Parametric Investigation and Optimization of the Newly Developed Pant Loading Ramp Machine

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ABSTRACT

Objective of the current study was to optimize newly developed pant loading ramp to perform manual handling task. Pant loading ramp was 19 feet in length, having width of 2 feet, anti-slippery, easy to move due to provision of rotating wheels, adjustable at varying heights of the loading vehicle (between 2.5-5 feet) and reduces the loading time up to 30 minutes. For this purpose experiments were conducted on a group of 20 experienced manual handlers in rice mills of Udham Singh Nagar district, Uttarakhand, India. The reliability and validity of the developed, loading ramp was assessed by using response surface methodology in terms of change in energy expenditure (EE), rate of perceived exertion (RPE), total cardiac cost of work (TCCW) and grip strength (GS). Therefore Response Surface Methodology (statistical tools to determine the significance of a factor over a response or collection of mathematical and statistical techniques for empirical model building) was applied to optimize the operating parameters of ramp such as load weight, height of ramp and time. As per Box Behenken design total 17 experiments were carried out each of which varied over three levels as load weight (40, 50 and 60 kg.), height of ramp (3, 4 and 5 feet), and time (3, 4 and 5 min.). ANOVA and coefficient of determination (R^2) test were applied. In result it was observed that use of pant loading ramp was able to reduce Energy Expenditure (EE) of respondents' from 14.55 kJ/min. to 11.41 kJ/min., Rate of Perceived Exertion (RPE) from 85.45 to 20 %, Total Cardiac Cost of Work (TCCW) from 996.3 to 564.36 beats and Grip Strength (GS) from 47.45 to 3.30 % with overall desirability of 0.84 %. In comparison

with traditional method it was also found to reduce Average Working heart Rate (AWHR) (14.55-11.41), Peak Energy Expenditure (PEE) (16-12), Rate of Perceived Exertion (RPE) (85.45-20), Grip Strength (GS) (47.45-3.30) and Total Cardiac Cost of Work (TCCW) (996.3-564.35). Relative advantages showed that more than 95 % users were highly satisfied and found it advantageous.

Key-words: Musculoskeletal disorders ergonomics volume of oxygen uptake

INTRODUCTION

According to Genaidy *et al.* (2003) operations related to manual handling include the acts of lifting, lowering, carrying, pushing, pulling, and holding items. National Institute for Occupational Safety and Health, 1997 reported that when handling and lifting items manually, there is always potential for injuries such as strains, sprains, fractures, cuts, lower back pain due to awkward postures, muscle fatigue and musculoskeletal discomforts (MSDs) problems. Among the injuries reported in industry, MSD have been recognized as one of the leading problem. Besides these, researches also show a significant linkage between musculoskeletal injuries and manual handling (Edlich *et al*., 2005; Hoozemans *et al*., 1998). It is found that manual handling injuries are a major burden to society, organizations and the sufferers themselves. The financial costs of manual handling injuries are estimated to be in the region of £2 billion a year (Tudor, 1998).

Recent statistics from the Health and Safety Authority (2007) indicate that, approximately one third of all reported work-related incidents are triggered by manual handling. The proportion of incidents associated with manual handling is particularly high in the wholesale and retail trade (47 %), manufacturing (40 %) and health and social care (38 %). The most common type of injury in 2006 was ‘physical stress or strain to the body’ (41 %) and the most frequently injured body part was the back (24 %). Health and related occupations are ranked sixth in the 'top 10 occupations of workers injured' (Health and Safety Statistics, 2012).

However workers in the rice mill industry have a high risk of musculoskeletal disorders because they are principally involved in manual material handling (MMH) task. Although today the tasks or processes of industries are being mechanized, but still many tasks are performed manually in the rice mills and the worker were sufferings from hazards like, force, awkward postures and repetitive motions that can lead to injuries, energy and time waste. Furthermore it was noted that rice mill workers were using the wooden plank for loading and unloading task which was narrow, short, non static and slippery. It was adjusted on different loading vehicle by using a drum which takes approx 35 min of time period. To avoid these problems, need was felt to redesign and develop a new loading ramp ergonomically which was able to reduce the drudgery of rice mill workers. To test the validity and reliability of pant loading ramp response surface methodology (RSM) was used. Thus the objectives of the present study were to verify the newly developed pant loading ramp by using the RSM statistical technique and to evaluate the relative advantages.

MATERIALS AND METHODS

In this study, the researcher observed the prevailing working environment and tool (wooden plank) for a period of 1 year that was used by the workers. After detailed analysis of wooden plank and it's functionality an urgent need was felt to redesign and development of a new pant loading ramp. Thus newly developed pant loading ramp (length of 19 feet, width of 2 feet and adjustable between 2.5-5 feet) was statistically tested by conducting the experiments of RSM technique and thereafter its acceptability was rated by taking the responses of workers. To fulfil this objective subjects were familiarized with the experimental procedure and some personal and physiological variables of the workers were also taken. For this study ethical approval was taken from ethical committee of G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India.

Subjects: A group of 20 male subjects were recruited. These workers met the following criteria a minimum of 5 year experience, age between 20-30 years, a low lifetime incidents of injuries, involve in loading and unloading of rice sacks and had a good physical fitness. All subjects were belonging to the very low socio-economic status and never received any ergonomic training.

Locale: Study was done in the rice mills of Rudrapur block; district Udham Singh Nagar, Uttarakhand, India.

Response surface methodology (RSM) analysis through box behenkan experiment design

Response surface methodology (RSM) is a collection of mathematical and statistical techniques for empirical model building by careful design of experiments (Sampaio *et al.*, 2006). The objective of RSM is to optimize a response (output variable) which is influenced by several independent variables (input variables) (Alvares, 2000), (Natarajan *et al.*, 2011). Hence, RSM technique was applied to test the efficacy of developed pant loading ramp in terms of energy expenditure (EE), rate of perceived exertion (RPE), total cardiac cost of work (TCCW) and grip strength (GS). Thus to conducting RSM analysis of the loading ramp, the selected process variables (load weight, height of ramp and time) were varied up to three levels. Load weight varied as 40, 50 and 60 kg., height of the ramp as 3, 4 and 5 feet and time was also varied as 3, 4, and 5 min. (Table 2). The Box Behenken design was used for modelling of experiments, where total seventeen experiments were conducted (Table 5).

The selected responses were energy expenditure (EE), total cardiac cost of work (TCCW), rate of perceived exertion (RPE) and grip strength (GS) (Table. 3) that were measured by using the formula and scales described below:

Energy Expenditure (EE) (kJ/min) = 0.159X HR (beats/minute)–8.72

Total Cardiac Cost of Work (TCCW) = CCW+ CCR

Cardiac Cost of Work (CCW) = AHR x Duration

Cardiac Cost of Recovery (CCR) = (Average Recovery HR - Average Resting HR) X Duration.

Grip strength (GS): Grip Strength was measured with the help of Digital Grip Dynamometer. It consists of a handle for handgrip connected with a spring to a pointer on the marked dial. The grip fatigue was measured by asking the subject to pull the grip handle before the start of the activity with right and left hand respectively and readings on the dial in kgs were recorded. Similar procedure was repeated immediately after the completion of the activity. Percentage decrease or increase in grip strength was calculated by the following formula.

$$\textbf{Grip Strength (\%)} = \frac{Sr - Sw}{Sr} \text{ X } 100$$

Sr = Strength of muscle at rest and Sw = Strength of the muscle at work

Rate of Perceived Exertion (RPE): For measuring RPE Borg 5-point scale (**Borg (1998)** was used. i.e., very light –1, light-2, moderately heavy-3, heavy-4, very heavy-5.

Thereafter optimized experiments were designed with the help of design expert 8.06 software. Besides this surfur software 9.0 was also employed for the graphical optimization of the multiple responses. The table, 1, 2, 3 and 4 showed the selected parameters of the study as constant, independent, dependent and process variables with their levels.

Table 1: Constant parameters for optimization

SI. no.	Parameters	Value/name
1	Back loading	-
2	Ramp length (16)	Feet

Table 2: Independent variables for optimization

SI. No.	Parameter	Level	Range
1	Load weight (kilogram)	3	40, 50, 60
2	Height (feet)	3	3, 4, 5
3	Time (minute)	3	3, 4, 5

Design of experiment

Design of experiment is required to extract meaningful conclusions from the measured responses Therefore, the experimental design was performed with the help of design expert 8.06 software and brainstorming approach as shown in Table 4 and 5.

Table 3: Dependent variables for optimization

SI. No.	Parameter	Value/name
1	EE (Energy Expenditure)	kJ/min.
2	RPE (Rate of Perceived Exertion)	%age
3	TCCW (Total Cardiac Cost of Work)	Beats
4	GS (Grip Strength)	%age

Table 4: Process variable and their levels

Independent variable		Codes level		
Name	Code	-1	0	1
		Actual level		
Load weight (kilogram)	X_1	40	50	60
Height of ramp (feet)	X_2	3	4	5
Time (minute)	X_3	3	4	5

Table 5: Experimental designs

Std	Run	Factor X_1 Load weight (kg.)	Factor X_2 Height of ramp (feet)	Factor X_3 Time (minute)
1	17	-1.00	-1.00	0.00
2	14	1.00	-1.00	0.00
3	6	-1.00	1.00	0.00
4	13	1.00	1.00	0.00
5	15	-1.00	0.00	-1.00
6	16	1.00	0.00	-1.00
7	2	-1.00	0.00	1.00
8	7	1.00	0.00	1.00
9	1	0.00	-1.00	-1.00
10	3	0.00	1.00	-1.00
11	10	0.00	-1.00	1.00
12	8	0.00	1.00	1.00
13	9	0.00	0.00	0.00
14	5	0.00	0.00	0.00
15	11	0.00	0.00	0.00
16	12	0.00	0.00	0.00
17	4	0.00	0.00	0.00

Coded value (CV): $\frac{x - mid\ value\ (centre\ point)}{Difference\ (internal\ gap)}$ Eqn. 1

Eqn. 1 showed about the method of calculating coded value

Besides response surface methodology, comparative performance evaluation and relative advantages of pant loading ramp was also assessed by using a developed interview schedule that includes the questions regarding the concept of drudgery reduction, adjustability, anti-slippery, strength and easy handling of loading ramp. Responses were recorded in Yes or No form.

RESULTS AND DISCUSSION

General characteristics of selected rice mill workers

The general characteristics of selected workers for the RSM experiments revealed that the mean±SD of age, height, body weight, body mass index of workers were calculated as 29.03±4.23 years, 162±12.67 cm., 53.65±9.28 kg, and 20.84 ±3.41. The mean±SD of aerobic capacity based on heart rate, BP, pulse rate and body temperature was 39.45 ±5.67 L/min., 117.53/72.15±12/8.4 (systolic/diastolic),76.54±7.56 beats/min. and 96.50 ±2.6^{0}F. Calculated MSD rate was 85.45% by using Nordic questionnaire (Kuroinka *et al.*,1987).

Design and development of pant loading ramp

After need assessment, pant loading ramp was ergonomically designed and developed to reduce the drudgery of rice mill workers which was made of wood and aluminium sheet (small hole were mounted on aluminium sheet). It was 19 feet in length, having width of 1.5 feet, anti-slippery, easy to move due to provision of rotating wheels, adjustable at varying heights of the loading vehicle (between 2.5-5 feet) and reduces the loading time up to 30 minutes. Finally it was found that the designing of loading ramp reduces the preparation time and delivers maximum output with minimum time (Plate 1). In terms of tool designing, Koivunen (1994) reported that the redesign of the tool must base on the problem analysis and user-centered design (Kardborn, 1998; Pheasant, 1996) that also provide a good basis for judgement (Sperling *et al.*, 1993; Kumar, 1994).

Optimization of process parameters using response surface methodology (RSM)

In this study the RSM was applied to optimize the operating parameters (load weight, height of ramp and time) considered during the experiment. ANOVA test was applied to evaluate the adequacy (by applying the lack-of-fit test) of different models and to evaluate the statistical significance of the factors in the model. In order to examine the goodness and evaluate the adequacy of a fitted model, the coefficient of determination (R^2) was calculated. Thereafter surfer software 9.0 was used for the graphical optimization of interaction of selected dependent and independent variables (Pishgar *et al*., 2012).

Front View **Internal view** **Top view** **Side view**

Plate 1: Different views of improved loading ramp

Development of second order model

A complete second mathematical model (Eqn 1) was fitted to the data and adequacy of the model was tested considering the coefficient of multiple determinations (R^2), fisher's F-test and lack of fit. The model was used to interpret the effect of load weight, ramp height and time of load carrying on back on various responses (Table 6) energy expenditure (EE), rate of perceived exertion (RPE), total cardiac cost of work (TCCW) and grip strength (GS). The second order mathematical response function for three independent variables has the following general form:

$$y = B0 \sum_{i=1}^{3} Bi \times i + \sum_{i=1}^{2} \sum_{j=i+1}^{3} Bij \times i \times j + \sum_{i=1}^{3} Bii \times i^2 \qquad \textbf{Eqn. 1}$$

Experimental data were analyzed by employing multiple regression technique to develop response functions and variable parameters were optimized for the best outputs. The regression coefficient of the complete second order model and their significance has been reported (Table 7). High P value indicated that a model had a significant lack of fit and therefore considered to be inadequate. The lower the value of P, better would be model thus model having P value lower than 0.1 were accepted.

Table 6: Experiment data for various responses from RSM technique

Std	Run	Factor X_1	Factor X_2	Factor X_3	Response 1	Response 2	Response 3	Response 4
		Load weight (kilogram)	**Height (feet)**	**Time (minute)**	**EE (kJ/min.)**	**RPE (percent)**	**TCCW (beats)**	**Grip strength (percent)**
1	17	-1	-1	0	10.86	30	676.65	3.22
2	14	1	-1	0	11.35	50	700	7.16
3	6	-1	1	0	10.99	30	536	5.34
4	13	1	1	0	11.65	50	594.04	6
5	15	-1	0	-1	11.63	20	553	5
6	16	1	0	-1	12	45	586.61	5.14
7	2	-1	0	1	11.47	30	796	4
8	7	1	0	1	12.2	40	920.5	6.21
9	1	0	-1	-1	11.81	30	532.84	4.3
10	3	0	1	-1	11.49	45	622.48	6.12
11	10	0	-1	1	11.36	40	746	4.24
12	8	0	1	1	12.96	45	1034.5	7.12
13	9	0	0	0	10.91	40	689.5	5.83
14	5	0	0	0	10.99	45	696	6.45
15	11	0	0	0	11.47	40	715	6
16	12	0	0	0	11.5	45	709	5.57
17	4	0	0	0	10.91	45	689.5	5.6

Table 7: Result of regression analysis for responses from RSM technique

Source	**Energy expenditure (kJ/min.)**		**Rate of perceived exertion (percent)**		**Total cardiac cost of work (beats)**		**Grip strength (percent)**	
	Coefficient	P value	Coefficient	P value	Coefficient	P value	Coefficient	P value
Model	11.156	0.0172	43	0.0035	699.8	0.0552	5.89	0.0387
X_1	0.28125	0.0276	9.375	0.0001	29.9375	0.3514	0.86875	0.0071
X_2	0.21375	0.0731	2.5	0.0838	16.44125	0.6005	0.7075	0.0183
X_3	0.1325	0.2328	1.875	0.1746	150.25875	0.0015	0.12625	0.6019
X_1, X_2	0.0425	0.7756	0	1.0000	8.6725	0.8438	-0.82	0.0405
X1, X_3	0.09	0.5503	-3.75	0.0700	22.7225	0.6087	0.5175	0.1574
X_2, X_3	0.48	0.0123	-2.5	0.1973	49.715	0.2794	0.265	0.4442
$X_{1,2}$	-0.01175	0.9354	-4.625	0.0305	-46.5275	0.2974	-0.40875	0.2403
$X_{2,2}$	0.06825	0.6404	1.625	0.3738	-26.6	0.5404	-0.05125	0.8767
$X_{3,2}$	0.68075	0.0018	-4.625	0.0305	60.755	0.1851	-0.39375	0.2564
R^2	0.8768		0.9246		0.8194		0.8398	
F Value	**5.54**		9.54		**3.53**		4.08	
Lack of fit	**NS**		**NS**		**S**		**NS**	

Effect of independent variables on different responses

When a regression model is fitted using two or more continuous predictors, it's useful to present a graphical visualization of the fitted surface (Lenth, 2012) in the form of contour plot. In a contour plot, two factors at a time can be visualized; the others have to be set to normally at their central values. Thus by response surface methodology, a complete realization of the process parameters and their effects were quantified by developing the contour plot under following heads:

Effect of load weight, height and time on energy expenditure (EE)

Significance of independent variable i.e. load weight, height and time on EE data was tested using ANOVA (Table 8) and total effect on EE was observed (Table 9). Contour plot Fig. 1 A1 depicting the effect of load weight and height on EE, it was observed that EE was found to be increased in linear pattern with the both i.e. ramp height and load weight. Fig. 1 A2 shows the effect of load weight and time on EE, it was observed that only time, affects the EE parameters. Whereas Fig. 1 A3 shows the effect of ramp height and time on EE, it was observed that only time affects the EE of human.

Table 8: ANOVA for energy expenditure (EE) during experiment

Source	df	Sum of square	Mean of square	F Value
Model	9	4.10	0.46	5.54**
Linear	3	1.14	0.38	4.63***
Quadratic	3	0.95	0.31	3.89*
Interactive	3	1.97	0.65	8.01**
Error	7	0.58	0.082	
Total	16	4.64		

***, **, * significant at 1, 5 and 10 % level of significance respectively; F tab value (9,7) = 6.71; F tab value (3,7) = 8.45 (1%); (3,7) = 4.34 (5%); F tab value (9, 7) =2.72; F tab value (3,7) = 3.07 (10%)

Table 9: Total effect of individual parameter on energy expenditure (EE) experiment

Source	df	Sum of square	Mean of square	F Value
Model	9	4.10	0.46	5.54**
Load weight **(x_1)**	4	0.66	0.16	2.04
Height **(x_2)**	4	1.31	0.32	4.01*
Time **(x_3)**	4	3.04	0.76	9.27***
Error	7	0.58	0.082	
Total	19	5.59		

***, **, * significant at 1, 5 and 10 % level of significance respectively; F tab value (9,7) = 6.71; F tab value (4,7) = 7.84 (1%); F tab value (9, 7) = 3.67 ; F tab value (4,7) = 4.12 (5%); F tab value (9, 7) =2.72; F tab value (4,7) = 2.96 (10%)

Effect of load weight, height and time on rate of perceived exertion (RPE)

Significance of independent variable i.e. load weight, height and time on RPE data was tested using ANOVA (Table 10) and total effect on EE was observed (Table 11). Contour plot Fig. 2 A1 depicted the effect of load weight and height on RPE, it was observed that RPE was found to be increased in linear pattern with the both i.e. ramp height and load weight. From Fig. 2 A2, which shows the effect of load weight and time on RPE, it was observed that only load weight affects the RPE parameters. Whereas Fig. 2 A3 shows the effect of ramp height and time on RPE, it was shows that a minimum region at center which is called as saddle point and shows that there is no effect of height and time on RPE.

Table 10: ANOVA for rate of perceived exertion (RPE) during experiment

Source	df	Sum of square	Mean of square	F Value
Model	9	1057.86	117.54	9.53***
Linear	3	781.24	260.41	21.14***
Quadratic	3	81.25	27.08	2.19
Interactive	3	191.23	63.74	5.17**
Error	7	86.25	12.32	
Total	16	1139.97		

***, **, * significant at 1, 5 and 10 % level of significance respectively; F tab value (9,7) = 6.71; F tab value (3,7) = 8.45 (1%); F tab value (9, 7) = 3.67; F tab value (3,7) = 4.34 (5%) F tab value (9, 7) =2.72; F tab value (3,7) = 3.07 (10%)

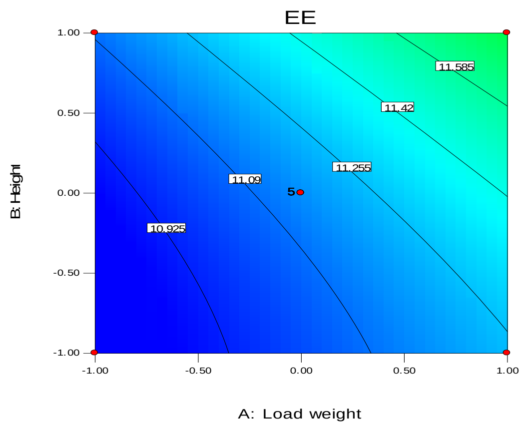
Table 11: Total effect of individual parameter on perceived exertion (RPE) experiment

Source	df	Sum of square	Mean of square	F Value
Model	9	1057.86	117.54	9.53***
Load weight **(x_1)**	4	849.43	212.35	17.24***
Height **(x_2)**	4	86.11	21.52	1.75
Time **(x_3)**	4	199.43	49.85	4.05*
Error	7	86.25	12.32	
Total	19	1221.22		

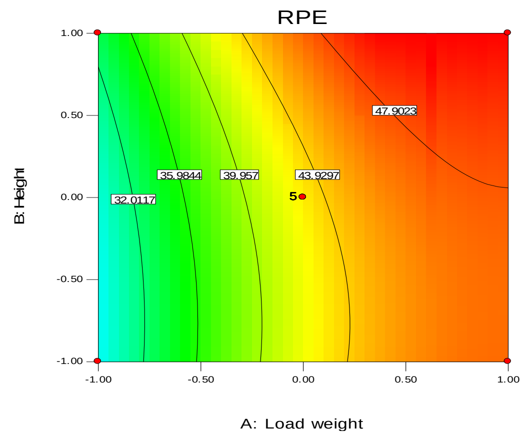
***, **, * significant at 1, 5 and 10 % level of significance respectively tab value (9,7) = 6.71; F tab value (4,7) = 7.84 (1%); F tab value (9, 7) = 3.67; F tab value (4, 7) = 4.12 (5%); F tab value (9, 7) =2.72; F tab value (4 ,7) = 2.96 (10%)

Effect of load weight, height and time on total cardiac cost of work (TCCW)

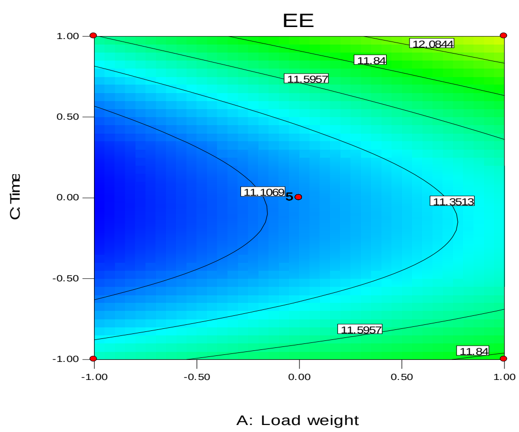
Significance of independent variable i.e. load weight, height and time on **TCCW** data was tested using ANOVA (Table 12) and total effect on EE was observed (Table 13). Fig. 3 A1 of contour plot depicting the effect of load weight and height on TCCW, it was observed that TCCW was minimum affected by the height of the ramp and only load weight affects the individuals TCCW. Fig. 3 A2 shows the effect of load weight and time on TCCW, it was observed that only time affects the TCCW parameters. Whereas Fig 3 A3 shows a minimum region at centre which is called as saddle point and showed that there is no effect of height and time on TCCW.



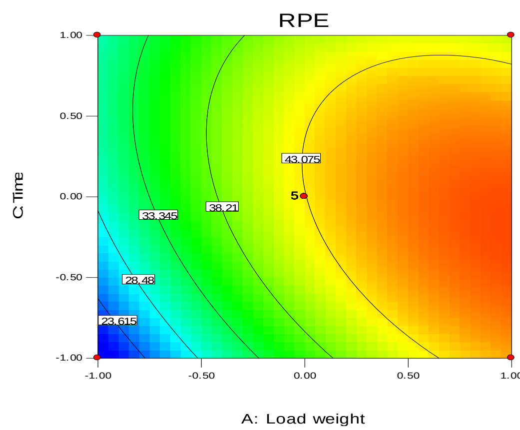
A1: Effect of loadweight and height on EE



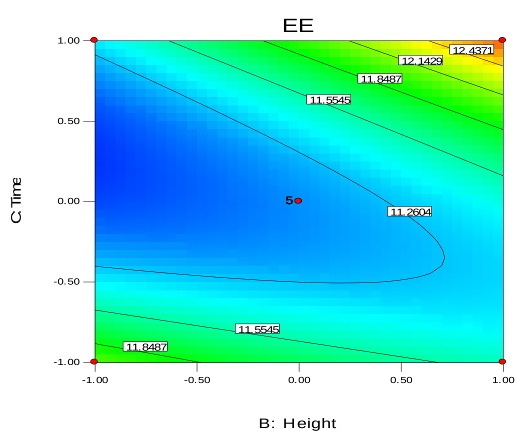
A1: Effect of loadweight and height on RPE



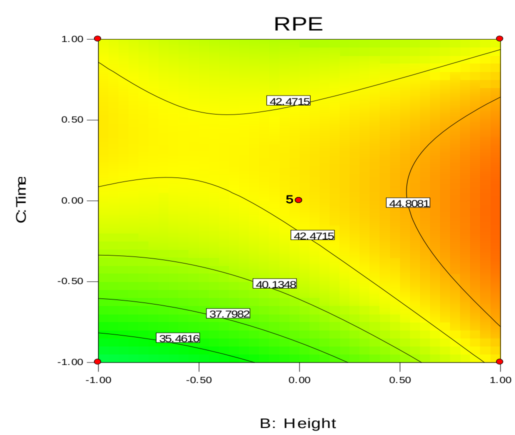
A2: Effect of load weight and time on EE



A2: Effect of load weight and time on RPE



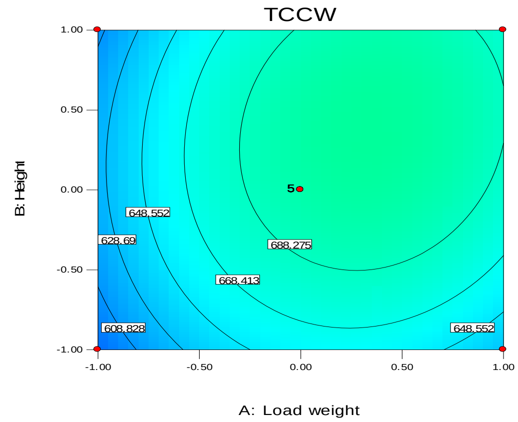
A3: Effect of height and time on EE



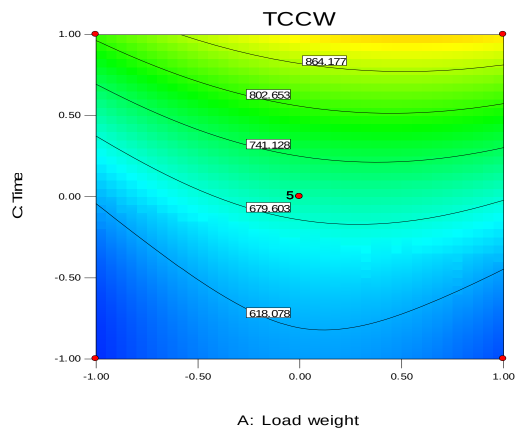
A3: Effect of height and time on RPE

Fig. 1: Contour plots for Energy Expenditure (EE) during experiment

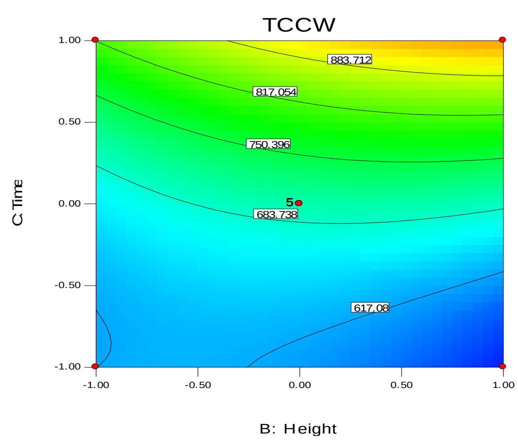
Fig. 2: Contour plots for Rate of Perceived Exertion (RPE) during experiment



A1: Effect of load weight and height on TCCW

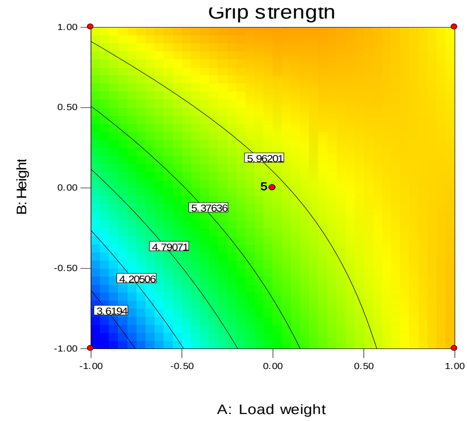


A2: Effect of load weight and time on TCCW

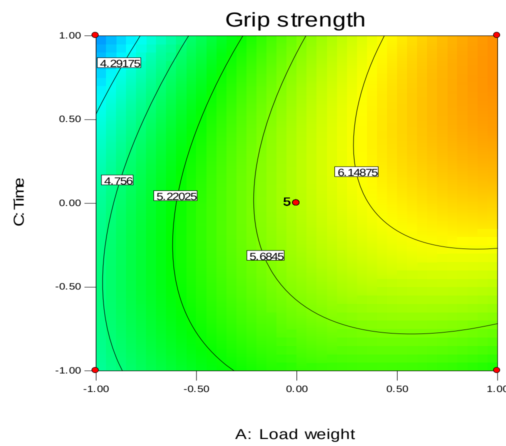


A3: Effect of height and time on TCCW

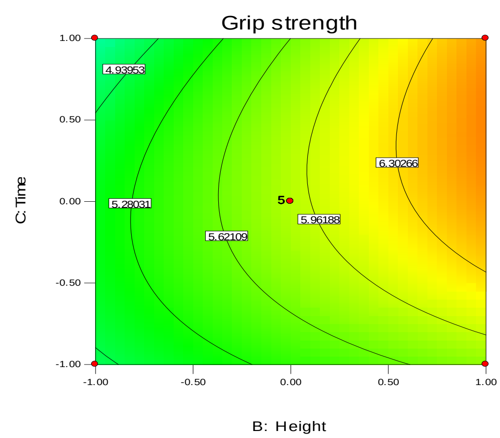
Fig. 3: Contour plots for total cardiac cost of work (TCCW) during experiment



A1: Effect of load weight and height on GS



A2: Effect of load weight and time on GS



A3: Effect of height and time on GS

Fig. 4. Contour plots for grip strength (GS) during experiment

Table 12: ANOVA for total cardiac cost of work (TCCW) during experiment

Source	df	Sum of square	Mean of square	F Value
Model	9	228496.67	15388.51	3.52
Linear	3	189954.07	63318.02	8.80***
Quadratic	3	12252.4	4084.13	0.57
Interactive	3	27635.74	9211.91	1.28
Error	7	50358.60	7194.08	
Total	16	280200.8		

***, **, * significant at 1, 5 and 10 % level of significance respectively; F tab value (9, 7) = 6.71; F tab value (3, 7) = 8.45 (1%); F tab value (9, 7) = 3.67; F tab value (3, 7) = 4.34 (5%); F tab value (9, 7) =2.72; F tab value (3, 7) = 3.07 (10%)

Table 13: Total effect of individual parameter on total cardiac cost of work (TCCW) experiment

Source	df	Sum of square	Mean of square	F Value
Model	9	228496.67	15388.51	3.52
Load weight **(x_1)**	4	1865	4662.77	0.65
Height **(x_2)**	4	15328.87	3832.21	0.53
Time **(x_3)**	4	208114.8	52028.71	7.23**
Error	7	50358.60	7194.08	
Total	19	275667.3		

***, **, * significant at 1, 5 and 10 % level of significance respectively; F tab value (9,7) = 6.71; F tab value (4,7) = 7.84 (1%); F tab value (9, 7) = 3.67; F tab value (4,7) = 4.12 (5%); F tab value (9, 7) =2.72; F tab value (4,7) = 2.96 (10%)

Effect of load weight, height and time on grip strength (GS)

Significance of independent variable i.e. loads weight, height and time on grip strength data was tested using ANOVA (Table 14) and total effect of individual parameters was also observed (Table 15). Contour plot Fig. 4 A1 depicting the effect of load weight and height on grip strength at centre point and it shows that grip strength was increased with load weight rather than height. Whereas Fig 4 A2, also showed the effect of load weight and time on grip strength at centre point and it shows that grip strength was increased with load weight rather than time. Fig 4 A3 shows the effect of time and ramp height on grip strength, it was observed that only height affects the grip strength rather than time.

Table 14: ANOVA for grip strength (GS) during experiment

Source	df	Sum of square	Mean of square	F Value
Model	9	15.68	1.74	4.07**

Linear	3	10.15	3.38	8.05**
Quadratic	3	4.03	1.34	3.20*
Interactive	3	1.36	0.45	1.08
Error	7	2.99	0.42	
Total	16	18.53		

***, **, * significant at 1, 5 and 10 % level of significance respectively; F tab value (9,7) = 6.71; F tab value (3,7) = 8.45 (1%); F tab value (9, 7) = 3.67; F tab value (3, 7) = 4.34 (5%); F tab value (9, 7) =2.72; F tab value (3, 7) = 3.07 (10%)

Table 15: Total effect of individual parameter on grip strength experiment

Source	df	Sum of square	Mean of square	F Value
Model	9	15.68	1.74	4.07**
Load weight (x_1)	4	10.48	2.62	6.23**
Height (x_2)	4	7.61	1.90	4.52**
Time (x_3)	4	2.12	0.53	1.26
Error	7	2.99	0.42	
Total	19	23.2		

***, **, * significant at 1, 5 and 10 % level of significance respectively; F tab value (9,7) = 6.71; F tab value (4,7) = 7.84 (1%); F tab value (9, 7) = 3.67; F tab value (4,7) = 4.12 (5%); F tab value (9, 7) =2.72; F tab value (4,7) = 2.96 (10%)

Optimization of parameters (load weight, height and time) for described responses

Numerical optimization was carried out using design software. The goal was fixed to minimize heart rate, energy expenditure and musculoskeletal disorder. The responses i.e. energy expenditure (EE), rate of perceived exertion (RPE), total cardiac cost of work (TCCW) and grip strength (GS) were taken into consideration for optimization. The goal seeking begins at a random starting point and proceeds up and down the steepest slope on the response surface for a maximum and minimum value of the response respectively. Importance to the responses and independent variables were given on the basis of the objective of the study. Maximum importance was (+++++) was given to time and EE, next importance were given to the TCCW (++++) RPE and GS, while the goal of load weight and height (+++) was kept at in range similar study was also reported by Rai *et al.* (2012). The goal setup and optimum value of different parameters obtained is given in Table 16.

Table 16: Constraints for optimization of parameters

Name	Goal	Lower Limit	Upper limit	Goal setting
Load weight	in range	-1	1	+++
Ramp height	in range	-1	1	+++
Time	minimum	-1	1	+++++
Energy expenditure (EE)	minimum	-1	1	+++++
Rate of perceived exertion (RPE)	minimum	-1	1	++++
Total cardiac cost of work (TCCW)	minimum	-1	1	++++
Grip strength (GS)	minimum	-1	1	++++

Table 17: Optimum values of parameters for experimentation of loading ramp

Value	Load weight (kg.)	Height (feet)	Time (minutes)	EE (kJ/min.)	RPE (%)	TCCW (beats)	Grip strength (%)	Desirability
Coded	-1	-1	-.71					
Actual	40	3	3.29	11.41	20.00	564.36	3.30	0.84

During optimization 17 solution were obtained, out of which the most suitable criteria, was selected. The selected solution was tested for the actual conditions and it was observed out of three independent variable optimum results were obtained when the load weight 40 kg., height 3 feet and time 3.29 minute (Table 17) which shows the reduction of energy expenditure from 14.55 kJ/min. to 11.41 kJ/min., RPE from 85.45 to 20 %, TCCW from 996.3 to 564.36 beats and GS from 47.45 to 3.30 % with overall desirability of 0.84 %. Hence, this combination shows the maximum efficiency with minimum time, energy, TCCW and grip strength by working with loading ramp. Similarly Pandey and Vinay (2016) in a study of RSM on use of pant loading ramp reported that it was able to reduce heart rate of selected respondent's from 135.4 beats/min. to 126.76 beats/min., MSD from 85.45 to 22.80 % and VO2 max from 39.45 to 34L/min. Similarly Aruna and Dhanalaksmi (2012) optimized the surface roughness when turning Inconel 718 with cermet inserts by using response Surface Method (RSM). Optimized machining parameters are validated experimentally, and it is observed that the response values are in reasonable agreement with the predicted values. Kumar *et al.* (2013) used RSM to determine the optimum machining parameters leading to minimum surface roughness and maximum metal removal rate in Surface grinding process.

Comparative performance of the pant loading ramp and existing wooden plank.

Use of developed loading ramp was able to reduce average energy expenditure of selected respondents from 14.55±3.12 to 11.41±1.10 kJ/min.., peak energy expenditure from 16±1.36 to 12±0.32 kJ/min., rate of perceived exertion from 85.45±8.43 to20±2.1 %, grip strength from 47.45±2.14 to 3.30±0.27 % and TCCW from 996.3±5.45 to 564.36±3.41beats. It means the energetic workload and perceived discomfort of the respondents in different body regions differ significantly for the use of both traditional and developed loading ramp.

Table 18: Comparative evaluation of pant loading ramp and existing wooden plank

S. No.	Physiological parameters	Wooden plank (Mean±SD)	Pant Loading ramp (Mean±SD)
1	Average Energy Expenditure (AWHR) (kJ/min)	14.55±3.12	11.41±1.10
2	Peak Energy Expenditure (PEE) (kJ/min.)	16±1.36	12±0.32
3	Rate of Perceived Exertion (RPE) (%)	85.45±8.43	20±2.1
4	Grip Strength (GS) (%)	47.45±2.14	3.30±0.27
5	Total cardiac cost of work (TCCW) (Beats)	996.3±5.45	564.36±3.41

Relative advantage regarding pant loading ramp

Relative advantages of pant loading ramp was evaluated on the basis of five parameter and the figure below depicted that 92.57 % respondents were satisfied with the drudgery reduction concept of ramp and all the respondents were believed that the improved loading ramp was adjustable and anti-slippery. While, 85.6 % workers were satisfied that the strength of loading ramp was good. Furthermore 96.45 % respondents revealed that ramp was very easy to handle from one place to another because of light weight and provision of rotating wheel.

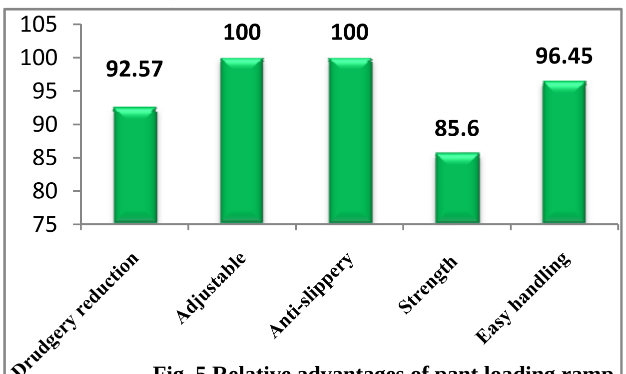


Fig. 5 Relative advantages of pant loading ramp

CONCLUSION

In conclusion it was observed that use of pant loading ramp was able to reduce Energy Expenditure (EE) of respondents' from 14.55 kJ/min. to 11.41 kJ/min., Rate of

Perceived Exertion (RPE) from 85.45 to 20 %, Total Cardiac Cost of Work (TCCW) from 996.3 to 564.36 beats and Grip Strength (GS) from 47.45 to 3.30 % with overall desirability of 0.84 %. Hence, this combination shows the maximum efficiency with minimum time, energy and psychophysical discomfort was obtained by loading ramp. In comparison with traditional method it was also found to reduce Average Working heart Rate (AWHR) (14.55-11.41), Peak Energy Expenditure (PEE) (16-12), Rate of Perceived Exertion (RPE) (85.45-20), Grip Strength (GS) (47.45-3.30) and Total Cardiac Cost of Work (TCCW) (996.3-564.35). Relative advantages showed that more than 95 % users were highly satisfied and found it advantageous.

REFERENCES

Genaidy, A. M.; Christensen, D.M.; Nogiates, C. and Deraireh, N. (2003). What is heavy? *Journal of Ergonomics*, 41 (4): 420-432.

Edlich, R.F., Hudson, M.A., Buschbacher, R.M., Winters, K.L., Britt, L.D., Cox, M.J., Becker, D.G., McLaughlin, J.K., Gubler, K.D. and Zomerschoe, T.S. et al. (2005). Devastating injuries in healthcare workers: Description of the crisis and legislative solution to the epidemic of back injury from patient lifting. *Journal of Long Term Effects of Medical Implants*, 15: 225-241.

Hoozemans, M.J., van der B, A.J., Frings, D.M.H., van Dijk, F.J. and van der Woude, L.H. (1998). Pushing and pulling in relation to musculoskeletal disorders: A review of risk factors. *Journal of Ergonomics*, 41: 757-781.

Health and Safety Authority. (2007). HSA summary of injury illness and fatality statistics 2005-2006.

Health and Safety Statistics (2012). Musculoskeletal disorders (MSDs) in Great Britain (GB).

Sampaio, F.C., Defaveri, D., Mantovani, H.C., Passos, F.M.L., Perego, P. and Converti, A. (2006). Use of response surface methodology for optimization of xylitol production by the new yeast strain debaryomyces hansenii UFV-170. *Journal of Food Engineering*, 76: 376-86.

Alvarez, L.E. (2000). Approximation model building for design optimization using the RSM and genetic programming, Ph.D. thesis, department of civil and environmental engineering, university of brandford, UK. 2000.

Natarajan, U., Periyanan, P.R. and Yang, S.H. (2011). Multiple-response optimization for microend milling process using response surface methodology. *The international Journal of advanced Manufacturing Technology*, 56 (1-4) 177.

Borg, G. (1998). Borg's perceived exertion and pain scales. Human Kinetics:Champaign, IL.

Kuorinka, A. *et al.* (1987). Participation in workplace design with reference to low back pain: a case for the improvement of the police patrol car. *Ergonomics,* 37 (7):1131-1136.

Koivunen, M.R. (1994). Actor Tools: tools for user interface modelling, developing and analysis. Acta Polytechnica Scandinavica, Mathematics and Computing in Engineering Design, 69, Helsinki.

Kardborn, A. (1998). Inter-organizational participation and user focus in a large-scale product development programme: The Swedish hand tool project. *International Journal of Industrial Ergonomisc*, 21: 369-381.

Pheasant, S.T. (1996). Body space: anthropometry, ergonomics and design of work, 2nd edition, Taylor & Francis, London.

Sperling, L., Dahlman, S., Wikström, L., Kilbom, Å. and Kadefors, R. (1993). A cube model for the classification of work with hand tools and the formulation of functional requirements. *Journal of Applied Ergonomics*, 24 (3): 212-230.

Kumar, S. (1994). A conceptual model of overexertion, safety and risk of injury in occupational settings. *Human Factors*, 36: 197-209.

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

Lenth, R.V. (2012). Surface plots in the RSM package.

Rai, A. (2012). Ergonomic evaluation of conventional and improved methods of aonal priking. Unpublished M.Sc. Thesis, Deptt. of Family Resource Management, CCS Haryana Agriculture University Hissar, India.

Pandey, K. and Vinay, D. (2016). Optimization of the process parameters in rice mill using response surface methodology (RSM). *Journal of Applied and Natural Science* 8 (3): 1267–1277.

Aruna M. and Dhanalaksmi V. (2012). Design optimization of cutting parameters when turning inconel 718 with cermet inserts. *International Journal of Mechanical and Aerospace Engineering*, 6: 187-190.

Kumar, P., Kumar, A. and Singh, B. (2013). Optimization of Process Parameters in Surface Grinding Using Response Surface Methodology. International Journal of Research in Mechanical Engineering & Technology, 2 (2):245-252.