Improvement of Workstation Design Based on Ergonomics' Principles

Prof. Dr. Hussein Salem Ketan
Email: hussket@yahoo.com
Engineering College-Baghdad University
Baydaa Ahmed Awad

Email: baydaaahmed1990@yahoo.com

Abstract:-

The purpose of this research is to explain and demonstrate the ability of applying ergonomics rules and principles for manual workstation design. The proposed methodology is composed of two stages: the first stage depends on the factorial experiment to develop the initial solution and treated a mixture of separate levels and factors; Taguchi (Design of experiment) approach is used for selection of main factors and levels for different workstation design. Jack software is used for drawing and simulates current workstation and the alternatives for different workstation design as well as performance (Ttask, Eshift, Btask, RWLtask) that are affected by design factors analysis. The second stage are to get the best solution based on desirability function that is scrutinized solution later using Response Surface Methodology (RSM) based on the economic and human performance measurements for both type of gender and the solution are compared with results of the current workstation. Performance (manually closing damper workstation) in the general hydraulic industries company. Based on achieved results one operator can perform the task activities for the proposed workstation instead of two workers of current workstation. Also, the production rate increased 38%, 1% for (male, female) respectively.

Key words: Workstation Design, Ergonomics, Digital Human Model (DHM), Design of Experimental (DOE), Virtual Reality.

1. Introduction

Although the progress of manufacturing process automatic, human workers continues to game a central role in the limitation and execution plurality of production system processes [14]. The general purpose of processing workstation planning the initial matter usually been the refinement of the performance of the task isolated and some consideration is offered for the sake of appropriate the capability of the worker with the task demands [5]. There are plentiful manual industrial workstations which lack of design and planning so there are disparities in comfort and worker performance for the completion of his work [3], conduct in lost operator productivity and needless trauma at the workstation [16]. So as to minimize the fatigue mandatory on the musculoskeletal framework through Manual Material Handling (MMH) task [8]. To reach the best workstation design that can remain the worker convenient should supply appropriate postural backup. Adequate apportionment of body /limb weight, normal body /limb situation and must order few requests to use utmost arrive or force [11].

2. Ergonomic interventions in workstation design

A workstation is known as “a location designed a specific task or activity where the operator may spend only apportion of the working shift.” Desks, offices, repair benches, tools, and computer terminals are examples of these special accommodations and equipment [10]. Workstation design is the ultimate space designing level. The procedure includes survey tasks, workers, and tools; specification tasks between the operators and machines and choosing or planning equipment and fixtures. Workstation design guide is intended to help employers and employees assess the degree of risk, identify hazards and the solutions to problems encountered in environment [13]. The manual workstation was planned and advanced taking into account the ergonomics in all aspects of plan and design with full amendment [9]. Workstation and workplace design have been dependent on psychological, physiological and biomechanical requirement of the operator [2]. The study of people in the work and the practice of matching the features of products and jobs to human capabilities are presented ergonomics [12]. Several ergonomic interventions are available to improve the posture of the pelvis and reduce posture constraint to the prevalence of back problems the degeneration of spinal structures such as the intervertebral disc [7]. Fig. 1 Application and areas of ergonomic [17], Physiology, biomechanics, and anthropometrics are the areas of ergonomics most useful to the workstations design. The reducing of the cumulative trauma and achieve productivity at the workstation have been helped motion economy. The principles of motion economy have been eliminated the loses in the motion, facilitating the tasks of operator, decrees fatigue and reduce cumulative trauma such as carpal tunnel and tendonitis [13].

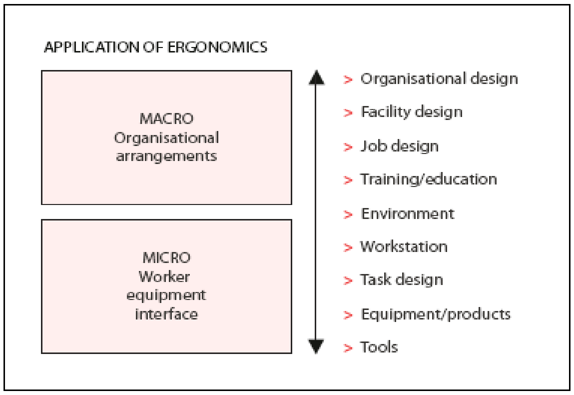


Fig 1. Application of ergonomics [4]

3. Design of experiments (DOE) and Digital human models and simulations (DHMS)

The design of experiments is a technique experiment as a test or series of tests which purposeful to change the input variables of a process so that may observe and identify the reasons for changes that may be observed in the output response, have been obtained analyzing the results data so that valid and objective conclusions [15]. Design of Expert (DOE) is a software application of different factors – levels help for design and analysis experiments and interpretation of multi-factor experiments. General Factorial, Design Expert software sets up saturated Taguchi designs orthogonal arrays – all main effect and no interactions. Digital human modeling and simulation (DHMS) is using to build models for production system where capabilities of the workers are related to the task requirements. Solve a problem tool for creating an artificial history of the system using Simulation [18]. The method allows design engineers to create an avatar (virtual human) with specific population attributes on their personal computers, which can then be inserted into the 3D graphic working environments [3]. The commonly used DHM software tools are includes. JACK, SAFEWORK, 3DSSP, RAMSIS, HUMANCAD, ANYBODY, SANTOS, these are use in current commercial [6].

4. Process (job) description:

The process starting with access of the dampers to the workstation after assembling the damper parts of the previous workstation as shown in fig. 2. The worker then manually takes off (lift) the parts from the container, and he loading it in the closure machine to close the damper to prevent the leakage of oil between compression & extension set. In this workstation, the empty container is exchange by a new one, and a new cycle starting. Fig. 4 illustrates the damper before and after the closure process and Fig. 5 represent th*e* shock absorber (damper) front for Toyota. The manual job (task) consists of the five activities:

1. Fixturing preparation – the worker performs the damper fixture.
2. Damper Loading – the worker is lifting damper from the container.
3. Closure tools setting – it considers that the tools to closure the damper previously mounted, only setting the closure tools.
4. Damper closure operation – the main task, the worker using two hands to close damper.
5. Damper unloading – after close the damper the worker takeoff the damper from the closure machine and put it in the container. Two workers are employed to implement this task in consequence periods. It is serious to identify each discrete type of lifting task. Fig. 3 illustrates the worker damper closing operation at the existing workstation.

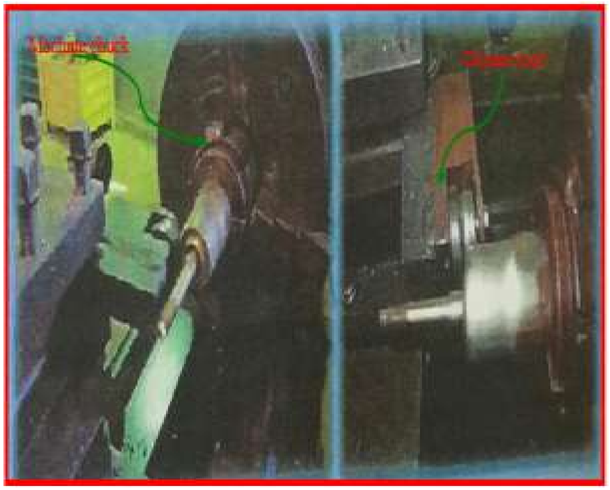


Fig 2. Damper Closure Machine

Fig 3. Damper Closing Operation

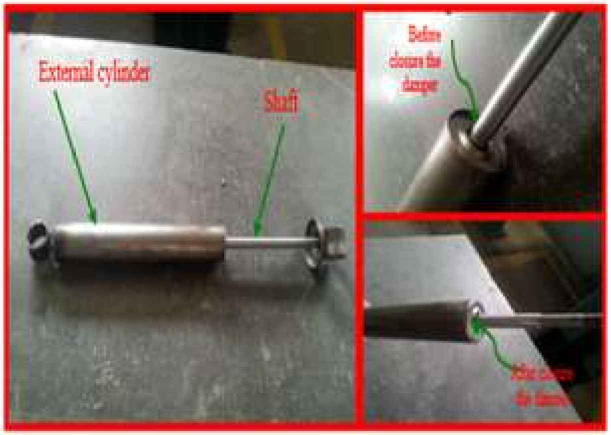


Fig 4 .Shock Absorber (Damper)

Fig 5. Shock absorber (damper) front for Toyota

5. The proposed methodology

The proposed methodology as a decision-making tool to choose the optimum configuration from alternative solutions of workstation design, is studied in two stage. The first stage settled on each criterion (Ttask, Eshift, Btask and RWLtask) / response to specify an individual desirability. Applying Harrington's method, to estimate the system desirability, individual criteria desirability's were combined using optimization Response Surface Methodology (RSM) popularized by Derringer and Such as techniques to find best solution is the second step. Using Design – Expert "DOE" is software for design and analysis of numerical experiments to find utmost desirability values of optimization objective. The Taguchi designs are a type of factorial design; design is available with differing numbers of factors and levels. The simulation model is developed by using the Compute - Aided – Design (CAD) software and Jack software to achieve the effective ergonomic design of the assembly workstation. Jack software is a human modeling tool that can be using to improve the ergonomics of product designs and refine industrial tasks. Jack and its optional toolkits provide human centered design tools for performs ergonomic analysis of virtual products and virtual work environments. as well as test designs for multiple factors, including injury risk, user comfort, reachability, lines of vision, energy expenditure, fatigue limits and other important human parameters. Figure (6) describes the flow chart of the proposed methodology [3, 1]:

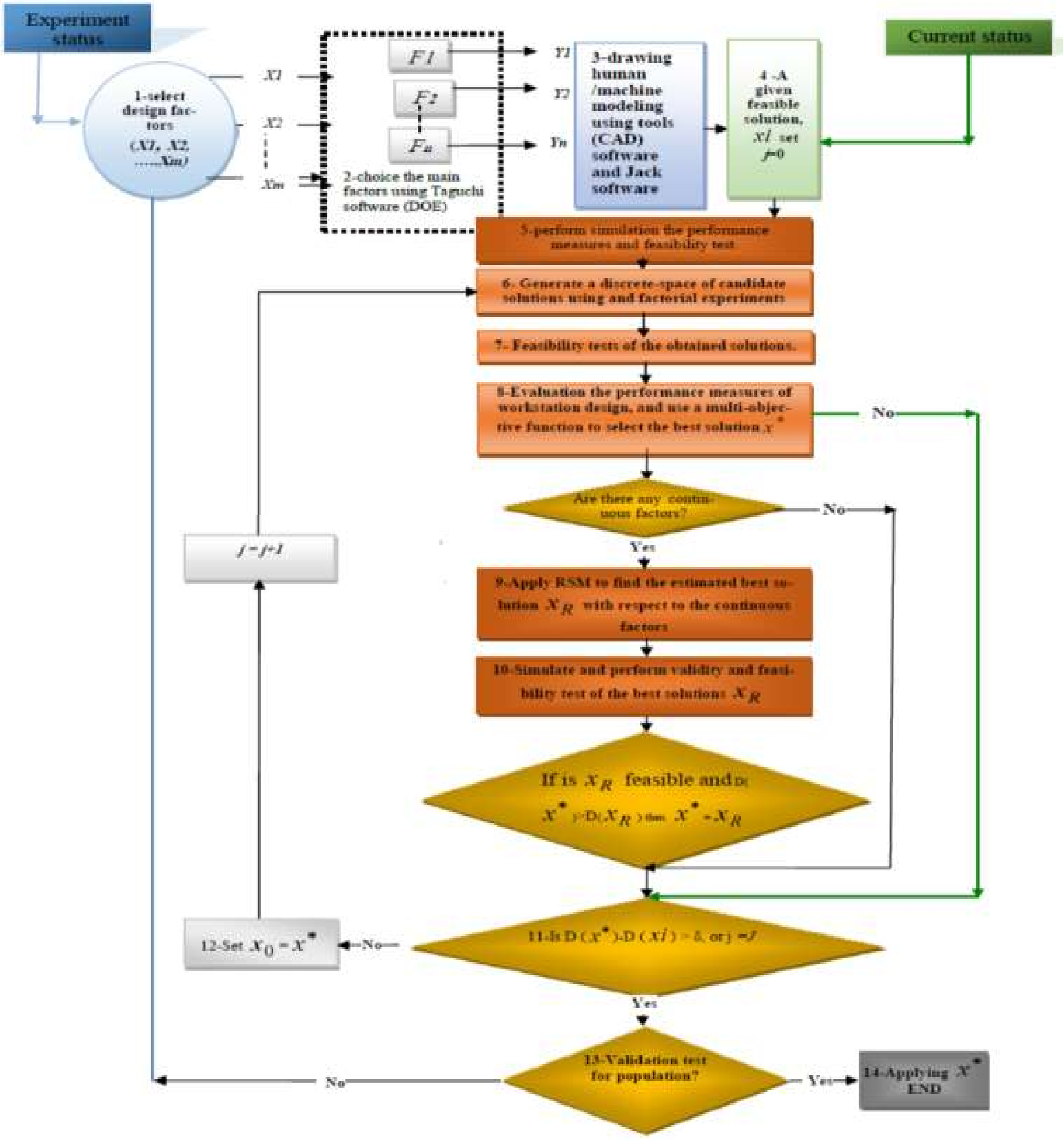


Fig 6. Flowchart of the suggested methodology

6. Applying the Suggested Methodology:

Step1: Selecting design factors

Choose design factors (independent variables) for workstation as (A, B, C, D), which influencing (ergonomics and economic measures) or performance measures. The manual handling of the damper at the closure workstation represent the major task. The improvement of ergonomics and minimize the cycle time of the task have been evaluated in the case study. Four design factors are considered as shown in figure (6). The following factors are located at closure workstation:

Factor (A) the altitude between the top of the container and the ground level are measured in centimeters.

Factor (B) the horizontal distance in centimeters between the worker midpoint of ankles bones and the container.

Factor (C) the machine chucks height in centimeters between the upper surface of the closure machine and the worker look –level.

Factor (D) is the skill level of the worker measured as a percentage to perform job on damper closure machine.

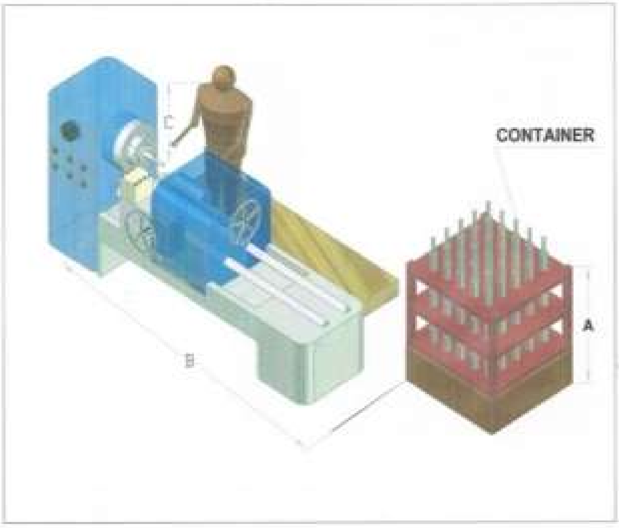


Fig 7. damper closure workstation

Step 2: choice the main factors

There is an experimental alternative (81) for each type of gender (female, mal). Taguchi design orthogonal array L9 (3*4) is used that chooses main factors.

Step 3: Design factors modeling

Model the main factors by using AutoCAD interface to graphically modeling the workstation design with Virtual Reality design tools (Jack software); for evaluation, the different design configurations for the model accurately.

Step 4: Initialization

The given feasible configuration of the workstation either from a current workstation or by initial modeling and a set of performance measures, denote the initial configuration of n design factors by x_i. That is, x_i is an n dimensional vector of factor levels (system setting).

***Step 5*: simulation**

Analysis the performance measures by simulation using jack software selected the four performance measures (dependent variables) and feasibility later integrated using multi-objective functions are:

1) Ttask: is an economical measure of closure damper workstation. The task cycle time consists of *m* individual operations, where perform the time each operation is denoted by t_i, $i = 1,\ldots, m$. The operations times are optained from the MTM tables in analysis software (jack).

$$\boldsymbol{Ttask} = \sum_{i=1}^{m} t_i \text{ (min. /unit) ……. (1)}$$

2) EShift: is a physiological measure to calculate the metabolic energy consumption in a shift according to Garg guidelines. The energy consumption rate per each individual operation, denoted by e_i, $i=1,\ldots, m$, is generated by option analysis in (jack) software using the Garg formula. (***Eshift***) is the time-weighted average of the energy consumption rates multiplied by the shift time (450 minutes), i.e. $\boldsymbol{Eshift}=450\left(\sum_{i=1}^{m} e_i \times t_i\right) \Big/ \boldsymbol{Ttask}$ (kcal)..…………… (2)

3) Btask: is a biomechanical measure. The (***Btask***) is used to evaluate the strength requirements at the joints and to estimate the low back spinal compression or shear forces for lifting tasks weighted average of the weight limits, denoted by B_i, $i=1,\ldots, m$. Thus,

$$Btask = \left(\sum_{i=1}^{m} L4/L5 \times t_i\right) \Big/ \; Ttask$$

(newton, N) ……………. (3)

4) RWLtask: is a psychophysical measure conducted on the lifting limitations according to the NIOSH guideline. ***RWLtask*** is the Recommended Weight Limit weighted average of the weight limits, denoted for each position by (w_i), $i=1,\ldots,m$, calculated only for those operations that involve weights,

$$RWL\text{task}=\left(\sum_{i=1}^{m} l_i \times t_i \times w_i\right) \Big/ \left(\sum_{i=1}^{m} l_i \times t_i\right) \text{(kg)}$$

……………. (4)

Dk: Assume that the designer has to evaluate *K* different solutions by using the desirability function. Accordingly, T_{k}, E_{k}, B_{k} and R_{k} denote respectively the *Ttask, Eshift, Btask* and *RWLtask* performance. Application the normalization methods of the following for finding of the performance measures values

$$\tilde{T}_k = (U'_T - T_k) / (1.2\,(U_T - L_T)) \qquad k = 1, \ldots\ldots\ldots, k, \ldots.(5)$$

$$\tilde{E}_k = (U'_E - E_k) / (1.2\,(U_E - L_E)) \qquad k = 1, \ldots\ldots\ldots, k, \ldots.(6)$$

$$\tilde{B}_k = (U'B - B_k) / (1.2\,(UB - LB)) \qquad k = 1, \ldots\ldots\ldots, k, \ldots\ldots\ldots(7)$$

$$\tilde{R}_k = (U'R - R_k) / (1.2\,(U_R - L_R)) \qquad k = 1, \ldots\ldots\ldots, k, \ldots..(8)$$

That were required between zero and one accordingly desirability function. upper (lower) limits of the four performance measures respectively $U_T (L_T)$,$U_E (L_E)$,$U_B (L_B)$, and $U_R (L_R)$ the

For the manual workstation, the individual desirability degree for each

$$U'_{T\backslash E\backslash P\backslash R} = U_{T\backslash E\backslash B\backslash R} + 0.1\,(U_{T\backslash E\backslash B\backslash R} - L_{T\backslash E\backslash B\backslash R}), \quad \ldots\ldots \ (9)$$

$$L'_{T\backslash E\backslash P\backslash R} = L_{T\backslash E\backslash B\backslash R} - 0.1\,(U_{T\backslash E\backslash B\backslash R} - L_{T\backslash E\backslash B\backslash R}) \quad \ldots(10)$$

performance measures coincide the one configuration of alternative represent, $\tilde{T}_k$, $\tilde{E}_k$,$\tilde{B}_k$ and $\tilde{R}_k$ the normalized values.

In mutual procedures of normalization, the upper (lower) limits assigned to the maximal (minimal) amounts of performance measures have been got on all existent solutions. Thus, assigning the degree zero to the worse got it and the degree one to the better-obtained solution. This approach is dubious since it appoints the zero grades to the worse solution got it, as if no worst solution exists. likeness, the better solution obtains the normalized amount of higher one, as if best solutions do not exist. Since the all solution space hasn't been covered by the present experiment, and it is supposed that best and worst solution may be present, the range of the upper and lower limits for all performance measures equal to 20% has been observed. This insures that the normalized values of, $\tilde{T}_k$, $\tilde{E}_k$, $\tilde{B}_k$ and $\tilde{R}_k$ are within the range 0.08─0.92.

In the next step, choose one optimal workstation alternative design and compare these alternative solutions by using composite desirability as a multiple objective function. To build a multiple objective function for each alternative are used desirability function called procedures for **Derringer and Suich** referred D_κ. It reflects the integrated desirable degree of the *k*th solution desirability with regard to all performance

***Step 6**:* **Factorial experimental and** Table (1) presents the choice ranges for the four design factors, a 3^4 factorial experiment with (81) different configurations are defined by considering the endpoints of the factor ranges and negligence higher order response models.

Table 1. Level of the investigated design factors

Parameter	Factor levels			Delta
	1	2	3	
A (cm)	70	75	80	10
B (cm)	50	55	60	10
C (cm)	45	50	55	10
D (skills %)	55	65	85	30

Step *7:* **Simulation and feasibility test** performed a validation on each model of the ergonomic constraints and it is found all alternatives are feasible. Simulation of each is done by jack software. An ergonomic data report, which is generated by this analysis software, is used to calculate the normalized performance measures. The experiments outputs are shown in table (2a), (2b) presents (9) configurations that are generated by editing the initial solution model for gender each type.

Step 8: **Analysis**

At this step, analyzed the simulation results of alternative solutions. Apply the desirability function to the multiple objectives. The desirability values for each configuration listed in table (2a), (2b) and the analyses result includes determination of each performance measures separately, and estimate of the multi-objectives by desirability function for all measures jointly.

Table 2a. Simulation results of the design alternative solutions

Alternative	Exp. ABCD	MTM analysis Ttask (Sec)		Garg analysis Eshift (kcal/min)		L4/L5 analysis Btask (N)		NIOSH 91 analysis RWL task (kg)		Desirability	Feasibility Test
		actual	Norm	actual	Norm	actual	Norm	actual	Norm		
1	3321	40.72	0.24	2.614	0.85	845.2	0.31	4.02	0.91	0.47	OK
2	**3132**	**31.49**	**0.59**	**2.657**	**0.78**	**719.8**	**0.84**	**4.29**	**0.80**	**0.72**	**OK**
3	1111	44.97	0.08	2.629	0.82	770.9	0.62	4.69	0.64	0.35	OK
4	2123	22.82	0.91	2.571	0.91	898.6	0.08	6.04	0.08	0.40	OK
5	1222	25.85	0.80	2.817	0.54	857.8	0.25	5.13	0.45	0.52	OK
6	3213	26.35	0.78	2.736	0.66	872.3	0.19	5.85	0.16	0.44	OK
7	2231	30.96	0.61	2.773	0.61	702.4	0.91	6.04	0.08	0.46	OK
8	1333	32.16	0.56	3.127	0.08	837.9	0.34	5.13	0.45	0.26	OK
9	2312	43.07	0.15	3.088	0.14	787.2	0.55	4.69	0.64	0.23	OK
Upper limit		44.976	----	3.127	----	898.686	----	6.04	----	----	
Lower limit		22.820	----	2.571	----	702.432	----	4.02	----	----	

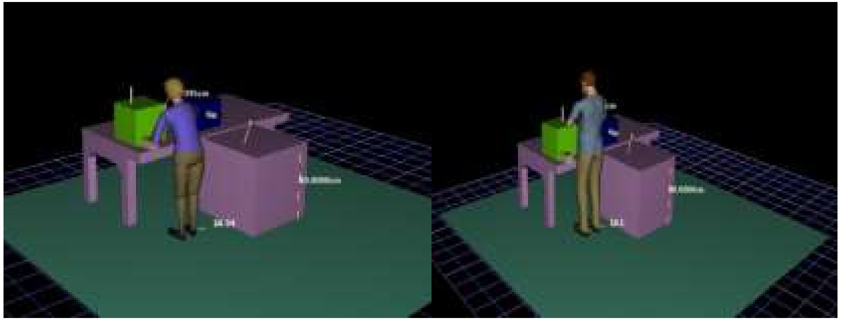


Fig 8. the current workstation design factors according to (male, female)

Table 2b. Simulation results of the design alternative solutions

Alternative	Exp. ABCD	MTM analysis Ttask (Sec)		Garg analysis Eshift (kcal)		L4/L5 analysis Btask (N)		NIOSH 91 analysis RWL task (kg)		Desirability	Feasibility Test
		actual	Norm	actual	Norm	actual	Norm	actual	Norm		
1	3321	37.12	0.08	2.820	0.08	537.8	0.10	5.24	0.57	0.11	OK
2	3132	24.41	0. 70	1.973	0.75	360.2	0.75	4.87	0.76	0.73	OK
3	1111	34.58	0.20	2.732	0.15	503.9	0.23	4.57	0.91	0.24	OK
4	2123	21.64	0.84	1.854	0.85	369.6	0.72	5.28	0.55	0.766	OK
5	1222	31.98	0.33	1.858	0.84	542.3	0.09	6.12	0.11	0.30	OK
6	**3213**	**20.08**	**0.91**	**1.952**	**0.77**	**366.3**	**0.73**	**5.24**	**0.57**	**0.768**	**OK**
7	2231	35.23	0.17	1.770	0.91	317.0	0.91	5.44	0.46	0.465	OK
8	1333	22.66	0.79	2.641	0.22	544.7	0.08	6.19	0.08	0.244	OK
9	2312	30.69	0.39	1.957	0.76	342.3	0.82	4.95	0.72	0.611	OK
Upper limit		37.129	----	2.820	----	544.742	----	6.19		----	----
Lower limit		20.08	----	1.770	----	317.052	----	4.57		----	----

Step 9: Applying optimization RSM techniques

To refine the design solutions, This step including three substep:

i) Polynomial Response Fitting and diagnostics

Performed once the experiments, model fitting techniques to describe analytically the relevance between input factors and all the performance measures. Table 3. Are obtained from the alternative workstation design for each type of gender, by using Design of Expert statistical software (DOE). These tables contain model-fitting measures, involving the contribution of each factor to the model sum-of squares and coefficients of determination. Fig. 8 represented normal probability plot of the residual for one type of gender and validate of none-linear response model. This non-linearity results from the significant interaction between factors C and D (machine chuck height& skill levels).

ii) The graphical analyses model of factors effect on performance measures:

Design- Expert software provides various graphs to help interpret the model selected, also help to choose the best axes to use for each of the graphs, you might want to begin by looking at the input variables analysis model. The primary graphs for Factorial designs are interest of the one factor, interaction, and cube. For Response Surface, the primary graphs will be the contour. Both of these shows how any two factors affect the response. It is important to focus on the effects of the significant.

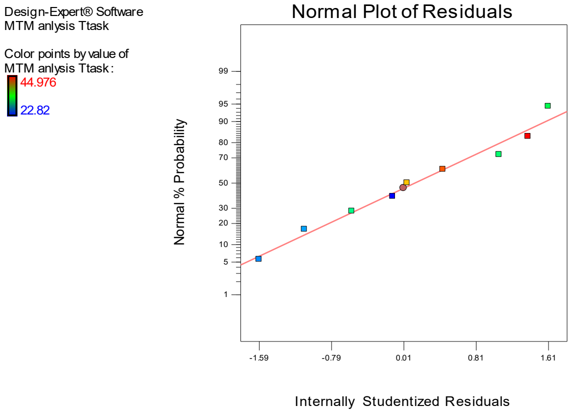


Fig 9 .A normal probability plot of the residuals of the response model for male *Ttask*

iii) Assignment of optimization design factors and its performance measures

Applied Response Surface Methodology (**RSM)** to find the best solution. As continuous the design factors, one can revise the best solution finding (workstation configuration 3132 , 3213 in table (2a)(2b) for gender male and female) respectively.

Step 10: Validation and feasibility test

Its predictable Performance measure (multi-objective) which Simulate ***x*R** and evaluate, denoted by ***D*** (***x*R**). If ***x*R** feasible and ***D*** (***x*R**) is found to be ascendant than (***x****), its obtained predictable multi-objective performance of the best design thus far, set ***x**** = ***x*R**

Table 3. Model fitting analysis with respect to the *Ttask* measure for male

Factor	*Sum-of-squares*	*DF*	*Mean square*	*F Value*	*p-value Prob > F*
Model	322.89	4	80.72	16.80	0.009
A	9.63	1	9.63	2.00	0.229
B	16.16	1	16.16	3.36	0.140
C	1.54	1	1.54	0.32	0.601
D	295.55	1	295.55	61.51	0.001
Residual	19.22	4	4.81	-	-
Cor Total	342.11	8	-	-	-

Model fitting measures

Std. Dev.	*2.19*	*R-Squared*	0.9438
Mean	*28.71*	*Adj R-Squared*	0.8876
C.V. %	*7.63*	*Pred R-Squared*	0.6763
PRESS	*110.73*	*Adeq Precision*	9.670

Expected ***Ttask*** (MTM)= **+ 27.95-1.27*A + 1.64*B – 0.51*C -6.89*D**

Factor	*Coef-ficient Esti-mate*	*DF*	*Stand-ard Error*	*95% CI Low*	*95% CI High*	*VIF*
Intercept	27.95	1	0.74	25.90	30.00	-
A	-1.27	1	0.89	-3.75	1.22	1.00
B	1.64	1	0.89	-0.84	4.13	1.00
C	-0.51	1	0.89	-2.99	1.98	1.00
D	-6.89	1	0.88	-9.33	-4.45	1.00

Table 4. Design solution improvement using RSM for male

Number	*Factor (A)*	*Factor (B)*	*Factor (C)*	*Factor (D)*	*Ttask*	*Eshift*	*Btask*	*RWLtask*	*Desirability*
DBS	**79.57**	**50.00**	**55.00**	**70.00**	**22.81998**	**2.57038**	**789.964**	**5.48703**	**0.859**
1	79.62	50.05	55.00	70.00	22.82	2.57097	790.177	5.48492	0.859
2	80.00	50.25	55.00	70.00	22.8201	2.57103	791.098	5.47211	0.856
3	79.98	50.00	54.49	70.00	22.8199	2.56515	796.415	5.49544	0.851
4	80.00	50.00	54.11	70.00	22.3413	2.571	804.362	5.54256	0.844
5	76.97	50.00	55.00	70.00	22.82	2.62031	789.707	5.5642	0.840
6	80.00	50.00	53.43	70.00	22.7376	2.5711	810.181	5.54289	0.835
7	75.80	50.01	55.00	70.00	22.8202	2.64322	789.682	5.5991	0.831
8	80.00	50.00	55.00	70.00	27.1601	2.5238	760.392	5.17679	0.799
9	79.98	53.64	55.00	70.00	22.8724	2.69429	805.697	5.44208	0.765
⋮	⋮	⋮	⋮		⋮	⋮	⋮	⋮	⋮
IS	**0**	**0**	**0**	**0**	**48.337**	**3.227**	**902.271**	**4.87**	**0.25**

Fig 10. Ramps represent expected Desirability grade by RSM technique for type's male

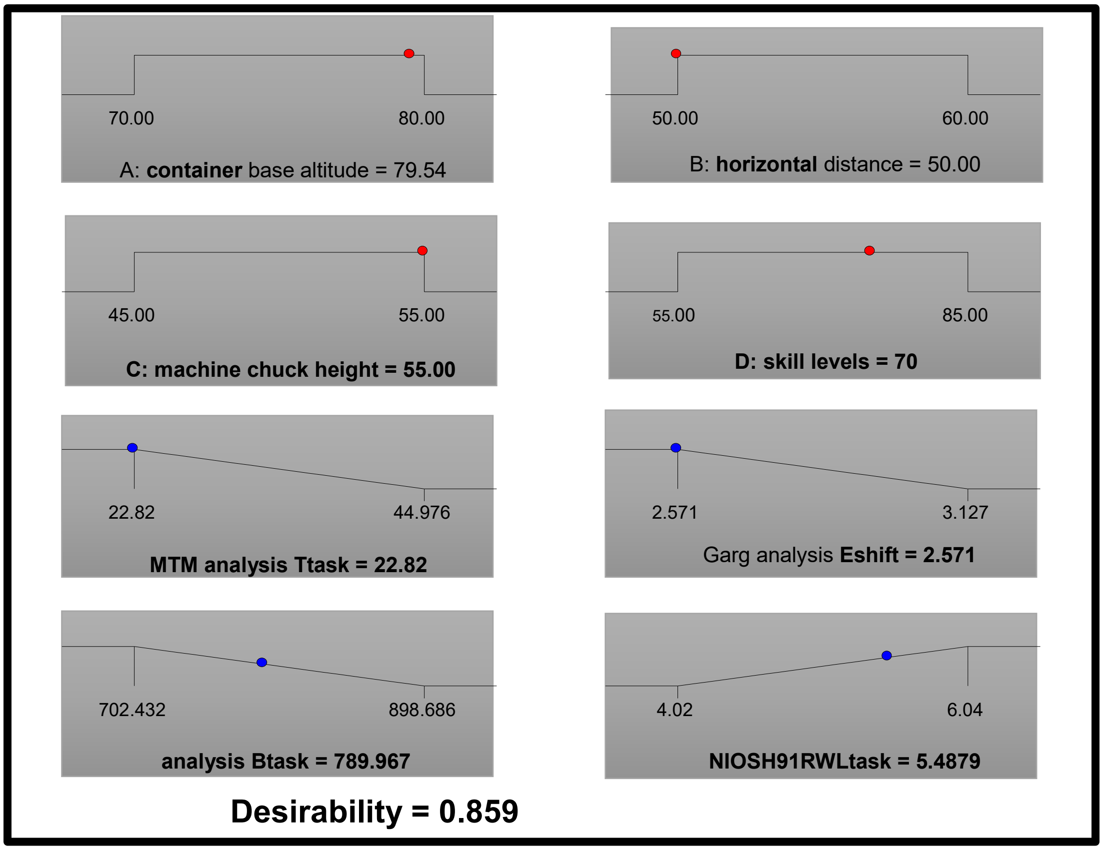
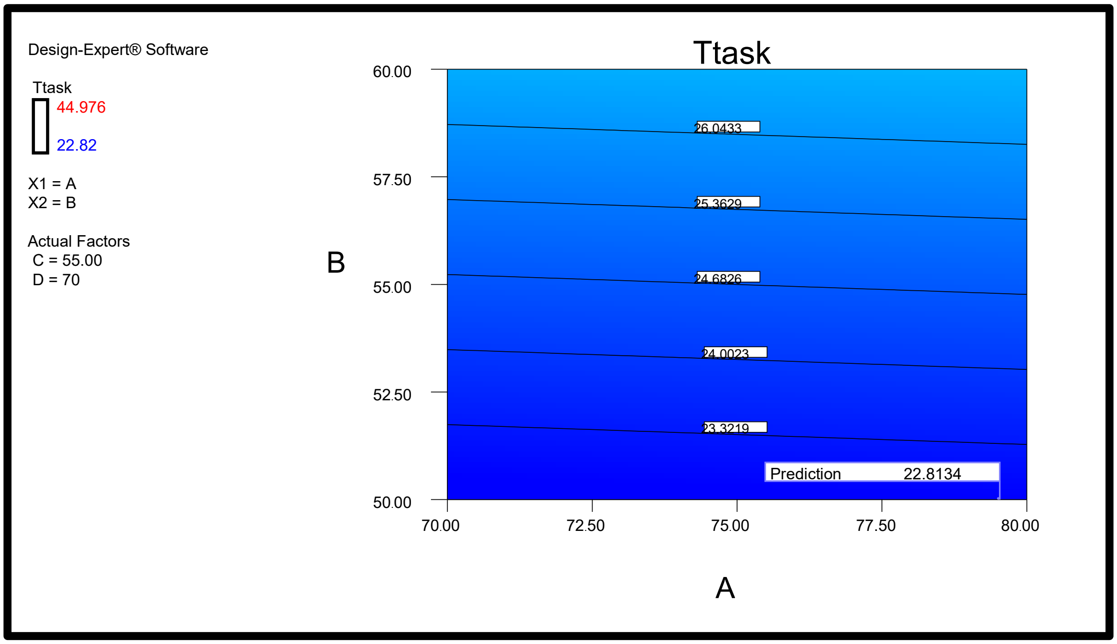


Fig 11. A contour plot of the *(Ttask)* measurement for factors A and B for male



Step 11: **Termination condition1**

At this stage, has achieved the improvement of the multi-objective performance $D(x^*) > D(x_0)$ and greater than δ (δ =0.24), i.e., $D(x^*) - D(x_0) > \delta$. Since $D(x^*) = 0.859, 0.737$ & $D(x_0) = 0.25$, then $(D(x^*) - D(x_0)) = 0.609, 0.487$.

***Step 12**:* **New search for best design**

In this research used experiment alternative parameters as input for best design factors by Taguchi approach to find the numerical optimization factors. The final results of this research found the 10 solutions for optimization configuration of the workstation design.

Step 13: **Termination condition 2: design workstation to accommodate people of different sizes**

Even that the workstation is designed for each type of gender based on dimensions at the 95th, 50th percentile value, to make sure a wide range of individuals when use of the workstation should be achieved the configuration design availability. It means when used a (male, female) respectively whom all her pertinent dimensions are at the 5th Percentile statistically value (height = 163.8, 152.1 cm, weight = 62,50kg). The optimum workstation design has a successful accommodation set up for various anthropometric so fits category of different sizes workers of the physical in various working postures.

Step 14: **Termination**

The termination condition of data has been checked in this step allowed only a single iteration. Therefore, (DBS) is choice the best design, denoted by (***x****), and have been reconfigured the process accordingly.

7. Conclusions:

In the research work, the following conclusion can be drawn:

1) Different workstation configurations and manufacturing systems redesign or design can be achieved through Virtual Reality and graphical simulation approach.
2) The complexities of the industrial workstation brought some negative influences on the experiment data collection, so there is no single ergonomic evaluation method presented an obvious means for quantifying level differences in physical stress among manual lifting tasks.
3) Applying ergonomic principles in workstation design, aimed to ensure fitness for use. By mitigate stresses and refine both performance and safety for the operator.
4) The companies should have a special significant role for finding a balance between job satisfactions and working methods. To achieve the balance situation continuous training, safety and health check to all workers at least once a year.
5) The gains of economic and ergonomic measures (performance measures) of the redesign of current workstation reflect the positive effect

of the intervention ergonomic with other design factors are as follows:

a) The cycle time was decreased about (53%, 59%) for (male, female) respectively, by comparing the proposed workstation design and current workstation design.

b) The metabolic energy expenditure associated with the job reduced from 3.277 to 2.57038, 1.98762 kcal/min for (male, female) respectively.

c) Compression force L5/S1 reduced from 902.271 N in real- life case study to 789.964, 368.11 N for two type of gender male, female respectively and the strength capability for small operator (5th percentile) decreased, but the recommended weight limit increasing from 4.87 Kg to 5.48703, 5.34569 for two type of gender male, female respectively.

d) Increasing the production rate in each shift (7.5 hour) approximately male, female (38%, 1%) respectively for proposed workstation design. And the job doing by one operator instead of two, this lead that the product cost will be reduced.

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Symbols	Description
$\tilde{B}_K$	Normalized Value of the *Btask* measure
Btask	The time weighted average of the compression and shear force
Cor Total	Sum of Squares Total Corrected for the mean
C.V. %	The Coefficient of Variation for the model
DF	Degrees of Freedom
d_i	Individual Desirability Function
Dk	Multiple Objective Function
D (xi)	Multi-Objective Performance for the initial configuration
D (xR).	Expected Multi-Objective Performance
D (x*)	Multi-Objective Performance for the best configuration
ei	Energy Consumption Rate per each individual operation
$\tilde{E}_k$	Normalized Value of the *Eshift* measure
EShift	Metabolic Energy Consumption in a shift
F Value	The Mean Square for the term divided by the Mean Square for the Residual
J	Number of iterations
L *B*	Lower limits of the *Btask* measure
L_E	Lower limits of the *Eshift* measure
CLI	Composite Lifting Index
L_R	Lower limits of the *RWLtask* measure
L_T	Lower limits of the *Ttask* measure
n	Number of design factors
PRESS	The Predicted Residual Sum of Squares for the model
P-value	The Probability value that is associated with the F Value for the model
q	Possible Level per Factor
$\tilde{R}_k$	Normalized Value of the *RWLtask* measure
RWL	Recommended Weight Limit
RWLtask	Recommended Weight Limit in each operation
ti	Time to perform each operation
$\tilde{T}_k$	Normalized Value of the *Ttask* measure
Ttask	Stacking Cycle Time
T_{taskj}	Time Duration of the j^{th}
U *B*	Upper limits of the *Btask* measure
U_E	Upper limits of the *Eshift* measure
U_R	Upper limits of the *RWLtask* measure
U_T	Upper limits of the *Ttask* measure

VIF	The variance inflation factor measures how much the variance of the model is inflated by the lack of orthogonally in the design
xi	Denote the initial configuration
xR	Denote the best solution obtained from the (RSM**)**
x*	Denote the best design solution
w_i	Importance Level of the i^{th} Response
y_i	Each Response
δ	Improvement of the multi –objective performance
95% CI Low	This is the lower bound of the 95% confidence interval that surrounds the coefficient estimate for this factor.
95% CI High	This is the upper bound of the 95% confidence interval that surrounds the coefficient estimate for this factor

تحسين تصميم محطة العمل بالاعتماد على مبادئ الاركونوميك

أ. د. حسين سالم كيطان

بيداء احمد عواد

كلية الهندسة جامعة بغداد

Email: hussket@yahoo.com

Email: baydaaahmed1990@yahoo.com

الخلاصة:

الغرض من هذا البحث هو لتفسير واثبات القدرة على تطبيق قواعد الهندسة البشريه ومبادئها في تصميم محطة عمل يدويا. ان المنهجيه المقترحه متكونه من جزئين: الجزء الاول يعتمد على التجارب العامليه factorial experiment لتطوير الحل الاولي ومعالجته منفصلا بمزيج من المستويات والعوامل , واستخدام طريقه Taguchi experiment design لاختيار العوامل الاساسيه ومستويات للتصاميم المختلفة لمحطه العمل, ويستخدم برنامج Jack software لرسم ومحاكاة لمحطه العمل الحاليه والبدائل للتصاميم المختلفه وكذلك تحليل قياسات الاداء(Ttask, Eshift, Btask, RWLtask) التي تتاثر بعوامل التصميم , اما الجزء الثاني فيتم الحصول على الحل الافضل بالاعتماد على الداله المرغوبية التي يتم تمحيص الحل فيما بعد للحصول على الحل الامثل باستخدام Response surface Methodology استنادا على قياسات الاداء الاقتصادية والبشريه لكلا الجنسين ويتم مقارنة الحل مع نتائج المحطه الحالية.ويتم التنفيذ في محطة غلق المخمد يدويا في الشركة العامه للصناعات الهيدروليكيه. بالاعتماد على النتائج التي حققت يستطيع عامل واحد تنفيذ نشاطات المهمه لتصميم المحطة المقترحة بدلا من عاملين لتصميم الحطة الحالية. ايضا ان الطاقه الانتاجية زادت للذكر والانثى 38٪,1٪ على التوالي.

كلمات البحث: تصميم محطة العمل, الاركونوميك, نمذجة الانسان الرقمي, التصميم التجريبي, واقع افتراضي.