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Development of Working-Posture Monitoring System for Ergonomic Manufacturing Work Environment

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Abstract. Ergonomic consideration on workers in manufacturing work has been attracted attention by industries. Physical safety and mental stability, which would be offered to workers by a well-designed ergonomic work environment, could not only provide job satisfaction to the workers, but also could enhance productivity in manufacturing work. This study develops a prototype monitoring system of ergonomic working posture in a manufacturing work environment. The methodology of this monitoring system is based on the experimental observation using an experimental tool of X-box cameras controlled by XAMPP software to monitor the posture of workers. As for the ergonomic environment measurement, the system installs the five types of instrumental sensors, which include sound, light, temperature, vibration and indoor air quality. Capturing the body posture of subjects, the system measures the frequency of body bending, the angle of body bending and the time period of the same position kept by the body. Potentially useful several parameters are used in the experiments of this study. These parameters include temperature, light, vibration, body posture, indoor air quality and noise. The parameters are captured in analogue signals, which can be converted to digital signals by a signal converter. The analysis of worker posture on RULA (Right Upper Limb Assessment) was also conducted by using several software tools. Reviewing the experimental results using the monitoring system in a manufacturing industry at welding assembly section, this paper shows the feasibility of the proposed system.

Keywords. ergonomics risk factor, ergonomic hazard, monitoring system, working posture, working environment

Introduction

Today, ergonomic consideration on workers in manufacturing work has been attracted attention by industries. Physical safety and mental stability, which would be offered to workers by a well-designed ergonomic work environment, could not only provide job satisfaction to the workers, but also could enhance productivity in manufacturing work. Various research papers show the positive effect of ergonomic principle in designing workplace, machines and facilities in manufacturing environment. By neglecting and ergonomic principle, it will create inefficiency and pain to the workplace. Thus it will cause physical and emotional stress, low productivity and poor quality of work. It's

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believed to be the root of the workplace health hazard, low level of safety and reduced worker productivity and quality. The ergonomic factors are identified [1] that caused low productivity, poor occupational health, and safety issues in a thermal power plant. If production workers dealing with machines for heavy works does not follow the standard operation procedure (SOP), the worker might suffer from an accident or become sick, which would lead to ergonomic hazards, such as Work-related musculo-skeletal disorder (WMSD), carpal tunnel disorder (CTS) and low back pain (LBP).

Studies of monitoring system of office workers have been reported to help ergonomic considerations. For example, using a marker in the body to detect the posture of computer worker in [2], 3D kinematic motion of the seated posture is recorded and monitored so that the office workers can avoid the back pain due to the poor sitting posture. Another study [3] uses a motion control camera and software tool (Kinect sensor and Microsoft Software Development Kit (SDK)) to monitor the head position and body posture of an office worker without using any marker.

However, studies of monitoring system for production workers were not so much reported. A monitoring system can be used, not only in monitoring the performance of the workers in their task but also in helping the prevension of an ergonomic hazard. For example, a monitoring system [4] analyzes the body posture of a production worker in lifting task by a Kinect sensor with Microsoft SDK. With the right body posture during a lifting task, the worker feels comfortable to work and back pain can be prevented. Otherwise, back and shoulder pain, muscle soreness and numbness might be occured by carrying a heavy weight. A monitoring system [5] of load carrying is not only industrial workers, but also general communities like school kids and adults. This monitoring system uses an wearable accelerometer placed on-body to detect extremen bivaration of body movement, such as load carrying and walking. Extreme vibration is commonly experienced by machine operators, who often suffers from CTS. A wireless vibration monitoring system [6] uses an accelerometer to gain the posture information. In order to gain a full-body vibration, four sets of accelerometer are put on the body to measure 3D linear acceleration.

The objective of this study is to propose a framework of monitoring system ErgoPEM (Ergonomic Posture and Environment Monitoring system) for ergonomic working posture and ergonomnic work enviroment for manufacturing workers. This paper overviews the framework, a prototype system ErgoPEM, and experimental results to show the feasibility of the system.

1. Methodology for analysis

1.1. Measurement factors

According to the observation of working environment, five ergonomic factors were identified, including environment and human factors, and measurement devices and parameter measurements were designed as shown in Table 1.

Table 1: Ergonomic factors, capturing devices and measurements in ErgoPEM.

Categories	Ergonomic factor	Device	Parameter Measurement (Unit)
Environmental factor	Room Temperature	Temperature Sensor	Celsius (C°)
	Humidity	Humidity Sensor	CO^2 Concentration (ppm)
	Lighting Intensity	Light Sensor	Lux (lx)
	Noise	Sound Sensor	Decibel (dB)
Human factor	Body Posture	Kinect Camera	Direction and Angle Degree (α°)

1.2. Working posture analysis by RULA

Body posture is recognized as the major factor of the cause of low back pain (LBP). ErgoPEM uses X-box cameras uder the control of XAMPP to monitor and obtain the data of frequency, angle and time period of body bending posture which was taken by the subject. Figure 1 shows the angle of the body bending and body bending position where the reference point is the waist.

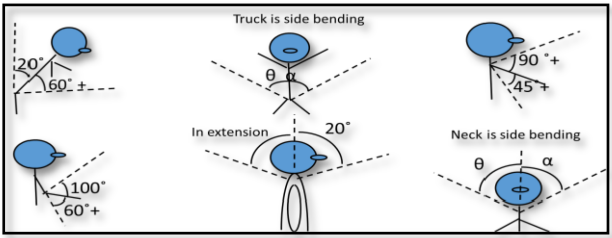


Figure 1. Angle of body bending and body bending position with the reference point of waist.

The RULA (Rapid Upper Limb Assessment) analysis tool [7] was developed to evaluate the exposure of indivisual workers to ergnomic risk ractors associated with upper extremity MSD. Using the RULA worksheet, the evaluator will assign a score for each of the following body regions: upper arm, lower arm, wrist, neck, trunk, and legs. Working posture analysis in this study employed the RULA.

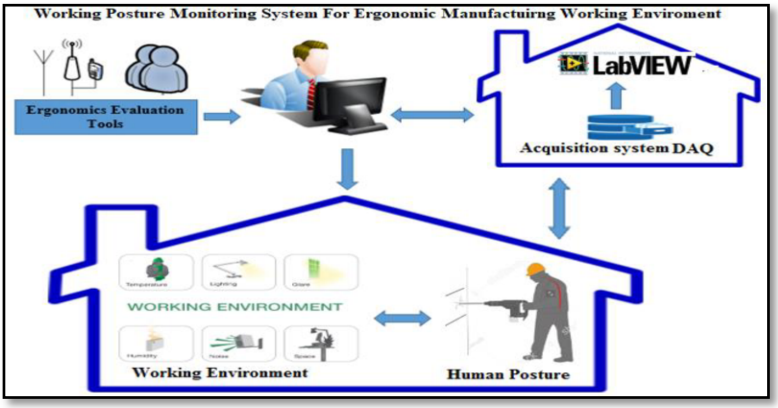


Figure 2. Concept of ErgoPEM monitoring for ergonomic manufacturing working enviroment.

2. ErgoPEM monitoring system

This study proposes a framework of ErgoPEM (Ergonomic Posture and Environment Monitoring) for ergonomic manufacturing working environment. ErgoPEM is composed of two types of modules, or posture detection module and environment parameter detection module. ErgoPEM monitors not only the posture of workers but also the working environment of the workers, and guides the appropriate working conditions for the workers. Figure 2 shows the concept of ErgoPEM monitoring system.

2.1. System configuration of ErgoPEM

System configuration of ErgoPEM is composed of two types of modules, or posture detection module and environment parameter detection module. Figure 3 shows the configuration of these two modules. The posture detection module is composed of motion capture camera (Kinect/Microsoft SDK [8]), control software (XAMPP [9]), and analysis software (CATIA [10]).

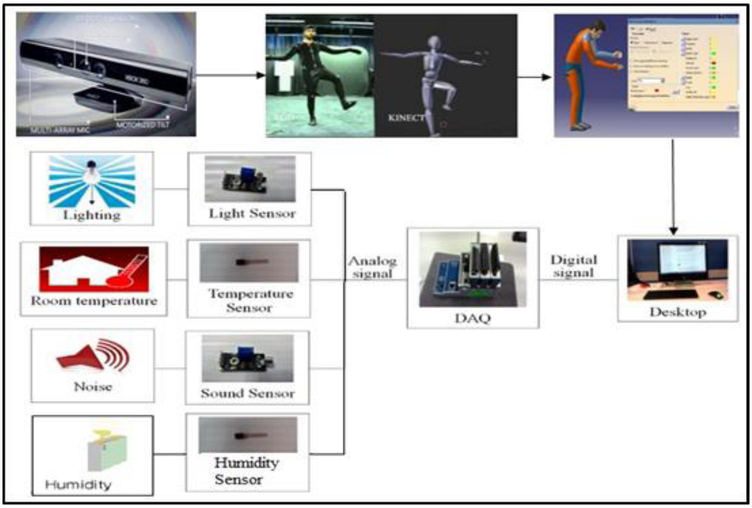


Figure 3. System configuration of ErgoPEM monitoring System.

2.2. ErgoPEM module for working environment measurement

The environment parameter detection module is composed of four types of sensors including temparature, humidity, lighting and sound. The image acquisition and processing was implemented under a graphical programming environment (LabView [11]). The internal code of temperature, humidity, light and sound sensors are shown in Figure 4.

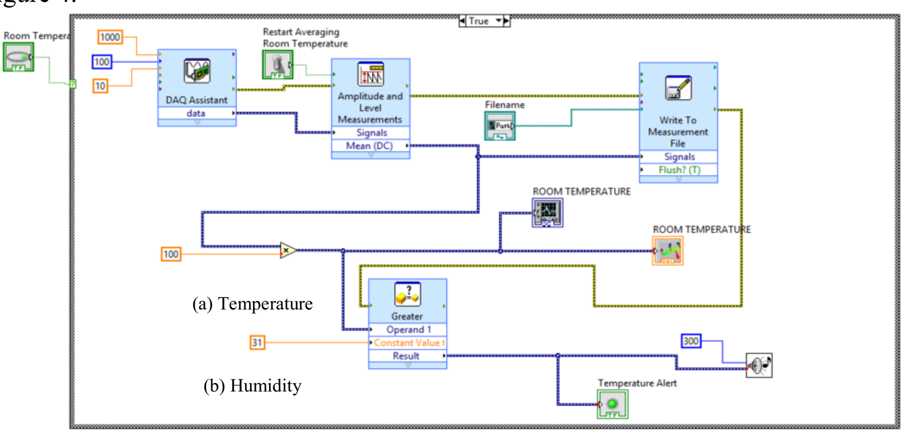


Figure 4. Programming example of date handling for temperature, humidity, lighting and noise.

2.3. ErgoPEM parameters for working posture analysis

Body posture of welding operators during welding work at the workstation was obtained and analysed by ErgoPEM, which is linked to an analysis software (Ergonomic design analysis, CATIA [12][11]). A manekin structure with anthropometry of the welding worker was built for the experiment. The posture video of the worker during the welding work was obtained by a motion camera of ErgoPEM, and the posture video was analyzed by RULA analysis. Figure 5 shows the final score of the manekin based on the RULA analysis box of the software. The final score is shown on the lowest part of the box, which indicates the colours that represent the ranges from 1 to 7; comprises of green (1&2), yellow(3&4), orange(5&6) and red (7 above) colour.

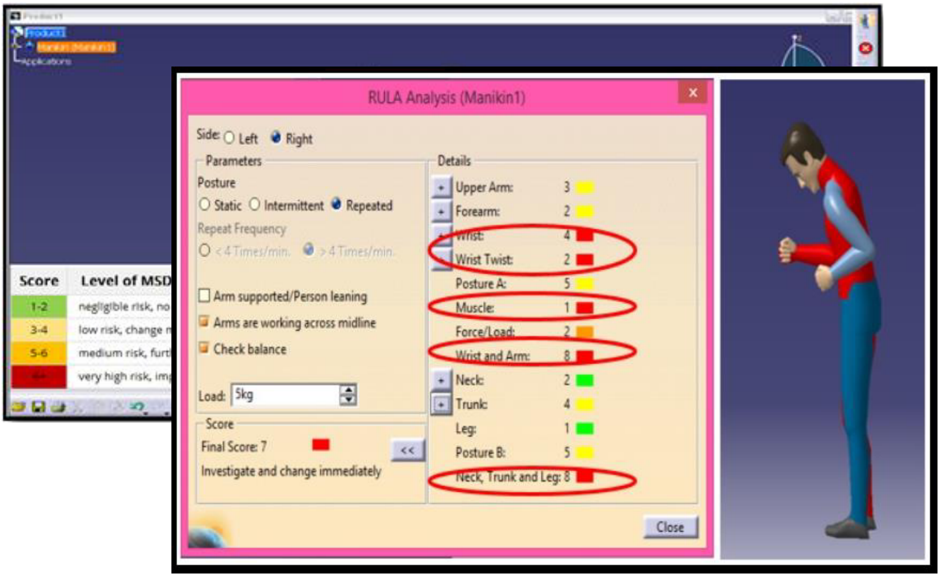


Figure 5: Example of final score by RULA analsys

3. Environment factor measurement and analysis

3.1. Experiment for environment analsysis by ErgoPEM

The experiment was conducted at a welding section of a manufacturing company in Melaka, Malaysia. The area size of the welding section for this experiment is 50 feet width and 100 feet length as shown in Figure 8. The area is divided into three sub-areas for this experiment, namely, welding workstation location composed of four sets of work tables (L1), welding surrounding location (L2) and office location near the workstation tables (L3). 20 lamps were equipped at the celing to cover the whole area. The four types of environmental factors including temparature, humidigy, lighting, and noise were validated in this company.

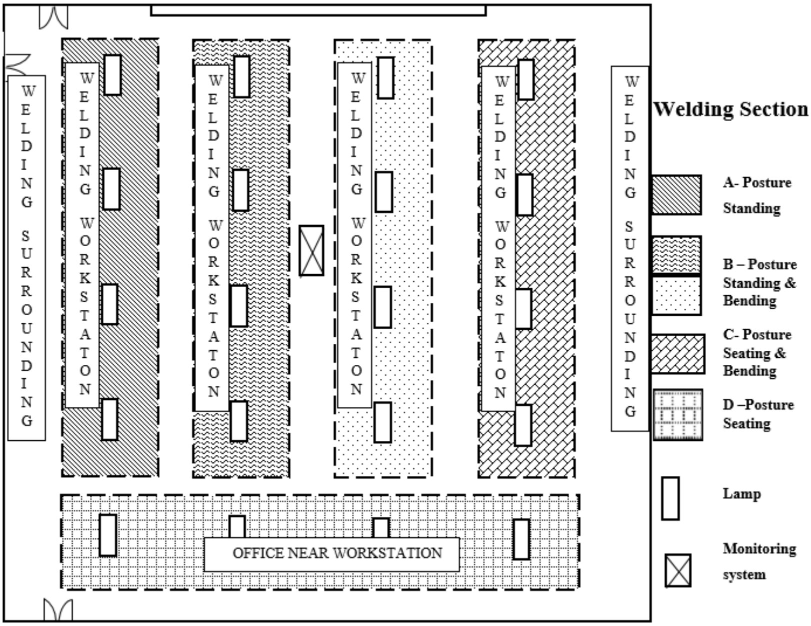


Figure 6. Layout welding section for ErgoPEM experiment.

According to (A) and (B)&(C) in Figure 6, "prolong standing posture" and "bending posture while standing" shows the same final score of 7, which indicates that the current posture need to be investigate and adjusted immediately since it causes critical pain on several parts of the welders' body. The body parts that are having critical pain are wrist twist, muscle, wrist arm, neck, trunk and leg.

(D) in Figure 6 shows that the final score of RULA analysis on "bending posture while siting" is 6, which indicates that the current posture needs to be investigated further and adjusted soon since it causes critical pain on several parts of the welders' body. The body parts that are having critical pain are muscle, trunk and on neck, trunk and leg.

The improvement in terms of working posture should be considered to avoid various occupational injuries such as musculoskeletal disorders, cumulative trauma disorders (CTD) and nervous systems disorder.

3.2. Working temperature measurement

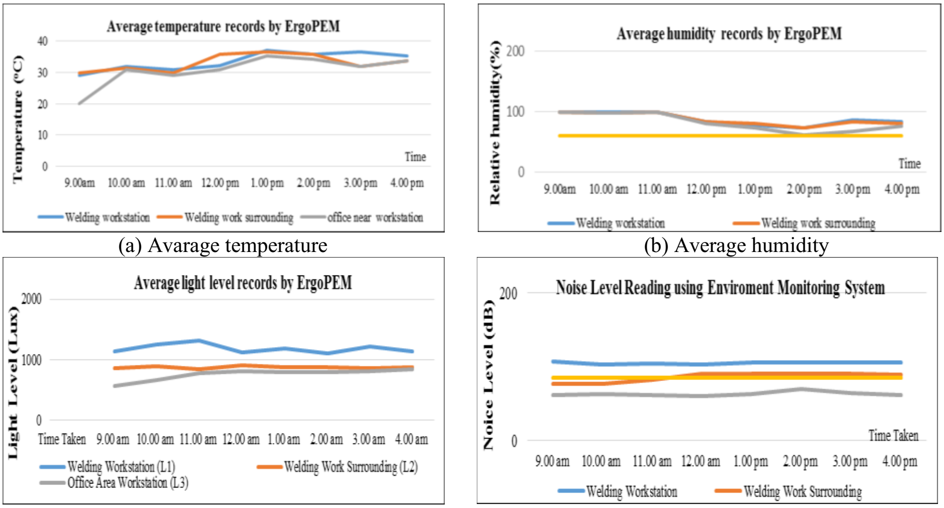
Temperature measurement for work enviroment analysis using ErgoPEM were conducted for 7 days, starting from Monday until Firday, during 7 hours between 9:00 am and 16:00 pm in each day. All of the data shown in the tables below are the average value of one week. Figure 7(a) shows the average temperature measured at three different locations of the welding section, namely L1, L2 and L3, starting at 9:00 am and ending at16:00 pm at every hour. The temperatures of the three locations were 29.1ºC, 30.0ºC and 30.1ºC at 9:00 am, which are relatively low temperature. The temperature gradually increases until 13:00 - 14:00 pm, then it slightly decreases after that in all of the three locations.

3.3. Relative humidity measueument

Figure 7(b) shows the average measurement of relative humidity at three locations at L1, L2 and L3 of the welding section measured by ErgoPEM. The humidity started at the same level in each section as high as 100% at 9:00 am. The relative humidity became low at 12:00 - 15:00, and became higher again at 15:00 - 16:00. Since the humidity of the welding section is much higher than the OSHA (Occupational Safety and Health Administration) standard of 60%, any countermeasures are required to be taken to meet the requirement.

3.4. Lighting measueument

Figure 7(c) shows the average values of lighting measurement at three locations of L1, L2 and L3 of the welding section for one week. The standard light and Lux levels at L1 ranged between 750 to 1000 Lux. In the mean time, the light levels at L2 and L3 were in the range of standard level for welding space. Low lux levels (insufficient light) are the common cause of fatigue and muscle strain. This becomes more apparent if the exposure to light fluctuation is consistent over longer periods of time. The same is true for high lux levels (excessive light). Glare and reflected light can distract an individual and impair his or her vision. This is particularly dangerous in such a job which requires the full attention of workers. For example, dangerous machinery jobs or hazardous chemicals handling jobs would increase much higher risks. Using a light or lux meter to regulaly measure light levels in workplace can be one solution to lower these risks. Protecting colleagues and employees is one of the critical issues to be considered in the working environment.



(a) Avarage temperature
(b) Average humidity
(c) Avarage lighting level
(d) Average noise level

Figure 7: Environmental measurement by ErgoPEM for temperature, humidity, lighting and noise.

3.5. Working noise measueument

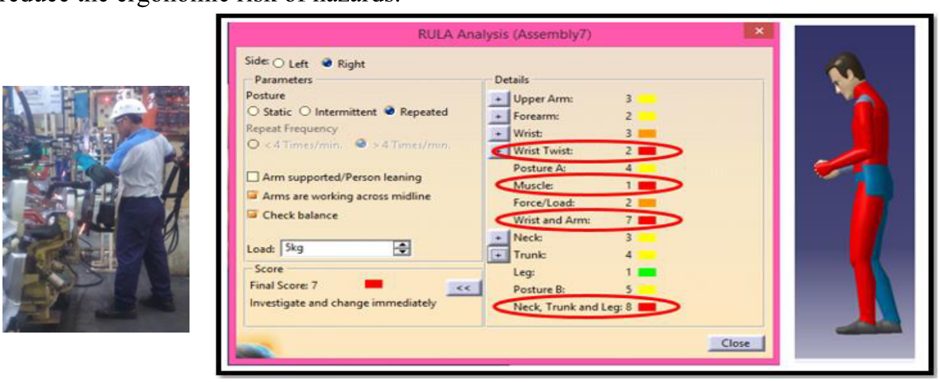
Grinding work is performed as the finishing job of the welding process. The majority of working noise comes from this grinding process. Each workstation conducts a different number of grinding work based on the evaluation of welding. Two grinding processes were conducted at L1, whereas only one grinding work was performed at L2 and L3. The noise level measured at earch location is shown in Table 2. The noise level at welding workstation L1 with two grinding machnes is higher than that of L2 or L3. The noise level at L1 ranges between 102.3dB and 106.3, all of which are higher than the OSHA standard of 85dB. This means that the grinding machine is the major source of noise at the welding section. Figure 7(d) shows the linear graph of the noise level on the secrenshot of EegoPEM.

Table 2. Noise level measurement data in three welding work area (L1, L2 and L3) by ErgoPEM.

Location/Time	**No of Grinders**	**9:00 am**	**10:00 am**	**11:00 am**	**12:00 pm**	**13:00 pm**	**14:00 pm**	**15:00 pm**	**16:00 pm**
Welding Workstation (L1)	2	106.3	102.3	103.9	103.2	105	105.5	105.5	105.3
Welding work surrounding (L2)	1	76.2	76.8	82.5	91	90	90.5	90.8	89.5
Office near workstation (L3)	1	61.7	62.5	61.5	59.5	63	70.2	63.6	61
OSHA Standard		**85**	**85**	**85**	**85**	**85**	**85**	**85**	**85**

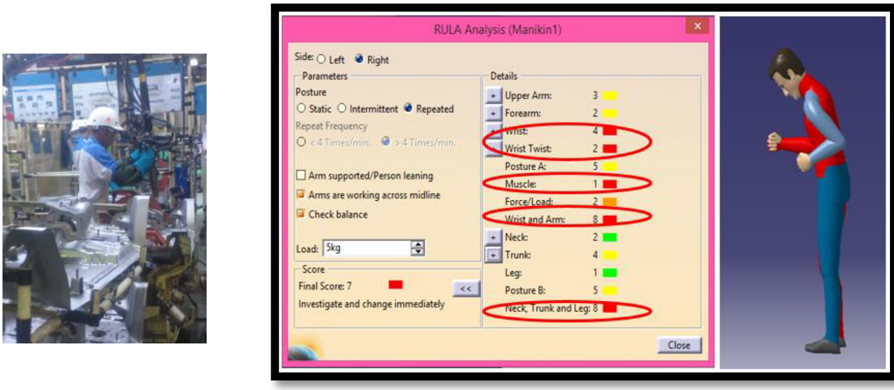
4. Experiment for working posture analysis by ErgoPEM

Analysis of working posture was conducted by RULA (Rapid Upper Limb Assesment), which shows the final score of each postures and indicates the body parts under any critical pains. Analytical results for bad examples of postures are shown in Figure 8, 9, and 10. (A) posture is taken at A-posture stantind area in Figure 8, followd by (B) posture at B-posture standing&bending area, and (C) posture at C-posture seating, respectively. In the experiment, the similar results were shown on the monitoring screen of the facility so that both the employer and employees could see/share the result of the current working posture, and were encouraged to make posture adjustment to reduce the ergonomic risk of hazards.



(A) Prolong standing RULA analysis for prolong standing posture

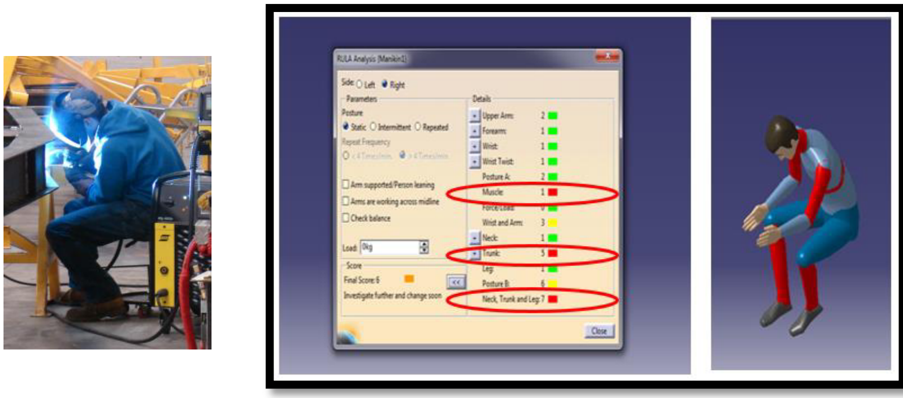
Figure 8. Example of bad posture during the welding work under prolong standing.



(B) Body bending while standing

RULA analysis for body bending while standing

Figure 9. Example of bad postures during the welding work under body bending while standing.



(C) Body bending while sitting

RULA analysis for body bending while sitting

Figure 10. Example of bad postures during the welding work under body bending while sitting.

5. Concluding remarks

Achievement of a safe and sound working environment is generally the ultimate goal of both the workers and employers. Productivity in manufacturing systems and performance of workers could be significantly enhanced by an ergonomically well-designed working environment. Avoidance of accidents in manufacturing facilities not only increases the motivation of workers, but also reduces the nucessesariliy cost, such as medical costs which would be needed in case of hazards in the facilities.

A framework for acquiring and monitoring ergonomic parameters has been shown and a prototype system of ErgoPEM has been developed as an implementation of the framework. Using ErgoPEM at the welding section of the experiment, information regarding current posture of workers and environment condition for the welding work were clarified, shared and understood for both workers and employers as a guidance towards setup of a safety and healthy working environment. The authors made an interview and questionnaire survey for the entire worker in the welding section regarding the environment and bad postures, in order to determine the parameters of ErgoPEM (Figure 11). For the next phase of this research, further study of the additional parameters, measurement of working efficiency by ErgoPEM, analysis on the voice of workers using ErgoPEM are under consideration.

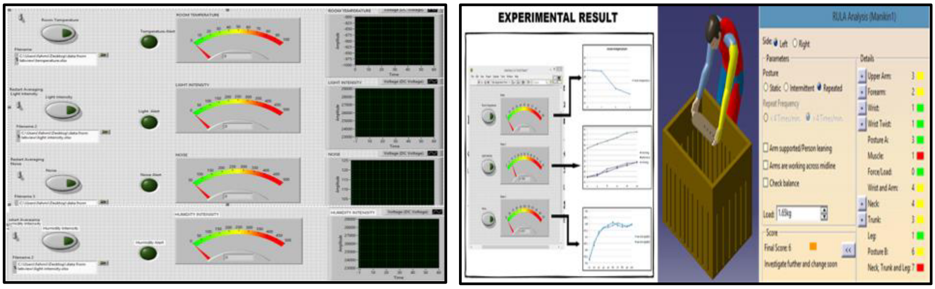


Figure 11. Snapshots of ErgoPEM monitoring screen projected on the wall of welding section

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References

[1] J.A. Hole and M. Pande, Worker Productivity, Occupational Health, Safety and Environmental, *Thermal Power Plant*, 2009, pp. 1082-1086.

[2] P. Walsh, L.E. Dunne, B. Caulfield, and Barry Smyth, Marker-Based Monitoring of Seated Spinal Posture Using a Calibrated Single-Variable Threshold Model, *Proceedings of the 28th IEEE, EMBS Annual International Conference*, New York City, USA, 2006, pp. 5370-5373.

[3] A. Uribe-Quevedo, Byron Perez-Gutierrez, and Cesar Guerrero-Rincon, Seated tracking for correcting computer work postures, *2013 29th Southern Biomedical Engineering Conference,* Miami, FL, USA,2013,pp.169-170.

[4] Chris C. Martin, D.C. Burkert, K.R. Choi, N.B. Wieczorek, P.M. McGregor, R.A. Herrmann and P.A. Beling, A Real-time Ergonomic Monitoring System using the Microsoft Kinect, *2012 IEEE Systems and Information Engineering Design Symposium,* University of Virginia, Charlottesville, 2012, pp. 50-55.

[5] M. Benoccit, M. Bachlin, E. Farellat, D. Roggen, L. Beninit and G. Troster, Wearable assistant for load monitoring: recognition of on-body load placement from gait alterations, *4th International Conference on Pervasive Computing Technologies for Healthcare 2010*, Munich, Germany, 2010, pp. 60-66.

[6] F. Petré, F. Bouwens, S. Gillijns, F. Massé, M. Engels, B. Gyselinckx, K. Vanstechelman and Ch. Thomas, Wireless Vibration Monitoring on Human Machine Operator, *2010 17th IEEE Symposium on Communications and Vehicular Technology in the Benelux (SCVT2010),* Enschede, Netherlands, 2010, pp. 1-6

[7] L. McAtamney and E.N. Corlett, RULA: a survey method for the investigation of work-related upper limb disorders, Applied Ergonomics, Vol. 24, 1993, pp. 91-99.

[8] Kinect, http://www.egr.msu.edu/classes/ece480/capstone/spring15/group02/assets/docs/dzappnote.pdf

[9] XAMPP, http://dalibor.dvorski.net/downloads/docs/InstallingConfiguringDevelopingWithXAMPP.pdf

[10] CATIA, https://www.3ds.com/products-services/catia/

[11] LabView, http://www.ni.com/pdf/manuals/373427j.pdf

[12] Human activity analysis, http://www.catiadesign.org/_doc/v5r14/catpdfhaaug_C2/haaug.pdf