# WORKSTATION PRODUCTIVITY ENHACEMENT WITHIN HYDRAULIC HOSES MANUFACTURING PROCESS

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**ABSTRACT**
The paper proposes the effective redesign of a workstation belonging to a manufacturing process devoted to produce high pressure hydraulic hoses. The objective of the study is to increase the workstation productivity in terms of number of Shop Orders being completed on monthly basis. To this end, the authors adopt an approach based on Modelling & Simulation as support tool for implementing a three dimensional environment capable of recreating, with satisfactory accuracy, the real workstation. A final configuration of the workstation is presented and higher productivity levels are achieved.

Keywords: Modelling & Simulation, productivity, workstation design

## 1. INTRODUCTION

An overview of the state of the art, starting from the second half of the 1990s, reveals that manufacturing systems continuously provide challenging problems for researchers and scientists working in this area. Actually the workstation effective design became more and more important due to their effects on system efficiency and productivity. A number of different research works and scientific approaches have been proposed, trying to achieve an effective design of the workstations belonging to a manufacturing system.

Das and Sengupta (1996) propose a workstation design procedure based on the optimization of the worker and total system productivity as well as worker physical and mental well-being, job satisfaction and safety.

Resnick and Zanotti (1997) develop a set of guidelines for the workstation design integrating ergonomics and productivity objectives. An application example is proposed for remarking that a workstation can be designed to maximize performance and reduce costs by considering both ergonomics and productivity together.

Engstrom and Medbo (1997) develop a video based observation method for time data collection and analysis of work time consumption. The method allows to measure the efficiency of the production system by separating between value and not value adding works activities. In this regards, the method can be used for increasing manufacturing systems productivity.

Vedder and Hellweg (1998) recorder twenty day and night shifts in a fibbre spinning area of a chemical plant by means of a stationary camera. A very long analysis of the videotapes allows them to povide the guidelines for redesigning the system under consideration in order to achieve higher productivity levels.

Laring et al. (2002) develop an ergonomic complement to a modern MTM system called SAM. In particular the authors propose a tool that gives the possibility to estimate simultaneously the consumption of time in the envisaged production, and the biomechanical load inherent in the planned tasks.

Udosen (2006) proposes a tools for construction, evaluation and improvement of a workplace for the assembly of a domestic fan. The tool can be used for minimizing the cycle time of the assembly operations.

In the last decade of the 20th century, researchers and practitioners started to develop research works for the workstation effective design by using Modelling & Simulation (M&S) as support tool for choosing correctly, for understanding why, for diagnose problems and explore possibilities (Banks, 1998).

Ben-Gal and Bukchin (2002) propose a structural methodology based on M&S for the workstation design. Factorial experiments and the response surface methodology are integrated in order to reduce the number of examined design solutions and obtain an estimate for the best design configuration with respect to multi-objective requirements (acceptable ergonomic risk levels and high productivity values).

Longo et al. (2006) use M&S for the effective design of an assembly line still not in existence. The authors propose a multi-measures approach with the aim of obtaining a different work assignment to each workstation, better line-balancing and better ergonomic solutions.

Chang and Wang (2007) propose a method for conducting workplace ergonomic evaluations and re-design in a digital environment with the aim of both preventing work-related musculoskeletal disorders during assembly tasks in the automotive sector and increasing the system productivity.

Santo et al. (2007) use M&S for solving ergonomic problems and achieving higher productivity levels. A case study based on a non repetitive manufacturing process is presented.

The objective of the paper is to achieve the effective design of a workstation (Pressure test workstation) belonging to a real manufacturing system. To this end, the authors adopt a M&S approach supported by a three dimensional virtual environment, in which the workstation has been recreated with high accuracy. The simulation model is used for developing an improved workstation configuration in terms of higher productivity levels. The choice of the final configuration is made according to the number of Shop Orders being completed on the monthly basis.

The paper is organized as follows. Section 2 describes the Pressure test workstation manufacturing process. Section 3 gives specific details on the simulation model implementation and validation. Section 4 presents a detailed analysis of the simulation results (number of Shop Order being completed on monthly basis) and shows how the final workstations configurations can be obtained. The last section reports the conclusions that summarize the scientific value of the work.

## 2. THE PRESSURE TEST WORKSTATION MANUFACTURING PROCESS

The research work focalizes on the effective redesign of the Pressure test workstation of a production process for manufacturing and assembling high-pressure hydraulic hoses. All the workstations of the production process are located inside the Assembly area and each workstation performs specific operations. A preliminary analysis carried out by the company top management shows that the productivity of the Pressure test workstation (evaluated on monthly basis) always falls below the target levels causing delays in Shop Orders (S.Os) completion.

Figure 1 shows the final products (the high-pressure hydraulic hoses).


Figure 1: Hydraulic hoses

Each hydraulic hose is made up of a rubber hose, two fittings and two ring nuts. In the workstation the test of the hydraulic hoses by using a pressure machine (setting a pressure value higher than the nominal value) is accomplished.

The operator of the Pressure test workstation performs the following operations:

1. he walks three steps to pick up the Shop Orders sheet, reads the information he/she needs and puts it back;
2. he takes the hydraulic hoses from a manual dolly and brings it on the work table;
3. he walks four steps to pick up the joints for connecting the hydraulic hoses to the pressure test machine;
4. he connects joints and hydraulic hoses;
5. he moves the hydraulic hoses from the work table to the testing machine;
6. he connects the hydraulic hoses to the testing machines, performs the security procedures and starts the testing phase;
7. he puts away from the machine the hydraulic hoses, performs the visual checks and moves the hoses on the work table;
8. he disconnects the joints from the hydraulic hoses;
9. he walks fours steps to put the joints back in the proper bins and comes back to the work table;
10. he brings the tested hydraulic hoses to a manual dolly;
11. he completes the Shop Order by setting the status “end of the operation” on the company informative system; in this regards he walks 8 steps to use the workstation PC;
12. he moves the materials to the successive workstation by using a manually operated dolly.

Note that, the operations 1, 11 and 12 are performed just once for the Shop Order completion. On the other hand all the other operations are cyclically performed for each hydraulic hoses. Obviously the frequency of such operations depends on the number of hydraulic hoses required for the Shop Order completion. In this regards, the authors take into consideration a typical Shop Order that requires the production of 12 medium section hydraulic hoses. Moreover, as concerns the work method, three hydraulic hoses must be simultaneously tested by means of the pressure machine.

## 3. THE SIMULATION MODEL DEVELOPMENT

The first step of the research work was the development of a simulation model representing the actual Pressure test workstation. The simulation modelling tools, used for developing the Pressure test workstation model are the CAD software Rhinoceros and the simulation software eM-Workplace.

All the tools used during the production process have been modelled by means of Rhinoceros. Obviously, the implementation of the geometric models has required an accurate data collection of objects types, dimensions and weights. The data collection includes the following elements of the real workstation: machines, equipment and tools, worktables, manual operated dollies, raw materials and bins.

Table 1 reports the objects description, dimensions and weights.

Table 1: Data collection for geometric model implementation

| Object Description | Object Type | Weight (Kg) | Dimensions (cm) L x W x H |
|---|---|---|---|
| Ring | Component | 0.168 | Depending on S.O. |
| Fitting | Component | 0.336 | Depending on S.O. |
| Marking die | Component | 1.800 | Depending on S.O. |
| Workstation stamp | Component | 0.100 | Depending on S.O. |
| Scanner | Component | 0.400 | 12 x 7 x 18 |
| Empty bin | Component | 0.300 | 30 x 20 x 15 |
| Rubber hose | Component | 1.020 | Depending on S.O. |
| Manual operated Dolly | Equipment | 35.300 | 100 x 120 x 76 |
| Rings bin | Equipment | 0.300 | 30 x 20 x 15 |
| Work table | Equipment | 100.800 | 240 x 220 x 95 |
| Pressure test machine | Machine | 1020.040 | 368 x 90 x 150 |

After the modelling phase, the geometric models have been imported into the virtual environment provided by eMWorkplace. Note that the geometric models have been located in the virtual environment considering the same position the real objects take place in the real system in order to recreate exactly the Pressure test workstation. Figure 2 shows a panoramic overview of the virtual Pressure test workstation.

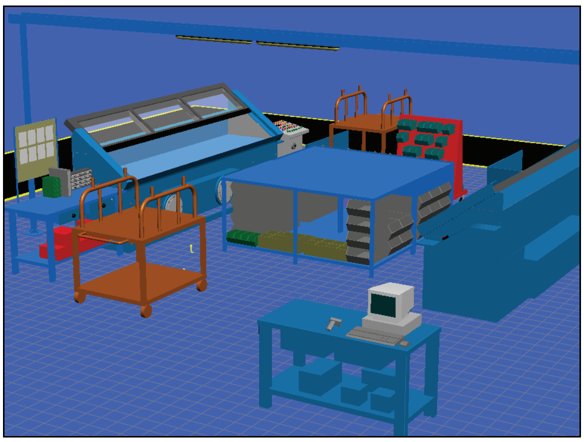

Figure 2: The virtual Pressure test workstation

The completion of the simulation model requires the insertion and training of human models capable of performing the workstation operations in the virtual environment. The selection of the human models type is based upon an accurate analysis of operators' characteristics (age, gender, height, weight and health). The objective is to select and import, from eM-Workplace libraries, human models representing as much as possible the real workers. After the insertion into the virtual environment, the human model is only able to stand in the waiting position; the model has to be trained to perform the manufacturing operations. In this regards, eMWorkplace provides the user with a programming language for teaching different types of activities and reproducing correctly each type of operation.

### 3.1. The simulation model validation

In order to increase the probability of success of a simulation study, the validation of the simulation model is a mandatory step. The main goal of the validation is to verify if the simulation model is capable of recreating the real system evolution over the time with satisfactory accuracy.

The simulation model validation has been carried out by the face validation technique. The face validation technique has been used for comparing the real process time and the simulated process time required for completing a typical Shop Order (production of 12 medium section hydraulic hoses). The real process time values are available on the company informative system (as mentioned in the section 2, at the end of each operation the worker sets the status "end operation" on the company information system). The real process time required for completing the Shop Order is 628.6 seconds. The simulated process time for completing the same Shop Order is equal to 602.2 seconds. An error of 4.2% reveals that the simulation model is capable of recreating the real Pressure test workstation with satisfactory accuracy.

## 4. THE SIMULATION RESULTS AND THE FINAL WORKSTATION CONFIGURATION

Let us consider the actual workstation configuration. The simulated process time for completing the Shop Order under consideration is equal to 602.2 seconds (about 10 minutes and 2 seconds). Taking into consideration the time allowance for personal, fatigue and delay (the time allowance is about the 16% of the total process time) and the 8 hours working shift, the number of Shop Orders per day being completed is 40. The workstation production on monthly basis is reported in figure 3.

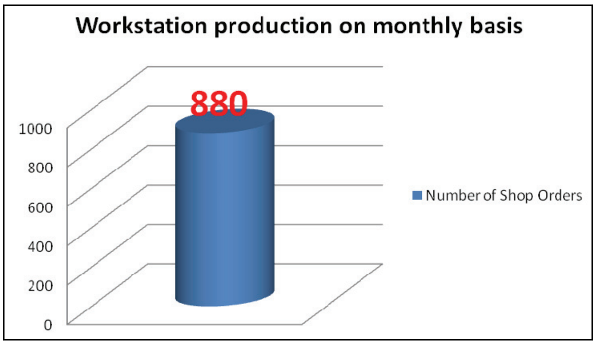

Figure 3: Monthly production of the Pressure test workstation

Once the initial solution was studied, a new workstation configuration was developed for achieving higher productivity levels. Let us list the workstation changes the authors propose:

- The manual dolly, the hydraulic hoses to be tested are placed on, has been located close the work table in order to eliminate the worker walking; figure 3 and figure 4 show respectively the actual and the final workstation configurations;


Figure 3: Manual dolly carrying the hydraulic hoses to be tested initial position

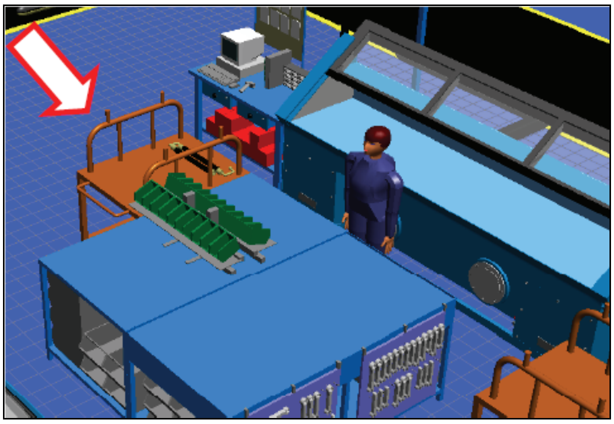
Figure 4: Manual dolly carrying the hydraulic hoses to be tested final position

- The manual dolly, the tested hydraulic hoses are placed on, has been moved near the work table; such change allows to reduce the time required by the operator for moving the tested hydraulic hoses. Figure 5 and figure 6 show respectively the actual and the final workstation configurations;

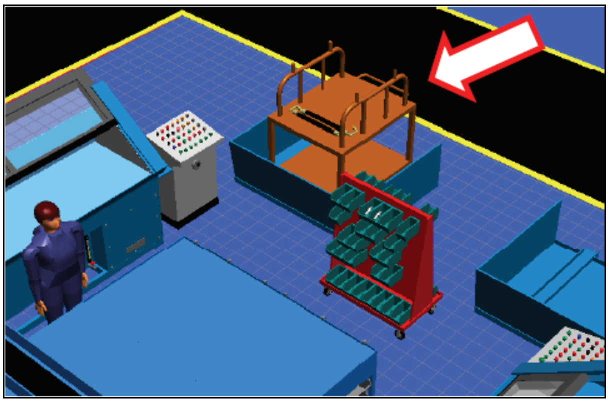
Figure 5: Manual dolly carrying the tested hydraulic hoses initial position

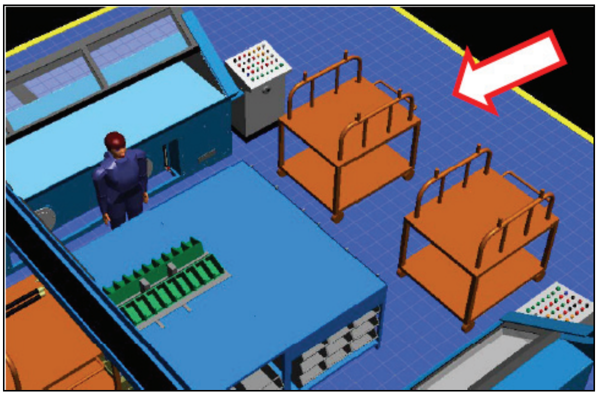
Figure 6: Manual dolly carrying the tested hydraulic hoses final position

- The PC location, used by the operator for setting the status “end of operation” on the company informative system, has been moved near the pressure test machine. Note that such change allows to reduce the number of steps required for performing the operation; figure 7 and figure 8 show respectively the actual and the final workstation configurations;

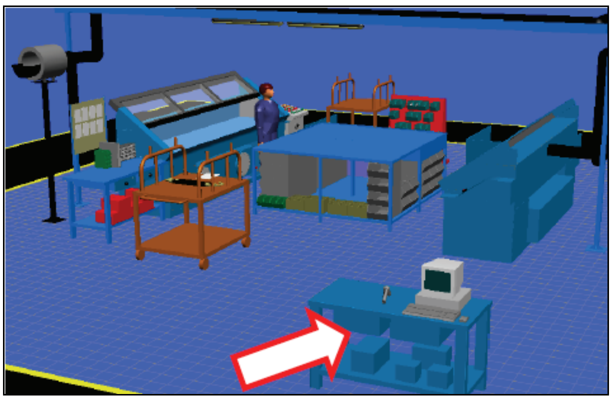
Figure 7: PC initial position.

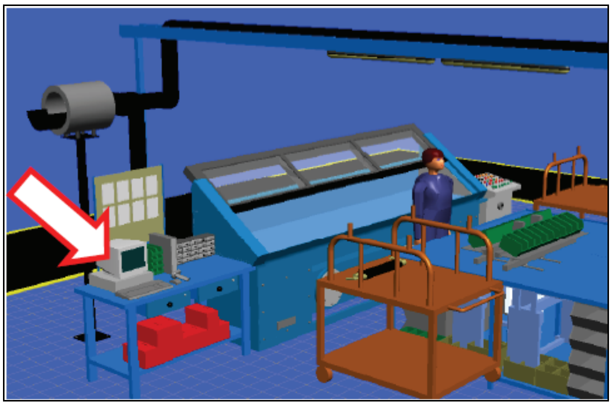

Figure 8: PC final position

- The joints bins have moved from the initial location (four steps far the work table) to the work table. Figure 9 and figure 10 show respectively the actual and the final workstation configurations;

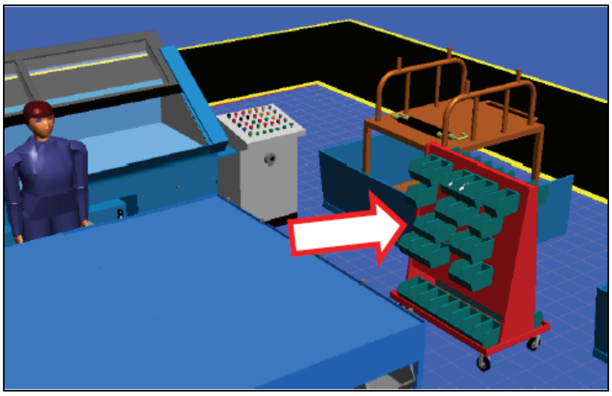

Figure 9: Joints bins initial position.

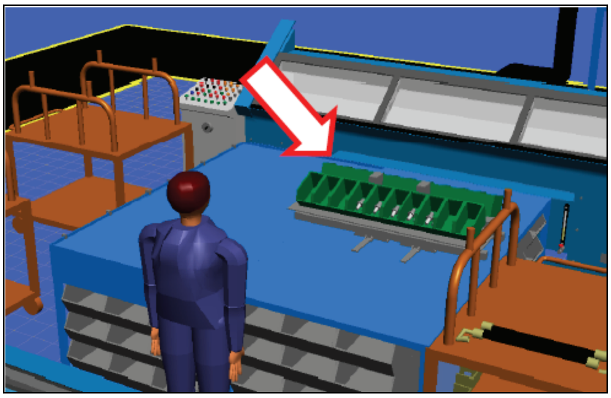

Figure 10: Joints bins final position.

The workstation changes allow the operator to have all the equipment and tools closer and in turn to reduce the time for performing the operations.

Let analyze the final workstation configuration in terms of number of Shop Orders being completed on monthly basis.

The simulation model evaluates in about 564 seconds (9 minutes and 24 seconds) the process time for completing the Shop Order under consideration. The number of Shop Orders per day being completed is 44.

The final workstation production on monthly basis is reported in figure 12.

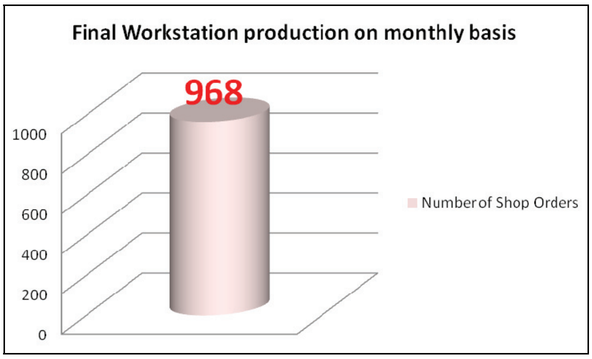


Figure 12: Monthly production for the final configuration of the Pressure test workstation

Compare now the productivity values for the actual and the final workstation configurations. Figure 13 reports the productivity values on monthly basis for both the configurations.

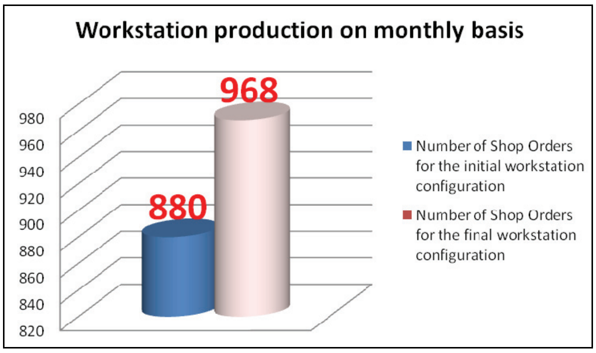


Figure 13: Productivity values for the actual and the final workstation configurations.

Note that the final workstation configuration allows to complete 88 Shop orders more the initial workstation configuration. In this regards the productivity improvement is about 10 % respect to the initial level.

The productivity growth has been appreciated by the company top management so that the workstation changes have been applied to the real system.

## 5. CONCLUSION

The research work proposes the effective redesign of a workstation belonging to a manufacturing process devoted to produce high pressure hydraulic hoses.

The objective of the study is to increase the workstation productivity in terms of number of Shop Orders being completed on monthly basis.

The authors started the research work by modelling the actual configuration of the workstation. The simulation model has been developed by using the CAD software Rhinoceros and the simulation software eM-Workplace.

The actual productivity level has been evaluated by means of the simulation model. Several workstation changes in terms of objects position have been accomplished and tested by the simulation model.

A final workstation configuration has been proposed achieving productivity levels higher than the initial ones.

## REFERENCES


Banks. J., 1998. *Principles of Simulation, Handbook of Simulation*. New York: Wiley Interscience.

Ben-Gal, I. and Bukchin, J., 2002. The ergonomic design of workstations using virtual manufacturing and response surface methodology. *IIE Transaction*, 34, 375-391.

Bocca, E., Longo, F., 2008. Simulation Tools, Ergonomics Principles and Work Measurement Techniques for Workstations Design. *Proceedings of Summer Computer Simulation Conference, 15-18 June, Edinburgh (UK).*

Chang, S.-W., Wang, M.-J. J., 2007. Digital Human Modeling and Workplace Evaluation: Using an Automobile Assembly Task as an Example. *Human Factors and Ergonomics in Manufacturing,* 17, 445-445.

Das, B., Sengupta, A. K., 1996. Industrial workstation design: a systematic ergonomics approach. *Applied Ergonomics*, 27, 157-163.

De Sensi, G., Longo, F., Mirabelli, G., 2007-a. *Modeling & Simulation Based Approach for Optimizing Seal Press Workstation in a Manufacturing System*, Proceedings of Business and Industry Symposium, March 25-29, USA.

De Sensi, G., Longo. F., Mirabelli, G., 2007-b. *Ergonomic work methods optimization in a three dimensional environment*, Proceedings of Summer Computer Simulation Conference, July 15-18, San Diego, California, USA

Engström, T., Medbo, P., 1997. Data collection and analysis of manual work using video recording and personal computer techniques. *International Journal of Industrial Ergonomics,* 19, 291-298.

Feyen, R., Liu, Y., Cha, D., Jimmerson, G., Joseph, B., 2000. Computer-aided ergonomics: a case study of incorporating ergonomics analyses into workplace design. *Applied Ergonomics,* 31, 291-300.

Kadefors, R., Forsman, M., 2000. Ergonomic evaluation of complex work: a participative approach employing video computer interaction, exemplified in a study of order picking. *International Journal of Industrial Ergonomics,* 25, 435-445.

Laring J., Forsman M., Kadefors R., Örtengren R., 2002. MTM-based ergonomic workload analysis. *International Journal of Industrial Ergonomics*, 30, 135-148.

Longo, F., Mirabelli, G., Papoff, E., 2005. *Techiche di analisi avanzate per la progettazione efficiente delle postazioni di assemblaggio manuale*, SdA – Soluzioni di Assemblaggio, VNU Business Publications Italia.

Longo, F., Mirabelli, G., Papoff, E., 2006-a. *Material Flow Analysis and Plant Lay-Out Optimization of a Manufacturing System*, International Journal of Computing, 5(1), 107-116.

Longo, F., Mirabelli, G., Papoff, E., 2006. Effective Design of an Assembly Line Using Modeling & Simulation. *Proceedings of the Winter Simulation Conference*, Monterey, California, USA.

Resnick, M.L., Zanotti, A., 1997. Using ergonomics to target productivity improvements. *Computer & Industrial Engineering,* 33, 185-188.

Santos, J., Sarriegi, J. M., Serrano, N., Torres, J. M., 2007. Using ergonomic software in non-repetitive manufacturing processes: A case study. *International Journal of Industrial Ergonomics,* 37, 267-275.

Udosen U.J., 2006. Ergonomic workplace construction, evaluation and improvement by CADWORK. *International Journal of Industrial Ergonomics,* 36, 219-228.

Vedder, J., Hellweg, 1998. Identifying postural hazards with a video-based occurrence sampling method. *International Journal of Industrial Ergonomics*, 22, 4-5.

Wilson J.R., 1997. Virtual environments and ergonomics: needs and opportunities*. Ergonomics,* 40, 1057-1077.

Zandin K.B., 2001. *Maynard's Industrial Engineering Handbook*, 5th ed. New York: McGraw-Hill.


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