Design of Blue Pottery Working Table for Indian Population Using Taguchi Approach

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Abstract - Blue pottery has been one of the famous art of India for last five centuries. A large number of workers from blue pottery industry left their jobs because of work related problems. A significant population of the workers are working in poor postures which have high risk of Musculoskeletal disorders (MSDs) and is one of the main reason for absenteeism and leaving the profession of blue pottery manufacturing. Worker's posture can be improved by optimizing design of workstation according to their anthropometric dimensions. The aim of this paper is to optimize the design of blue pottery working table for Indian population. Taguchi Design of Experiment method is used for optimization. Height of the Table, Table width, Arm length and Shoulder height of the workers have been used as critical parameters for this purpose. Delmia V5 was used to evaluate the designed table for different Indian populations.

Keywords: Blue pottery, Workstation, Design of Experiments (DOE), Musculoskeletal disorders (MSDs)

1. Introduction

Blue pottery manufacturing is one of the famous art in India, very old profession employing many people. As an unorganized sector, no statistical data are available to date such as the number of people employed, accident rates, and other problems. There were four main steps involved in blue pottery manufacturing process. 1) Pottery Making 2) Designing & Painting 3) Glazing and 4) Firing. The pottery making activity involves rolling of dough, filling the mould with rolled dough, removing unwanted dough from edges, filling it with ash which helps in retaining its shape in mould and staking it for drying and for this worker is required to work in different awkward postures as show in the Figure (1).

Fig. 1: Awkward postures of the workers in the pottery making.

The industrial classification of bricks, pottery, glass and cement has been identified to pose greater risk of inflammation of tendons of the hand, forearm or associated tendon sheaths [1]. Further, the awkward posture shown in Figure (1) leads to musculoskeletal disorders [2] thereby decline in productivity and quality of life [3]. Hence it is required to design a working table for this kind of activities to eliminate the awkward posture of the workers. The objective of this paper is to design a working table for blue pottery manufacturing using anthropometric analysis and taguchi approach.

2. Body Part Discomfort Assessment

For this assessment 30 male workers are selected using convenient sampling. Based on the Body Part Discomfort [4] survey, the occupation related body pains experienced by the blue pottery workers were identified. According to survey there were no parts of the body that had no discomfort at all ie. all parts have been affected to some extent, low or high. Table 1 shows the list of body parts experiencing discomfort by the blue pottery workers and the percentage of those who experienced it. It was found that 100 % of workers experienced the discomfort in the lower back and knee. The least experienced discomfort was pain at neck and legs, with 62.5%.

Table 1: Percentage Workers Experiencing Pain.

Body Part	No. Of Workers With Discomfort	% Of Workers With Discomfort
Neck	15	62.5
Shoulders	27	92.5
Wrist	28	95
Elbows	29	97.5
Forearms	25	87.5
Upper back	29	95
Lower back	30	100
Knee	30	100
Feet	29	97.5
Leg	06	40

Body part discomfort survey is valuable indicator of mismatch between the task and worker [3]. Hence to fit the job to the worker, it is required to design the workstation according to the worker anthropometry.

3. Design of working table: Taguchi approach

For designing the working table for blue pottery workers using Taguchi approach, five levels (5th, 25th, 50th, 75th and 95th) of anthropometry data was used as shown in the table (2). Shoulder height, Arm length, table width and Table height are taken as the critical parameters which influence the arm reach over the working table. The modified arm reach equation [5] was used as the response equation i.e.

$$\text{Theoretical Response, R (mm)} = C - \sqrt{B^2 - (A - D)^2} \tag{1}$$

Where A= shoulder height, B= arm length, C = Table width and D= Table height. Any change in the height (eg. increase in height will result in arms raised) and width (eg. increase in width will result in bending of trunk forward) of working table will influence the efficiency. However, the effect of change in length is negligible and has not been considered as the worker can walk along the length of working table.

Table 2: Five levels of variation in critical parameters.

Parameters		Levels				
		L1 (5th %)	L2 (25th %)	L3 (50th %)	L4 (75th %)	L5 (95th %)
Shoulder Height(A)	(mm)	1271	1338	1381	1420	1485
Arm Length (B)		549	571	588	596	618
Table width (C)		615	642	662	671	693
Table Height(D)		920	978	1014	1047	1098

Minitab-16 was used to apply the Taguchi's Design of Experiment method to analyze the working table interface. L25 orthogonal array was select by degree of freedom approach for five level and four critical control parameters with no noise level. Table 3 shows the L25 orthogonal array with theoretical response (Reach). S/N ratio is calculated even though there is no noise parameter. Table 4 shows Analysis of Variance for SN ratios to optimize the design parameters. As the goal is to minimize the response "smaller is better" signal to noise ratio is selected.

Table 3: L25 Orthogonal array indicating critical parameters and reach.

Shoulder Height (mm)	Arm Length (mm)	Table Width (mm)	Table Height (mm)	Arm reach (mm)
1271	549	615	920	1037.14
1271	571	642	978	1132.09
1271	588	662	1014	1190.86
1271	596	671	1047	1223.30
1271	618	693	1098	1286.29
1338	549	642	1014	1085.20
1338	571	662	1047	1153.28
1338	588	671	1098	1207.79
1338	596	693	920	1117.84
1338	618	615	978	1117.32
1381	549	662	1098	1132.44
1381	571	671	920	1007.93
1381	588	693	978	1121.18
1381	596	615	1014	1084.60
1381	618	642	1047	1161.97
1420	549	671	978	996.63

Shoulder Height (mm)	Arm Length (mm)	Table Width (mm)	Table Height (mm)	Arm reach (mm)
1420	571	693	1014	1094.50
Shoulder Height (mm)	**Arm Length (mm)**	**Table Width (mm)**	**Table Height (mm)**	**Arm reach (mm)**
1420	588	615	1047	1069.55
1420	596	642	1098	1143.53
1420	618	662	920	1025.21
1485	549	693	1047	1023.99
1485	571	615	1098	1034.85
1485	588	642	920	804.85
1485	596	662	978	975.32

In the Table (4), analysis of variance for SN ratios are tabulated and it is found that SN ratio for shoulder height and table length factors and the interaction terms are significant at an α-level of 0.10. For means, all the factors and the interaction terms are significant at an α-level of 0.10. Figure (2) and Figure (3) shows the Main Effect Plot for SN ratios and main effect plot for means respectively.

Table 4: Analysis of Variance for SN ratios.

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Shoulder Height	4	7.2989	7.2989	1.8247	16.78	0.001
Arm Length	4	1.1355	1.1355	0.2839	2.61	0.116
Table Width	4	0.9279	0.9279	0.2320	2.13	0.168
Table Height	4	5.2732	5.2732	1.3183	12.12	0.002
Residual Error	8	0.8699	0.8699	0.1087		
Total	24	15.5054				

Hence the optimum design values for "smaller is better" are shoulder height as 1485mm, Arm length as 549mm, table width as 642mm and table height as 920mm. To evaluate the optimized design Delmia V5 Ergonomics design and analysis module was used in which the table is designed according to the optimized table height and table width dimensions and the manikins of 5th, 25th, 50th, 75th and 95th percentile are used respectively for ergonomic analysis.
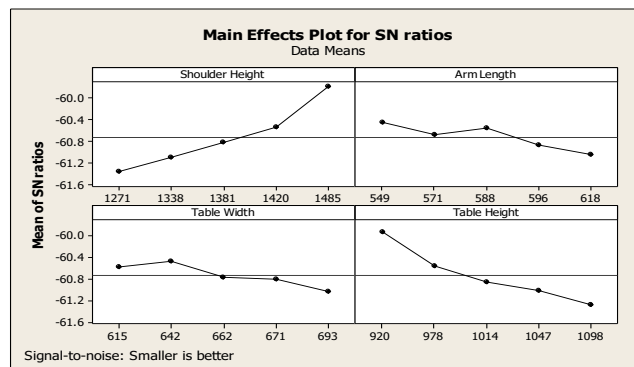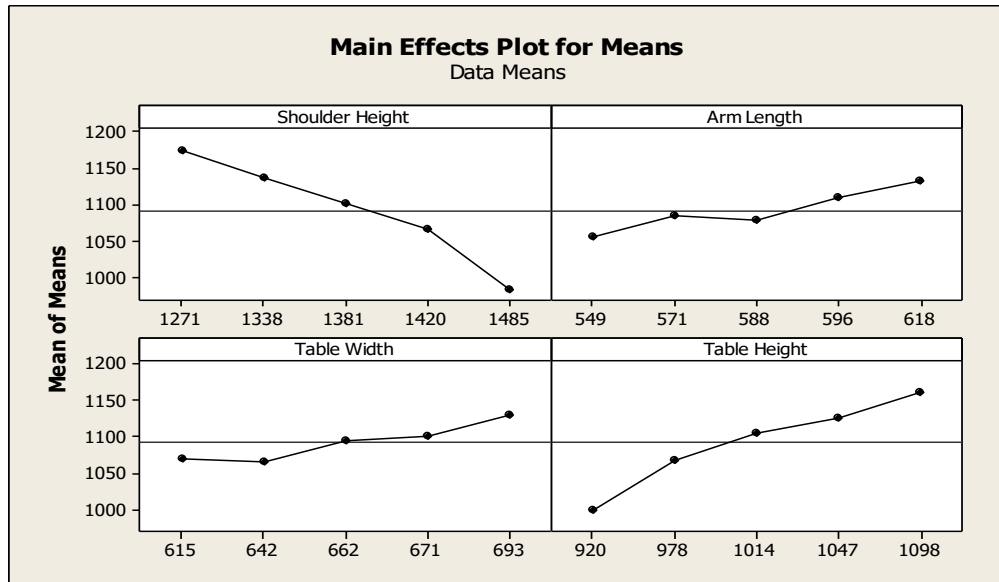

Fig. 2: Main Effect Plot for SN ratios.
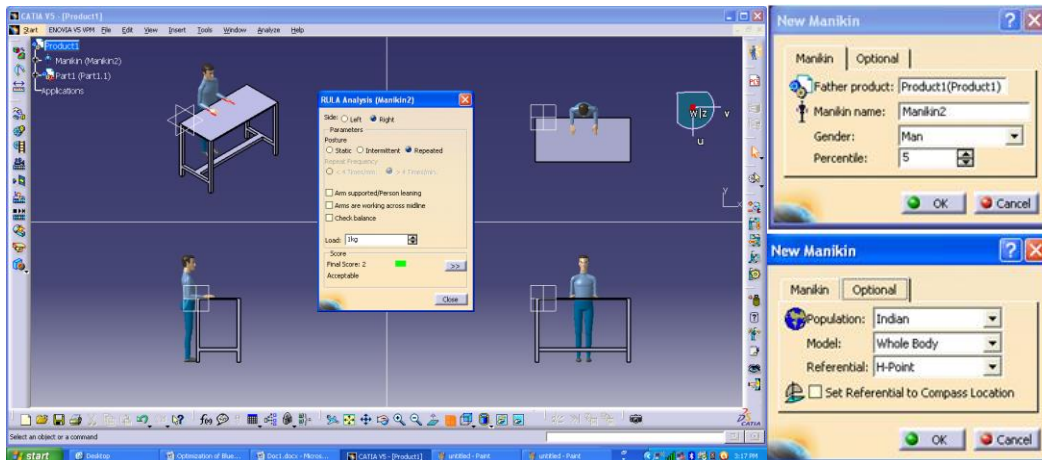
Fig. 3: Main Effect Plot for Means.

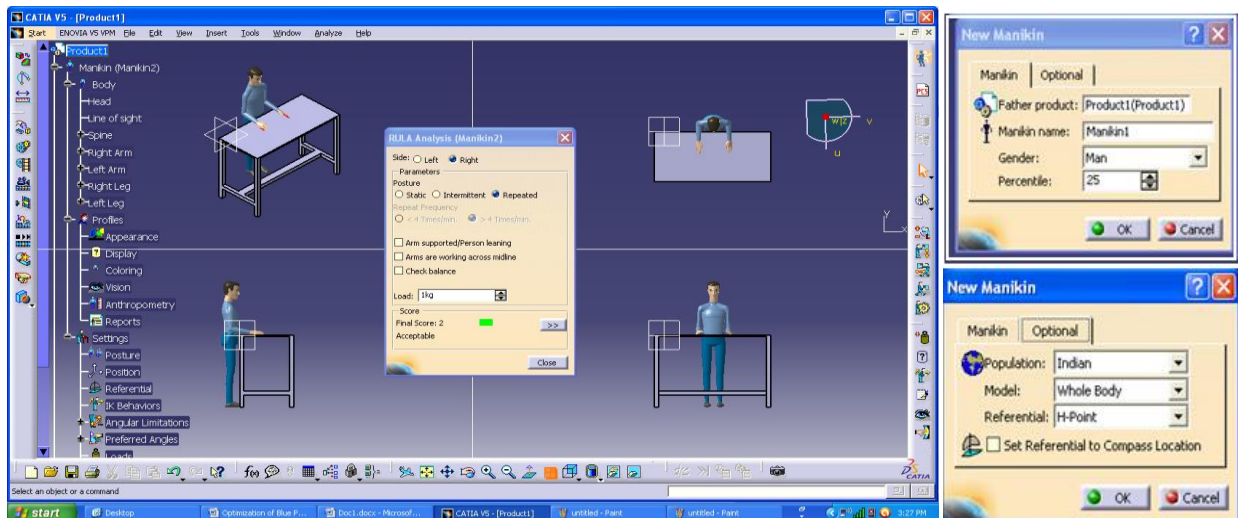Fig. 4: Manikin of 5th percentile of Indian population on optimized working table with RULA score.

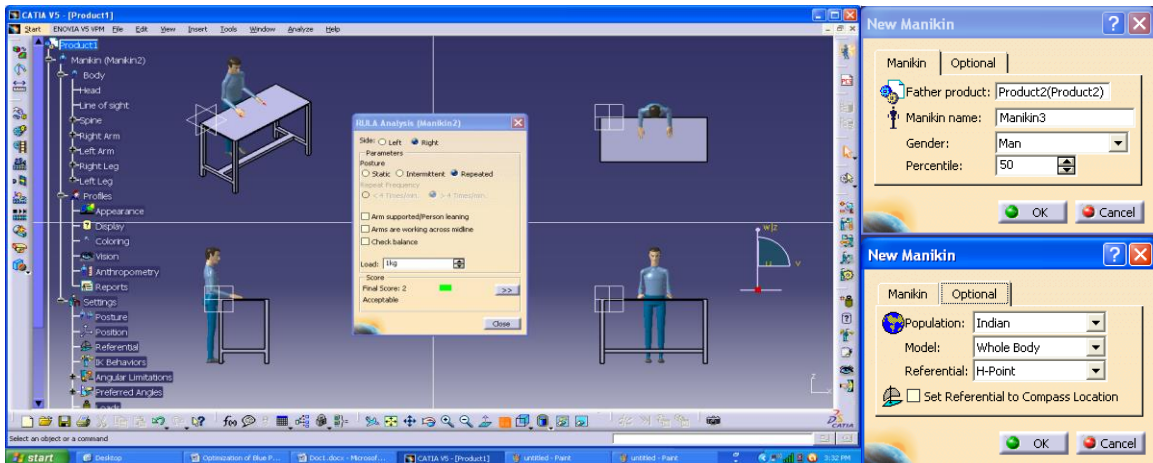Fig. 5: Manikin of 25th percentile of Indian population on optimized working table with RULA score.

Fig. 6: Manikin of 50th percentile of Indian population on optimized working table with RULA score manikin.

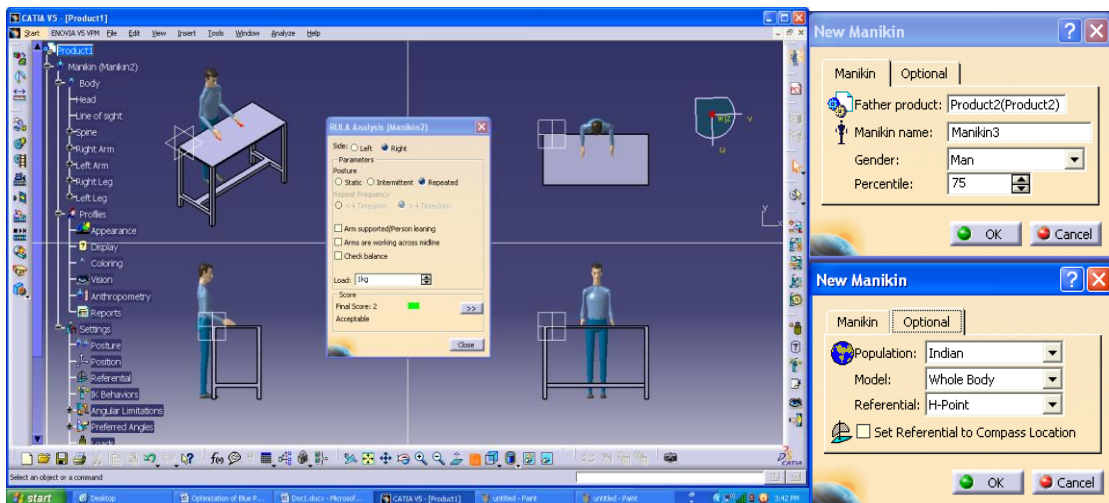
Fig. 7: Manikin of 75th percentile of Indian population on optimized working table with RULA score.

Figure (4) to figure (8) shows the ergonomic posture (RULA) analysis of 5th, 25th, 50th 75th and 95th percentile manikin of Indian population anthropometry. RULA [6] analysis shows that the scores of two (2) (Accepted) are same for five different levels of anthropometry.
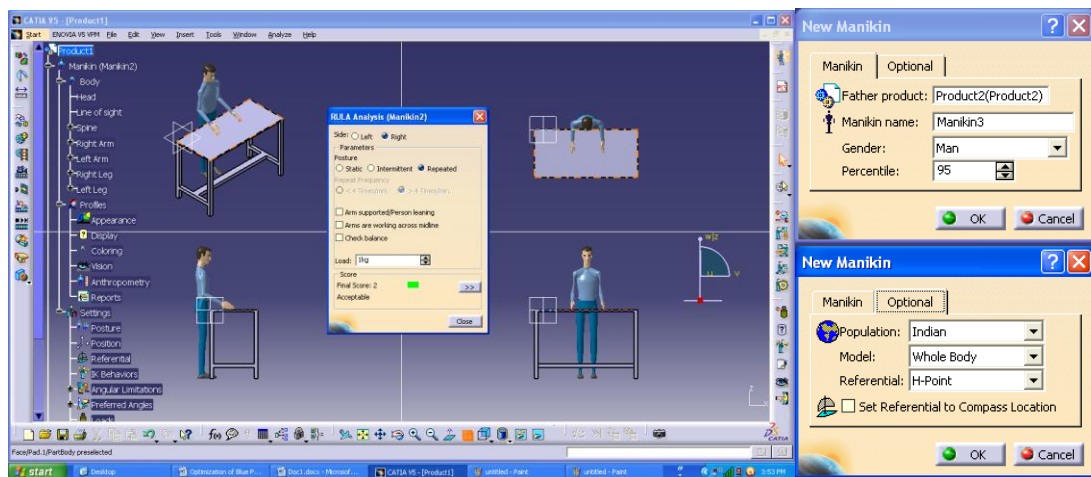

Fig. 8: Manikin of 95th percentile of Indian population on optimized working table with RULA score.

4. Conclusion

An ergonomic work table was designed using Taguchi's Design of experiment approach and the optimized dimensions of table height and width are 920mm and 642mm respectively. The designed work table was evaluated using Ergonomics Design and analysis module of Delmia V5 software. The RULA scores for 5 levels of anthropometry are two (2) which indicate the posture is accepted. Even though the scores are same but for the 5th and 25th population there is raise in shoulders however this problem can be solved by using a platform of 100mm.

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