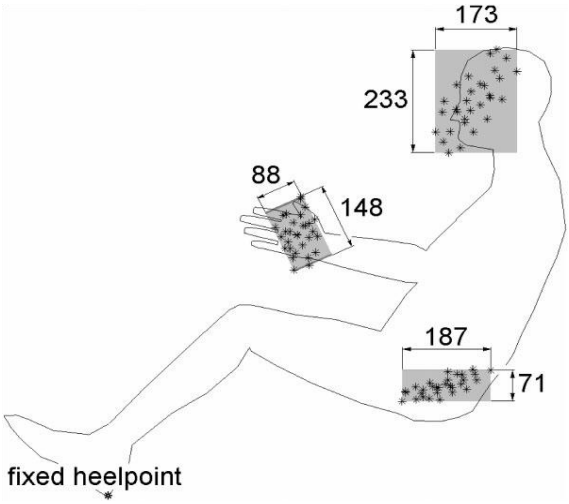

Figure 3. Fixed heel point (Vogt et al., 2005)

Pedals are very important in ergonomic design (as in Figure 1), especially because design the most often starts from fixed heelpoint, as in Figure 3. But, studies of the comfort of pedal operation have very rarely been reported in existing literature (Pannetier & Wang, 2014). Despite today's the risk awareness, incidents in crane's operations have not substantially decreased. Novel seat design and its adjustment to pedals which enables the operator's fatigue and stress reductions, and leads to increasing the productivity of the crane and safety and security while decreasing production and insurance costs, is needed. Till now, there are only few patents focused on problems of crane cabin brake - Actuator mechanism for crane turntable brake and Dual piston swing brake system for cranes (Jackson & Jackson, 2000; Pottorff, 1974).

3. METHODOLOGY AND RESULTS

Solution needed for ergonomic adjustment of operator seat offers our patent WO 2020/149757 A1 (Spasojevic Brkic et al., 2020).

For measurement of pedal brake force Mark 10 EK3 200 ergonomic test kit was used. Experimental tests to measure operators` force exertion on brake pedals in working position have an aim to prove that proposed positions are comfortable were conducted.

Results which test our novel solution are as follows.

There were 68 crane operators in the sample. Their task was to use brake pedal with maximal possible force. Three measurements were taken, as in Table 1.

Table 1. Descriptive statistics

Measurement	N	Me	Med	Min	Max	R	SD	cv(%)	VT
Height (mm)	68	1815.882	1810.000	1570.00	2010.00	440.000	87.660	4.83	par.
Weight (kg)	68	79.382	80.000	50.000	125.000	75.000	13.760	17.33	par.
BMI	68	24.006	23.862	17.500	34.626	17.126	3.398	14.16	par.
1st measurement (N)	68	241.125	215.750	45.000	553.500	508.500	114.720	47.58	npar.
2nd measurement (N)	68	242.993	220.500	79.000	556.000	477.000	115.888	47.69	npar.
3rd measurement (N)	68	239.853	225.000	65.500	709.000	643.500	133.302	55.58	npar.
Average value of force (N)	68	241.324	225.750	74.000	579.000	505.000	109.886	45.53	npar.
Deviation from aver.value 1	68	0.199	-3.417	-237.667	151.000	388.667	54.402	27402.71	npar.
Deviation from aver.value 2	68	-1.669	2.083	-164.667	96.667	261.333	42.622	-2553.56	npar.
Deviation from aver.value 3	68	1.471	-2.750	-161.000	165.833	326.833	57.958	3941.11	npar.
Absolute measurement error	68	55.775	44.417	4.333	237.667	233.333	42.650	76.47	npar.

Note: *N- number of subjects, Me - mean, Med - Median, R -rank, SD - standard deviation, cv-coefficient of variation, VT - variable type, par. - parameter, npar. non-parameter.*

Spearman's correlations of the considered variables are shown in Table 2. It is evident that there is a statistically significant correlation between BMI-index of body mass and mean value of force, as well as between BMI and absolute measurement error.

Table 2. Spearman's correlations of the considered variables

			p - value	significance
height	*v.s.*	mean value of force	0.00356	*n.s.*
height	*v.s.*	Absolute measurement error	-0.0527	*n.s.*
weight	*v.s.*	mean value of force	0.02508	*n.s.*
weight	*v.s.*	Absolute measurement error	-0.00358	*n.s.*
BMI	*v.s.*	mean value of force	0.32728	<0.01
BMI	*v.s.*	Absolute measurement error	0.13180	*n.s.*
mean value of force	*v.s.*	Absolute measurement error	0.40487	<0.001

Note: *p- value - p level of test, significance - level of significance, n.s. not significant*

The graphs below show the ratios of mean force to height, mean force to weight, mean force to BMI, absolute errors to height, weight, and BMI (Figures 4-9):

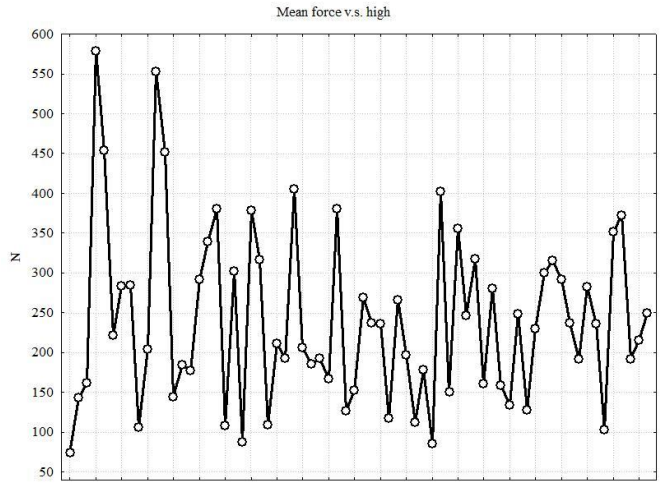

Figure 4. Interrelations between mean force and high

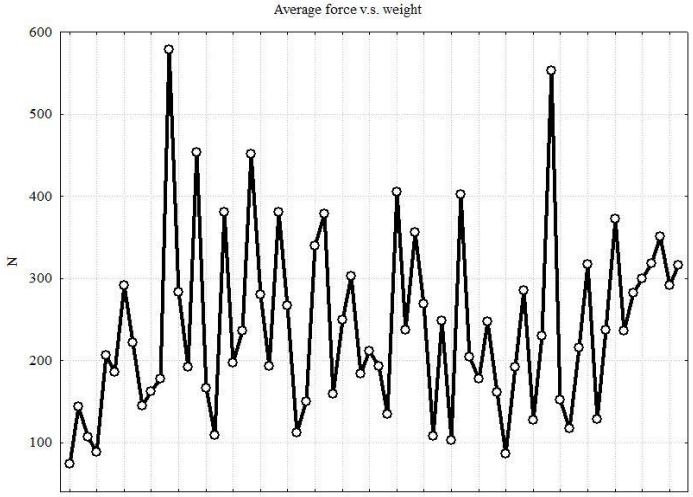

Figure 5. Interrelations between average force and weight

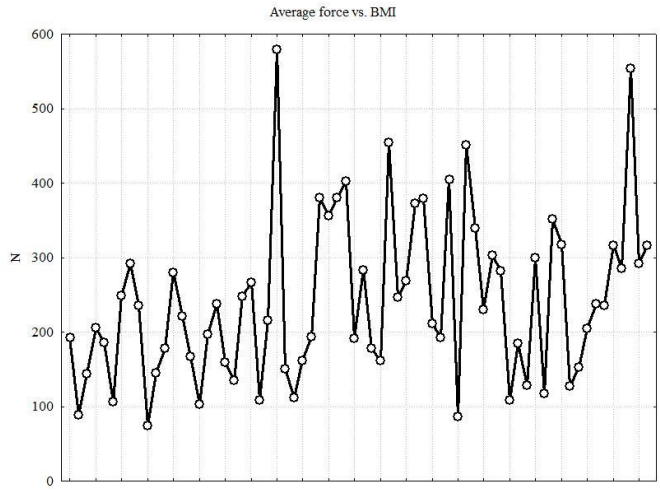

Figure 6. Relationship between average force and BMI

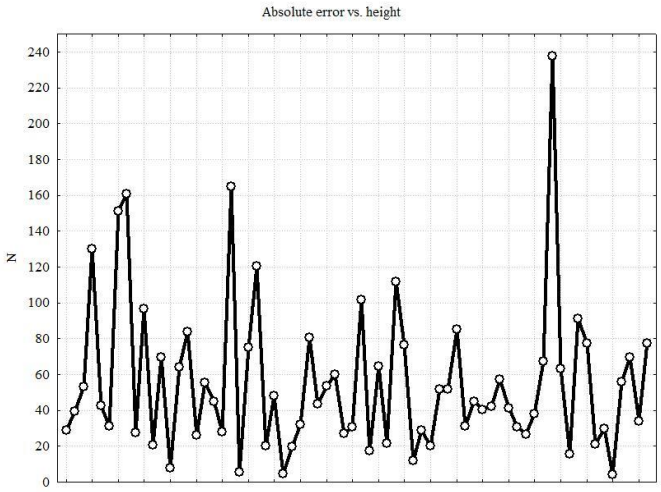

Figure 7. Relationship between absolute error and height

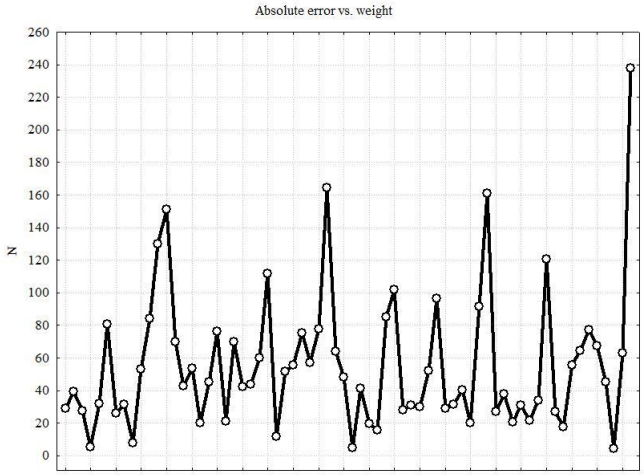

Figure 8. Relationships between absolute error and weight

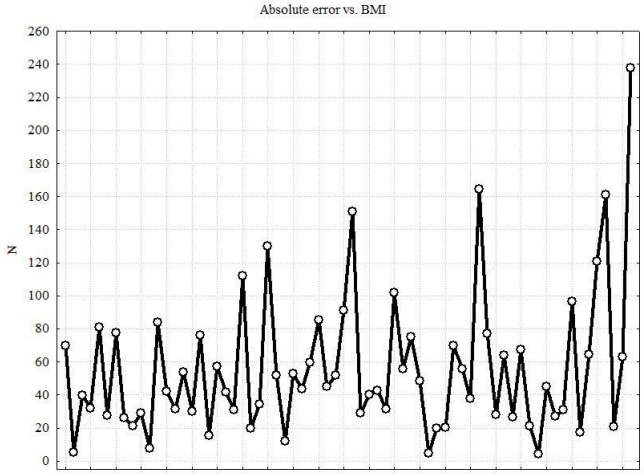

Figure 9. Interrelationships between absolute error and BMI

4. CONCLUSION

Crane operators execute very demanding, hard job, most frequently in not comfort position. Survey aimed to enable crane operators greater comfort appear more frequently in the last few years. Anyhow, solutions which lead to greater operator comfort are still rare.

This paper aimed to test relation between ergonomically adapted seat and brake pedal usage.

Results show that the measured forces that the crane operator achieves on the brake pedal in the working position have the expected values, which means that proposed seat solution is adequate. Survey has also proved a statistically significant correlation between BMI-index of body mass and mean value of force, as well as between BMI and absolute measurement error.

It is recommended, in future research to enlarge sample and repeat statistical testing.

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