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Analysis of Load Constant in Manual Material Handling Task by Taguchi Technique & Mathematical Regression Modeling

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Abstract: *Now a day, the working in the industries is not as comfortable as they were in the earlier time. The man power is decreasing day by day and new recruitments are not in the same ratio as the person leaving industries. This in turn increases the work load on the present employees. It has been seen that the workers are not assigned to the appropriate machine according to their physical aspects and strength. This causes an uneven distribution of work in the industries, which in turn causes severe physical problems to the employees and also decreases the productivity of industry. The purpose of this paper is to efficiently determine the optimum combination of three parameters (Worker age, Worker weight and strength) for mitigate the load constant of the worker, the researcher have used the Taguchi parameter optimization methodology, and finally the Modeling of input parameters (Worker age, worker weight and strength) and output parameter (Load constant) is done using regression modeling and MATLAB Software R2011b. With the help of mathematical modeling one can select the appropriate person for a particular load for a particular work to minimize the fatigue of worker in the industry.*

Keywords: *Manual Material Handling, Load Constant, Regression Modeling, Taguchi Techniques.*

I. Introduction

Manual Material Handling (MMH) including lifting, lowering, pushing, pulling, twisting, carrying and holding is a regular task that almost everyone performs every day. There are kinds of injuries and disabilities associated with MMH tasks, among which Low back disorders (LBDs) are the most common of all musculoskeletal disorders and are a major health and socioeconomic problem in the western world (Woolf and Pfleger, 2003). According to Punnett et al (2005) about 37% of all LBDs are directly attributable to occupational risk factors (RFs). Thus identifying and preventing risk of LBD is the most significant problem complained by workers and it is still a hard topic for researchers (Kuiper et al., 1999). Many researchers have developed tools and techniques for identify jobs which are associated with risk of LBD (Ciriello & Snook, 1999; Marras, 2000; Marras, Fine, Fergusan, & Waters, 1999; Zurada, Karwowski, & Marras, 1997). Chaffin and Park (1973) developed a lifting strength ratio (LSR) and demonstrated its relationship to LBD. LSR was defined as the ratio of the maximum load lifted on the job and lifting strength in the same load position for a large/strong man. Snook (1978) defined MMH limits for lifting, lowering, pushing, pulling and carrying activities based on psychophysical criteria. In 1981 the National Institute for occupational Safety and Health (NIOSH), a US federal agency recognized the problems related to lower back injuries and published the Work Practices Guide for manual lifting. This contained a summary lifting related literature before 1981, and guidelines are also given for lifting (Ayoub, Selan, Jiang, 1983).

In this MMH area load that lifted by the person is play important role LBD problem. Load is also known as load constant it is load that is lifted by worker without any musculoskeletal problem. NIOSH (1991) is set the value of load constant, which is 23 kg., but researcher are going to find that it may change with age, weight and strength of worker. In this paper researchers derive a formula for calculating load constant for the worker which is assign for the lifting work.

For calculating the load constant researcher applied the Taguchi Optimization Technique and calculates the load constant according to worker's age, worker's weight and strength of worker. Taguchi methodology is described in next chapter.

II. Taguchi Methodology

Taguchi method is a powerful methodology/ technique for the design of high quality systems (Taguchi, 1990) and has been widely used in engineering design (Ross, 1988). Taguchi design provides a simple, efficient and systematic approach to optimize design for performance, quality and cost over a verity of conditions. Taguchi steps are shown in figure 1 for present research work.

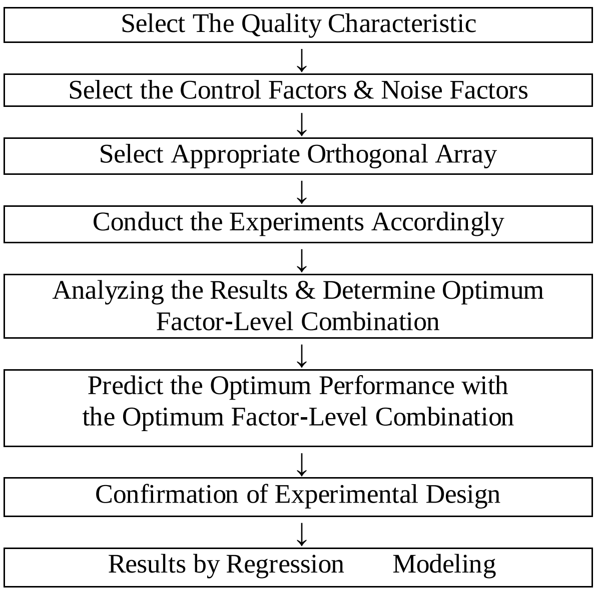

Figure 1: Steps of Taguchi Method

2.1 Design of Experiment

The experimental design was done according to L9 orthogonal array based on the Taguchi method. The use of Taguchi orthogonal array would evidently reduce the number of experiments. The L9 orthogonal array had three columns and nine rows, so it had six degrees of freedom to manipulate three parameters with three levels as indicated in Table 1. Thus, in this investigation three parameters with three levels were indicated in Table 2.

Table 1: Orthogonal L9 Array of Taguchi

Experiment S.No.	Parameters		
	1	2	3
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	3
5	2	2	1
6	2	3	2
7	3	1	2
8	3	2	3
9	3	3	1

Table 2: Process Parameters and their Levels

S. No.	Process Parameter	Process parameter	Levels		
			Lower 1	Medium 2	Higher 3
1.	A	Age of Worker (yrs)	20-35	36 -50	51-65
2.	B	Weight of Worker (Kg)	50- 59	60 -69	70 -80
3.	C	Worker's Strength (Newton)	2	3	4

For this research work, researchers visited to S. & H. Gears Dewas (M.P.) and collect data which are require for the research these are shown in Table 3. This data is randomly selected among the workers of company which represent random age group, weight and strength.

Table 3: Data Collected from the Industry

S. No.	Name	Age (yrs)	Weight (kg)	Strength (Newton)	LC (kg)
1.	R.K.Dewedi	35	56	2	28
2.	Bharat Pandit	34	62	3	34
3.	Dharmendra Sharma	26	80	4	50
4.	Kishore Kale	45	57	4	44
5.	Ramesh kohle	48	60	2	29
6.	Prakash Carpenter	47	75	3	36
7.	Kamal Singh	51	50	3	39
8.	K.S.Hada	53	65	4	41
9.	K.K.Dev	52	74	2	23

III. Taguchi Parametric Optimization technique

The collected data are arranged according to L9 array. As per the Taguchi Technique the Quality characteristic utilized in the research is larger the Better. Researchers have calculated Load Constant, Mean Slandered Deviation (MSD) of Load Constant and Signal to Noise Ratio (S/N) for analysis of the data. Following formula is used for calculation of larger the better. Data analysis is shown in table 4.

$$MSD = (1/Y1^2 + 1/Y2^2 + 1/Yn^2 \ldots\ldots) / N$$

$$S/N = -10 \log_{10} (MSD)$$

Table 4: Data Analysis

S. No.	Worker age	Worker Weight	Strength (Newton)	LC	MSD	S/N ratio
1.	L	L	L	28	1.275×10^{-3}	28.94
2.	L	M	M	34	8.650×10^{-4}	30.62
3.	L	H	H	50	4×10^{-4}	33.97
4.	M	L	H	44	5.165×10^{-4}	32.86
5.	M	M	L	29	1.189×10^{-3}	29.24
6.	M	H	M	36	7.716×10^{-4}	31.12
7.	H	L	M	39	6.574×10^{-4}	31.82
8.	H	M	H	41	5.948×10^{-4}	32.25
9.	H	H	L	23	1.890×10^{-3}	27.23

3.1 Load Constant (LC)

The analysis of each controllable parameter is done and the effects of each parameter at individual level (i.e. at 1, 2, 3 levels) is shown in Table 5. This analysis is shows that at the lower age, man having the higher strength and vice-versa.

(a) Case 1: The main effect of the worker age on Load Constant at various level is calculated as follows:

For lower level:

$(28 + 34 + 50) / 3 = A_1 = 37.33$

For medium level

$(44 + 29 + 36) / 3 = A_2 = 36.33$

For higher level

$(39 + 41 + 23) / 3 = A_3 = 34.33$

(b) Case 2: The main effect of worker's weight at various levels are calculated as:

For lower level

$(28 + 44 + 39) / 3 = B1 = 37$

For medium level

$(34 + 29 + 41) / 3 = B2 = 34.67$

For higher level

$(50 + 36 + 23) / 3 = B3 = 36.33$

(c) Case 3: The main effect of the Strength at various levels are calculated as:

For lower level

$(28 + 29 + 23) / 3 = C_1 = 26.67$

For medium level

$(34 + 36 + 39) / 3 = C_2 = 36.33$

For higher level

(50 + 44 + 41) / 3= C3= 45

Table 5: Factors Effect Table for Load constant

Symbol	Controllable Factors	Level 1 Lower	Level 2 Medium	Level 3 Higher
A	Worker's Age	**37.33 (A1)**	36.33 (A2)	34.33 (A3)
B	Worker's Weight	**37 (B1)**	34.67 (B2)	36.33 (B3)
C	Strength	26.67 (C1)	36.33 (C2)	**45 (C3)**

The values in bold in table 5 show the Larger the better criteria as proposed by Taguchi method. The value obtained from table 5 are plotted to visualize the effect of the three parameters at three levels on mean response graph which is shown in figure 2.

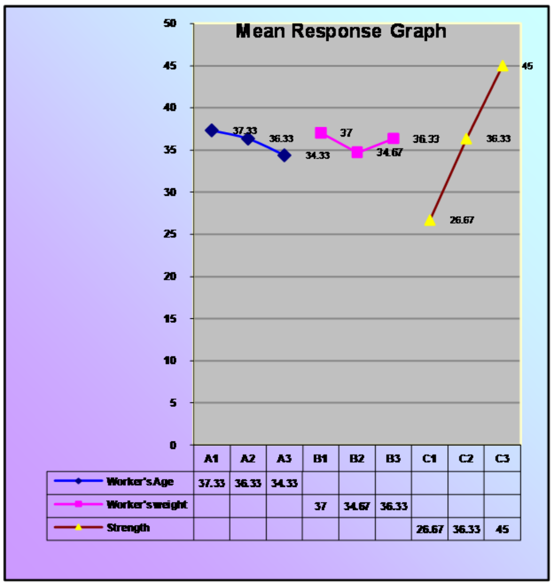

Figure 2: Mean Response Graph

3.2 Analysis of Signal to Noise (S/N) Ratio

According to the Taguchi approach, the term signal represents the desired value (mean) for the output characteristics and term noise represent the undesirable value (standard deviation) for the output characteristics. Therefore S/N ratio is the ratio of mean to the standard deviation. Taguchi uses the S/N ratio to measure the quality characteristics deriving from desired value. The S/N ratio is defined as given equation.

For Higher the better

It is when the occurrences of some undesirable product characteristics are to be maximized. It is given by

S/N = -10 log ((Σ1/ yi2)/N……….

All the three level of every factor are equally represented in the nine experiments. S/N ratio and Load Constant for each parameter at each level and Load Constant for each of the Parameters at each level is calculated. These also called as main effects.

Table 6: Effect of S/N, corresponding to chosen parameters

Symbol	Controllable Factors	Level 1 Lower	Level 2 Medium	Level 3 Higher
A	Worker's Age	**31.17**	31.07	30.43
B	Worker's Weight	**31.20**	30.70	30.77
C	Strength	28.25	31.18	**33.02**

The values in bold in table 6 show the Larger the better criteria as proposed by Taguchi method. The value obtained from table 6 are plotted to visual seize the effect of the three parameters at three levels on mean response graph which shown in figure 3.

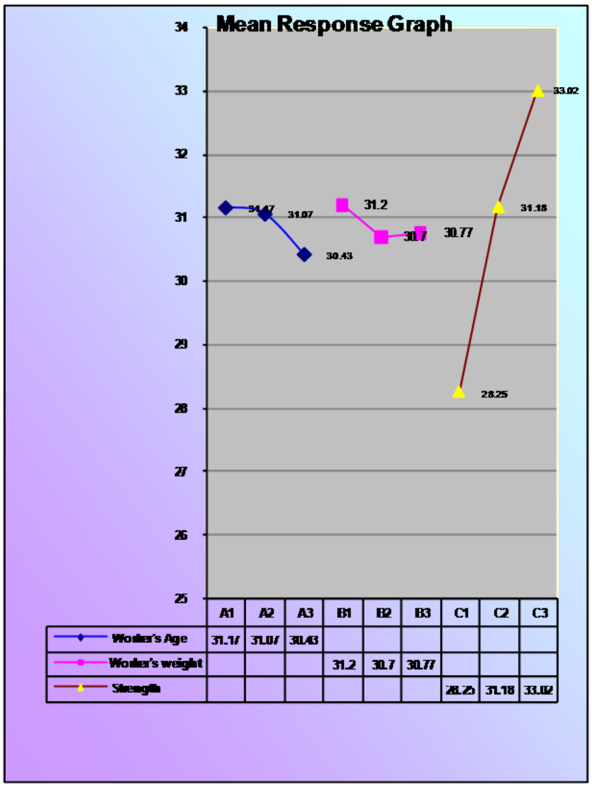

Figure 3: Mean Response Graph for S/N Ratio

IV. Mathematical Regression Modeling

Defining the formula of load constant, researchers use the regression modeling techniques. Previously, Load constant is tabulated as per combination of parameters. Empirical formula has going to be drawn in following steps.

4.1 Modeling of Parameters

To generalize the results, the Modeling of input parameters (Age of Worker, Weight of Worker and strength) and Load constant is done using Regression modeling with MATLAB software R2011b.

The parameters under consideration are

1. Age of worker.
2. Weight of Worker
3. Strength of worker

The regression analysis has been adopted. Load constant(LC) has been taken as single output parameter (Y) whereas Age of worker (X_1) and Weight of Worker (X_2) and strength (X_3) has been taken as input parameter X = [X_1, X_2, X_3]. The Load Constant is a function of Worker Age, Worker weight and Strength.

LC α Worker Age * Component weight * Strength

LC = (Worker Age)^{C_1} *(Worker weight)^{C_2} *(Strength)^{C3}

L_n (LC) = $C_1 l_n$ (Worker age) + C_2 l_n (Worker weight) + C_3 l_n (Strength)

Where, C_1, C_2, C_3 are constants which are to be determined by Regression Modeling and using MATLAB software R2011b. The following results were obtained.

C_1 = 0.1563; C_2 = 0.5149; C_3 = 0.7840

Putting these values the equation becomes.

LC = $(W_a)^{0.1563}$ * $(W_w)^{0.5149}$ * (Strength)$^{0.7840}$

Here Wa is Age of Worker,
Ww is Weight of Worker.
LC is load constant.

V. Summary

Finally a formula is obtained for load constant by the application of Taguchi Methodology and Mathematical Regression Modeling the researchers have find out a way to calculate the correct load constant of the correct person. By using this formula problem of LBD is minimized in all kinds of industry where manual material handling is done.

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