Conference Paper

Development of Green-Affective Work System for Food SMEs

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Abstract

Work system of food Small and Medium-sized Enterprises (SMEs) is influenced by various factors as worker performance, characteristics of raw material, value-added process and workplace environmental ergonomics. Green-affective design analyzes properties of work systems and how these technical attributes could be sensible to the environment (Green) and worker (Affective). The research objectives were: 1) To explore the relationship between green and affective parameters in work systems of Food SMEs; 2) To design a green-affective work system for Food SMEs. Six (6) SMEs of different food products were used for the case studies as Crackers, Nuggets, Fish Chips, Bakpia, Tempe and Herbal Instant Beverages. Air conditioner was suggested to set the temperature set points for controlling environmental ergonomics. Green parameters were analyzed using calculation of air conditioner electricity cost at different workplace temperature set point. Affective parameters were analyzed using heart rate, worker energy consumption and rowan incentive plan. Research findings indicated air conditioner could be used to control environmental ergonomics based on the satisfied temperature set points and efficient electricity cost in work system of food SMEs.

Keywords: Air Conditioner; Environmental Ergonomics; Heart Rate; Rowan Incentive Plan

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INTRODUCTION

Work system of Food Small and Medium-sized Enterprises (SMEs) is influenced by various factors as worker performance, characteristics of raw material, value-added process and workplace environmental ergonomics. Environmental ergonomics is the

dynamic effects of workplace heat and cold, vibration, noise level and lighting condition on the health, comfort and performance of human being [8]. Temperature set point is critical factor of environmental ergonomics which influence worker workload and thermal satisfaction [6, 15]. Global competitiveness required industry to apply green parameters as energy saving and environmentally responsible manner [4].

Dües et al. [4] have applied the green prespectives to lean manufacturing. Dües et al. [4] have combined the lean and green perspectives to fulfill the consumer needs in environmental friendly perspectives. Ushada et al., [11] have simulated the workplace environment in a confined space using greening material approach. However, the application of green parameters should fulfill the affective parameters as worker satisfaction and workload. Works system should be designed combining green and affective perspectives to increase the total industrial productivity without worker rights for optimum environmental ergonomics.

Ushada et al. [13] have explored the affective perspectives for developing work systems of SMEs using Kansei Engineering and information technology. The term of affective refers to quantification of worker responsiveness to production target and environmental ergonomics.

Worker affective states to production target was measured in our previous research [12]. Integrated workload was assesed using an intelligent sensor based on total mood disturbance and heart rate [12]. In addition. worker affective states to environmental ergonomics have been measured in our previous research [14] and other research [5, 10]. Workplace environment is usually quality controlled based on value-added process, for instance frying and cutting the raw material. However, environmental ergonomics based on worker workload are left uncontrolled.

Based on literature review, none of these have literally combined green and affective parameters for works system of SMEs. Green-affective design analyzes properties of work systems and how these technical attributes could be sensible to the environment (Green) and worker workload (Affective).

The research objectives were: 1) to explore the relationship between green and affective parameters in work systems of Food SMEs; 2) to design a green-affective work system for Food SMEs. The research advantage is to support the implementation Indonesian President's vision of Digital Economy 2020 for SMEs.

MATERIAL AND METHODS

Air conditioner was suggested to control the temperature set points for creating environmental ergonomics in a work system [1, 7]. The utilization of air conditioner should consider combining green and affective parameters to achieve satisfied workplace temperature (Thermal comfort) and reducing energy consumption.

Six (6) SMEs of different food products were used for the case studies. In this research, the scope of SMEs were industries which produces product of Crackers, Nuggets, Fish Chips, Bakpia, Tempe and Herbal Instant Beverages. 380 data set were analyzed in this research. The data set consist of heart rate after working, temperature set points and ambient temperature.

Affective parameter was analyzed using worker energy consumption and rowan incentive plan [9]. The energy consumption (kcal/minutes) was calculated using heart rate based on the linear regression as shown in the equation 1 [3]:

$$Y = 1,80411 - 0,0229038 \times X + 4,71733 \times 10^{-4} \times X^2 \quad (1)$$

where:

Y = energy consumption (kcal/minutes)

X = heart rate (pulse/minutes)

Rowan incentive plan was used since energy consumption is an appropriate parameter to represent green perspective. It was calculated using equation 2 [9]:

$$I = (E_u - E_s/E_u) \times 100\% \quad (2)$$

where:

I = Rowan incentive plan (%)

E_u = Energy consumption (kcal/minutes)

E_s = Energy standard or average values of energy consumption (kcal/minutes)

Green parameter was analyzed using calculation of air conditioner's electric power/PAC (kWatt) at different workplace temperature set point [16]. PAC was interpolarized based on the data of air conditioner's specification data in Wang et al. [16]. In this system, the AC utilization was suggested 4 hours per day. Most of the SMEs suggested the air conditioner utilization on 10.00 AM to 12.00 PM and 13.00 PM to 15.00 PM. The working day was assumed for 20 days per month. The electricity tariff per August 2016 was decides as Rp. 1410,12.

Table 1: Green Parameters of Air Conditioner (n = 380).

Statistics	Temperature set points (°C)	Temperature after working (°C)	PAC (kWatt)	Electricity cost (Rp/month)
Minimum	24,8	27,3	0,872	98.370
Maximum	33,1	46,3	1,070	120.706
Modes	30,2	34,2	0,935	105.477
Averages	29,2	33,3	0,965	108.848
Standard Deviation	1,8	2,8	0,039	4.426
Notes: Total electricity cost (Rp/month) =Rp. 700.000,- Electricity tariffs (Rp/kWh) =Rp. 1410,12				

Table 2: 2016 Regional Minimum Wages (RMW) of D.I. Yogyakarta [2].

No	District / City	RMW (Rp)
1	Yogyakarta	1.452.400,-
2	Sleman	1.338.000,-
3	Bantul	1.297.700,-
4	Kulonprogo	1.268.870,-
5	Gunung Kidul	1.235.700,-
Average		1.318.534,-

RESULTS AND DISCUSSION

Table 1 indicated the descriptive statistic for green parameters of air conditioner. The temperature set point was measured before working since it was closest to the comfortable and efficient temperature in the morning time. The set points ranged from 24.8 to 33.1 °C. The temperature after working was indicated as the ambient temperature which was closest to the outdoor temperature. The set points ranged to 27.3 to 46.3 °C. PAC ranged from 0,872 to 1,070 kWatt. Electricity cost was calculated from Rp. 98.370 to Rp. 120.706 using the asumption of electricity tariffs of Rp. 1.410,12/month. The cost were approximately 10% from the total electricity cost in SMEs of Rp. 700.000,-/month.

Table 2 indicated the regional minimum wages for Yogyakarta Special Region consisted of district/city: Yogyakarta, Sleman, Bantul, Kulonprogo and Gunung Kidul. The average regional minimum wages value of Rp. 1.318.534,- in Table 1, was used to calculate the rowan incentive plan in Table 3.

Table 3: Affective Parameters of Heart Rate (n = 380).

Statistics	Heart Rate (Pulse/ Min)	Energy (Kcal/ min)	% Incen-tives	Wages(Rp/ mo.)
Minimum	66	2,35	-51,24	642.972,84
Maximum	123	6,12	42,03	1.872.705,60
Modes	98	4,09	13,20	1.492.636,34
Averages	89	3,55	-3,20	1.276.286,00
Standard Deviation	10	0,66	17,57	231.712,57
Notes: Average regional minimum wage was the average value in table 2 = Rp. 1.318.534,-				

Table 3 indicated the descriptive statistic of affective parameters of heart rate. The heart rate was measured from 66 to 123 pulse/minutes. The incentives were calculated in percentage ranges from -51,24 to 42,03%. The wages from rowan incentive plan were calculated from Rp. 642.972,84 to Rp. 1.872.75,60.

CONCLUSIONS

Research findings indicated that the integration of green and affective parameters could bring benefit to works system of food SMEs. Green-affective work system was developed for food SMEs. In this system, air conditioner could be used to control environmental ergonomics based on the optimum temperature set points and minimum electricity cost. Air conditioner utilization was suggested for 4 hours per day. The air conditioner electricity cost was calculated from Rp. 98.370,- to Rp. 120.706,-. The 4 hours utilization generated 10% cost from the total electricity cost in SMEs work system. Based on temperature set points, worker workload could be calculated to detemine the rowan incentive plan. The wages per month was calculated from Rp. 642.972,84 to Rp. 1.872.705,60.

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