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Lack of knowledge on job heaviness may cause occupational stress in welders while working under hostile work environment in a public domain

This research tries to find out the cardiac load during pre-working, working and post-working period of electric arc welders who are engaged in fabricating job for Periodical Over Hauling (POH) in mechanical workshop of Government sector. Their working heart rate (WHR) reflects that the job category is in the range of very heavy to extremely heavy. The hostile working environment with a mean air velocity of 0.1 ms-1 throughout the year and unscientific working posture also increases the adverse effect on workers' health due to their occupation. The work rest regimen also should be rectified as per recommendation of American Conference of Governmental Industrial Hygienist (ACGIH). Due to hostile nature of environment in the site, the effective hours should be less as compared to that of previous effective hours in respect of work-rest scheduling recommended by ACGIH. So it seems that environmental unfriendliness has a huge role in varying productive hours during the work-shift.

The Resting heart rate (RHR), heart rate at site (HRS) and Pre working heart rate (PWHR) values of the welders of age less than forty years and greater than forty years are respectively 86, 94 100 bpm and 83, 97, 111 bpm. The WHR of the senior group is 126bpm which is quite greater than the other group which is 108bpm and it reflects on the vast range of peak Heart rate (HR) from (96-130) bpm for the junior group and (95-223) bpm for the senior group. The Net cardiac cost (NCC) value of the age group of below 40 years is 22bpm, whereas the other group is 43bpm. The % of Relative cardiac cost (RCC) value are 22 % and 55 % respectively for junior and senior group which reflects very significance difference. The Energy Expenditure values i.e. 4 kcal/min for junior group and 5 kcal/min for senior group also reflects the high strain among the seniors than the age group of below 40 years.

It is seen from the study made for occupational fatigue applying Brouha's standard index that all the workers are in 'No Recovery' group

Similarly the energy cost of the welders are heavy in nature. Higher energy demand of the task makes it harder to execute continuously in expected pace. Environmental heat load at the work field imposes extra load on the workforces. The ET value is above the permissible heat exposure limits as suggested by World Health organization (WHO). As a consequence the body of the working personnel in above than 40 years group is observed to be affected much more than that of the less than 40 years group.

A little bit of ergonomic approach along with engineering control and workers sincerity may improve this situation which reflects on workers' health and productivity index in the near future.

Keywords: Electric arc welder, job heaviness, occupational health, workload, working heart rate, worksite environment.

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1.0 Introduction

In the journey from "developing to developed", industrial growth plays a very important role. During the course of rapid industrial generation or progress industrialist or sometimes the Government (in case of Public Sector Unit) have to face competition which reflects on workers by giving high production in a comparatively less time. This phenomenon is very common in almost every industry. For establishing a profitable and stable organization set up the management demands highly skillful product in a minimum operational time. On the other hand early finish craze and ignorance about rules and regulations the worker faces health disorders due to occupational hazards. For this absenteeism occurs and compensation have to pay by the management to the worker in case of health related problem which results loss in productivity and loss in profitability too.

After reviewing different literatures in this field both in national and international level, the author finds that the research in the field of finding causes of occupational health disorders among the industrial workers and trying to find out the possible way out is very less and in the third world country it is almost negligible. So, it seems to the author that, this study will help the workers to get the better working environment and at a time the management will gain high productivity index which will help to strengthen the economic growth of the nation.

The aim and objectives of this present research work are:

- Find out the root causes of occupational hazards which are generally faced by the electric arc welders during their daily work.
- Evolution of occupational stress from the ergonomic angle.
- Try to find out the possible remedies.

Previous works done by different researchers in both national and international level which are almost similar to the topic are follows,

In this connection a very important guideline was given by DuBois and DuBois [1] for estimating the approximate surface area of a human being when height and weight be known. For analyzing the working environment the contribution of Mookherjee and Sharma[2] is really appreciable. They have classified the working zone in three types i.e. hot, very hot and extremely hot, based on the effective temperature (ET) value. Later Yaglogou and Minard [3] shared their experience regarding the Wet Bulb Globe Temperature (WBGT), which is a very important environmental parameter while dealing with the occupational stress. Another eminent scientist Chamoux et al. [4] also explained his view by calculating the workload classification focusing on the net cardiac cost (NCC). Further, scientist Brouha [5] evaluated the fatigue among the industrial workers after completion of their daily work by calculating the recovery period. Another very important physiological parameters i.e. energy cost of different muscular exercise tests performed by the Indian subjects, was found by Ramanathan et al. [6]. Again the recommendation of World Health Organization (WHO) [7] for finding out the nature of job by considering the effective temperature (ET) value also helps the researchers to study in this region [8]. American Heart Association Committee of exercise offered an equation for calculating maximum heart rate of a person in their book which has very important aspect for finding the occupational stress due to cardiac load of a worker. Further American Conference of Governmental Industrial Hygienist (ACGIH) [9] recommended the threshold value for chemical substances and physical agents in the workroom environment. This categorization helps to find out the environmental status of the particular working station on the basis of Wet Bulb Globe Temperature (WBGT). Later Lablache-Combier and Ley [10] expressed their research result on relative cardiac cost (RCC) and also recommended the standard value. An eminent scientist Astrand [11] estimated the workload classification on the basis of working heart rate (WHR). Another very important physical index i.e. body mass index (BMI) was calculated by Naidu and Rao [12]. They described their valuable equation regarding BMI which is a very remarkable measurement to find out the nutritional status in Indian population. Kiirkhon [13] et al stated about workplace risk and musculoskeletal disorders (MSD) for the workers assigned in agricultural production sector. They experimented on the degree of MSDs where musculoskeletal problems have been treated as pain indicator which ultimately makes the basis of chronic disease. Further Newmann et al. [14] worked on pinpointing on the root cause of low back pain as reported from substantial proportion of subjects engaged in automotive industry. Later Neumann et al. [15] tried to explain the importance of implementation of ergonomics practice in production by relating ergonomics, production engineering and corporate strategy all together. Further Kazmierczak et al. [16] described and examined the workload and performance level of worker, assigned in an engine assembly work. They tried to collect data from observation and after classification interpret those on worker's performance, which would help to minimize the losses of both economical and physical. Agrawal et al. [17] tried to improve workers performance at work by developing an autonomous rhythm at work which will synchronize physical, physiological and psychological aspects which are responsible for human behaviour and efficiency at work and stands as a key factor deciding workers effectiveness. Further Andrews et al. [18] selected an automobile assembly plant and considering epidemiology and biomechanical approach, they have tried to establish that the questionnaire and checklist method are very effective for estimating peak physical load among worker, than more expensive video analysis method. Eminent scientist Braam et al. [19] focused on an interesting event that mechanization plays an important role in the industry, partly for economic reason and partly to reduce workload but the most important question is does mechanization really reduces physiological and mechanical workload? The authors showed that due to poor ergonomical design unscientific working posture still exist and it is very necessary to investigate the method of prevention from this to save the worker to save the world. Haboubi [20] stated the effect of temperature variations on the oxygen consumption of moderate work. This study examines the apparent conflict via a new theory. The theory effectively states that at sub maximal work, VO_2 is lowest at the acclimatized environmental condition. According to the work in this paper, the energy expenditure for moderate work is lowest at the acclimatized environmental condition. Hence, work done during the transitional period is performed at no optimal efficiency.

2.0 Methodology

SUBJECT

Thirty male subjects who are engaged themselves for the electric arc welding operation during POH of different coaches of Indian Railways and have no previous history of medical illness, as per record of local health unit, volunteers for the participation in the experiment. All the subjects have minimum two years of working experience in this field and as because they have been acclimatized in this nature of job. They are again segregated in two subgroups of below and above forty years of age.

Task

During POH of coaches the electric arc welders are playing very important role. As we all know that welding is nothing but joining of two similar or dissimilar metals with or without use of pressure and in this case each and every item done by the welders are critically examined as because of considering these items as 'safety items'. In this case if any discriminency is found then major punishment will be charged to the welders as in most of the cases it relates with the life of passengers. So during working the welders have to think over it and so they are in mental pressure. On the other hand sometimes they have to work in semi confined places (i.e. driver's cab, low tension or high tension electric cabin) along with different categories of worker (fitters, oxy-cutters etc.) and most of the times in an awkward posture (upwards welding in a half bent posture etc.). During summer and rainy season it becomes truly intolerable where atmospheric temperature with relative humidity and almost stagnancy of air (mean air velocity 0.1ms-1) merge with electric arc welding temperature.

Parameters

- Direct environmental parameters:
  1. Dry bulb temperature, DBT, °C.
  2. Wet bulb temperature, WBT, °C.
  3. Natural wet bulb temperature, NWBT, °C.
  4. Air velocity, AV, m/sec.
- Derived environmental parameters:
  1. Relative humidity, RH, %.
  2. Wet bulb globe temperature, WBGT, °C. It is derived from the following formula [3]

     $WBGT = 0.7T_w + 0.2T_g + 0.1T_d$ …(1)

     [Where, T_w = NWBT, °C. T_g = Globe thermometer temperature, °C. T_d = DBT, °C.]

     Indoors, or when solar radiation is negligible, the following formula is often used:

     $WBGT = 0.7T_w + 0.3T_g$ …(2)
  3. Effective temperature, ET, °C.
- Direct physiological parameters:
  - i) Weight, Kg.
  - ii) Height, m.
  - iii) Resting heart rate (RHR), beats per minute, bpm,
  - iv) Working heart rate (WHR) bpm,
- Derived physiological parameters :
  - i) Maximum heart rate (HR_{max}) [8] bpm: HR_{max} = 220–Age.
  - ii) Heart rate reserve (HRR) bpm: $HRR = HR_{max} - HR_{rest}$.
  - iii) Heart rate recovery ($HR_{recovery}$) bpm: It is the reduction in heart rate at peak exercise and the rate as measured after a cool-down period of fixed duration. Recovery heart rate is measured in a sitting posture after the completion of work and is obtained by counting the pulse of the subjects for three minutes on each last 30 seconds of a minute hence it is denoted as P1, P2, P3.
  - iv) Net cardiac cost (NCC) bpm, NCC= WHR – RHR.
  - v) Relative cardiac cost (RCC) %: It is obtained by expressing the NCC as % of the heart rate reserve (HRR) of the subjects.
  - vi) Energy expenditure (EE)[6] Kcal/min: It can be obtained by the following mathematical equation, $EE = 0.045 \times HR_{peak} - 1.42$.

The major physical features considered for the study are age (years), height (m), weight (kg), body surface area [1] (m^2) and body mass index [12] ($Kg\ m^{-2}$). By measuring pulse rate of individual workers in a resting position before engaging in the work for three consecutive times RHR is measured and the mean value is taken. WHR is measured throughout their work schedule by using the portable telemetric heart rate monitor (Sports Tests PE 3000, Polar Electro, Finland). Directly measured environmental parameters are DBT, WBT, NWBT, T_g and AV. WBGT measurements are based on the formula given by Yaglogou and Minard [3] while calculation of ET is done (using basic scale) by taking into consideration DBT and WBT with respect to corresponding AV of working place.

Throughout the year environmental parameters are regularly taken and mean values are used to find thermal load.

3.0 Results and discussion

Table: 1. Physical characteristics of the subjects, Mean+ SD (range)

Variables	Subjects	
	≤ 40 years (n=15)	> 40 years (n=15)
	Mean ± SD (range)	Mean ± SD (range)
Age (years)	32.26 ± 2.52 (28-36)	52.33 ± 4.12 (42-59)
Working experience (years)	7.2 ± 3.66 (2-17)	26.53 ± 7.73 (8-39)
Height (m)	1.69 ± 0.07 (1.54-1.77)	1.65 ± 0.09 (1.50-1.83)
Weight (kg)	67.6 ± 9.78 (49-83)	65.4 ± 9.62 (42-76)
BMI ($kg\ m^{-2}$)	23.56 ± 2.88 (18.54-29.53)	24.01 ± 3.68 (15.89-30.72)
BSA (m^2)	1.77 ± 0.14 (1.48-1.99)	1.72 ± 0.15 (1.41-1.95)

Legends: SD= Standard Deviation, BMI= Body mass index, BSA= Body surface area.

Physical characteristics of the subjects (Table 1) shows that the mean age of both groups are 32.26 ± 2.52 and 52.33 ± 4.12 with a vast range of working experience from 2-17 years for the age group of below forty years and from 8-39 years for the case of other group in continuation a body mass ranging from 49-83 kg and 42-76 kg. The mean values of BMI and BSA are 23.56 ± 2.88 and 1.77 ± 0.14 and 24.01 ± 3.68 and 1.72 ± 0.15 and in both the cases the values of BMI [12] and BSA [1] are within acceptable range.

Descriptive statistics comprising means, standard deviation and range are calculated for each subject. Difference between mean values of environmental parameters along with work stress indicating factors of two groups of oxy-cutters are tested by two-tailed, homoscedastic test with level of significance (p value) 0.05 and 0.01 respectively.

Table 2: Direct and Derived Physiological Variables of the Subjects and their Statistical Analysis

Variables	Subjects (Welders)		p-value
	≤ 40 years (n=15)	> 40 years (n=15)	
	Mean ± SD (range)	Mean ± SD (range)	
RHR (bpm)	86 ± 8.37 (70-102)	83 ± 10.02 (70-109)	ns
HRS (bpm)	94 ± 8.85 (77-108)	97 ± 15.29 (77-134)	ns
PWHR (bpm)	100 ± 8.38 (85-114)	111 ± 19.15 (86-146)	<0.05
WHR (bpm)	108 ± 8.78 (94-122)	126 ± 28.71 (92-202)	<0.05
Peak HR (bpm)	114 ± 9.88 (96-130)	132 ± 32.48 (95-223)	<0.05
NCC (bpm)	22 ± 9.09 (8-41)	43 ± 25.80 (14-115)	<0.01
RCC (%)	22 ± 8.68 (7.62-39.52)	53 ± 33.13 (16.3-145.06)	<0.01
EE (kcal/ min)	4 ± 0.44 (2.9-4.43)	5 ± 1.46 (2.85-8.615)	<0.05

Legends- SD= Standard Deviation, RHR= Resting heart rate, HRS= Heart rate at site, PWHR= Pre Working heart rate, WHR= Working heart rate, NCC= Net cardiac cost, RCC= Relative cardiac cost, EE= Energy expenditure.

Table 2 reflects the direct and derived physiological variables of two groups of welders with their statistical inference through two-tailed, homoscedastic t test with level of significance (p value) 0.05 and 0.01 respectively. It is clearly seen that the RHR, HRS and PWHR values of junior and senior group are respectively 86, 94, 100 and 83, 97, 111 bpm. The WHR of the senior group is 126 bpm which is quite greater than the other group which is 108 bpm and it reflects on the vast range of peak HR from (95-223) bpm for the senior group and (96-130) bpm for the junior group. The NCC value of the age group of below 40 years is 22 bpm, whereas the other group is 43 bpm. The % of RCC value are 22% and 53% respectively for junior and senior group which reflects very significance difference. The Energy Expenditure values i.e. 4 for junior group and 5 for senior group also reflects the high strain among the seniors than the age group of below 40 years. The workstation and the resting place of the worker are so adjacent that the t test value reflects non significance in case of RHR and HRS but in all the other cases there are significant variations.

Workload classification of welders with respect to various physiological indices i.e. WHR, EE, NCC are shown in Table 3. Workloads are estimated based on WHR, NCC and EE values for both groups according to Astrand [11], Chamoux et al. [4] and Ramanathan et al. [6] classification respectively. From the observed mean values it is clearly seen that working heart rate of below 40 years remains in moderate category whereas welders having more than 40 years of age are in heavy group as per workload classification given by Astrand [11]. Mean values of energy expenditure of junior group of welderlies in moderate category and the senior group reflects heavy in nature according to the classification proposed by Ramanathan et al. [6], 1967. NCC of the younger group is moderate in nature whereas the senior workers are in the very heavy group which reflects the heaviness of the job and its adverse effect on them.

Comparison of different direct physiological parameters between the welders of age group above and below forty years is clearly expressed in Fig.1. If we look through it is clearly seen through starting work from almost same mean RHR the value of mean WHR reaches 108 bpm for junior and for seniors it becomes 126 bpm. In case of peak WHR with reference to mean RHR the percentage increase of junior

Table 3: Physiological work load categorization and comparison with observed values

Parameter	Reference	Classification of workload					Welders		Remarks	
		Light	Moderate	Heavy	Very heavy	Extremely heavy	>40yrs (n=15)	<40 yrs (n=15)	>40yrs (n=15)	<40 yrs (n=15)
WHR (beats/min)	Astrand	<90	90-110	111-130	131-150	151-170	* 108	*126	Moderate	Heavy
EE (kcal/min)	Ramanathan, et al	1.0-2.5	2.6-4.0	4.1-6.0	6.1-8.0	>8	*4	*5	Moderate	Heavy
Net Cardiac Cost (beats/min)	Chamoux et al	≤20	20-30	31-40	41-50	51-60	*22	*43	Moderate	Very heavy

* Mean value.

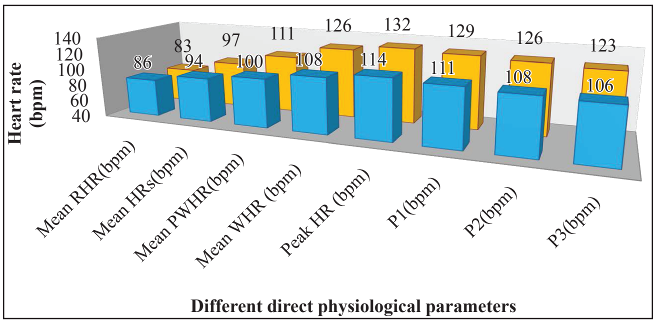

Fig.1: Comparison of different direct physiological parameters of the Welders between the age group of above & below forty years

and senior groups are 32.55 % and 59.03 % respectively and this difference in percentage signifies the workload of senior welders clearly.

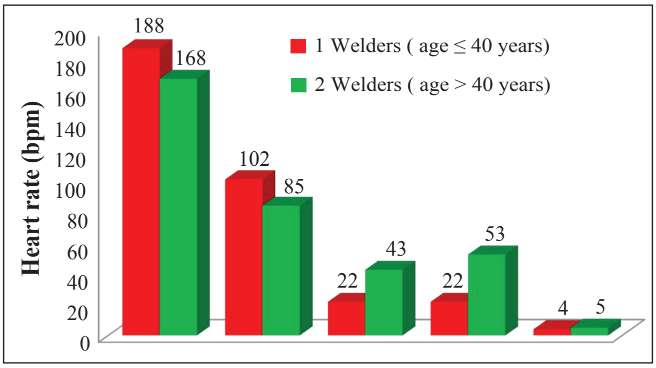

Fig.2: Comparison of different derived physiological parameters of the Welders between the age group of above & below forty years

Fig.2 articulates the comparison of derived physiological parameters between the welders of age group above and below forty years. If we look through the NCC value the work load of senior groups is in 'very heavy' range as per recommendation of Chamoux et al. [4]. The EE value of both the groups of worker also expresses their physiological discomfort during working. Especially the senior group is in 'heavy' category as per classification of eminent scientist Ramanathan et al. [6].

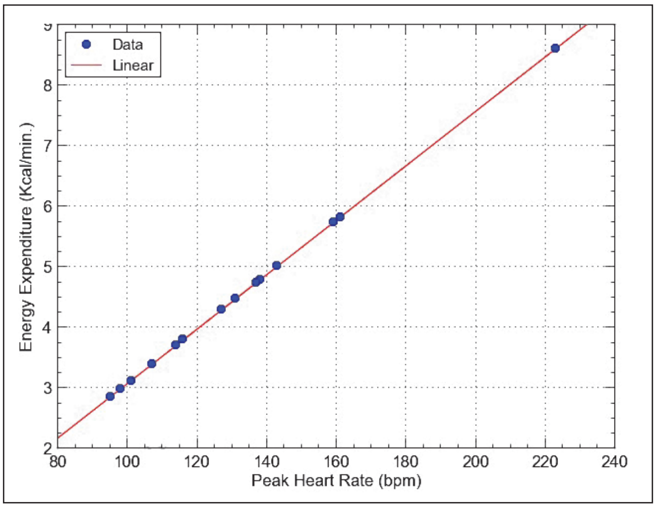

Fig.3: Linear regression curve of welders of age greater than forty years

In Fig.3, the curve is expressing peak working heart rate (peak WHR) of the senior welders along X axis and energy expenditure (EE) for the corresponding peak WHR along Y axis. It is assumed that the best fit equation for this case is linear regression curve following the equation y = a + b * x with number of independent variable is 1. There is negligible standard error (i.e.= 1.54820009033e-15), correlation coefficient = 1.000000, with degree of freedom = 13. The value of a and b with standard errors and range are given in the table below:

	Value	Standard error	Range (95 % confidence)
a	-1.420000	0.000000	-1.420000 to -1.420000
b	0.045000	0.000000	0.045000 to 0.045000

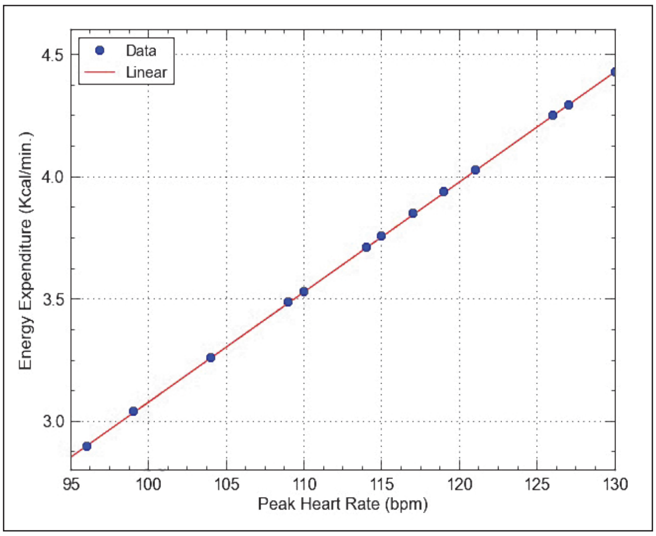

Fig.4: Linear regression curve of welders of age lesser than forty years

In case of above curve (Fig.4) it is expressing peak working heart rate (peak WHR) of the junior welders along X axis and energy expenditure (EE) for the corresponding peak WHR along Y axis. It is a linear regression curve as it is assumed as the best fit, following the equation y = a + b * x with number of independent variable is 1. There is negligible standard error (i.e.= 0.00267729825723), correlation coefficient = 0.999983, with degree of freedom= 13. The value of a and b with standard errors and range are given in the table below:

	Value	Standard error	Range (95 % confidence)
a	-1.416468	0.008303	-1.434407 to -1.398530
b	0.044990	0.000072	0.044833 to 0.045146

Table 5: Prevailing environmental conditions in the working sites

DB (°C)	WB (°C)	GT (°C)	NWB (°C)	WET BULB DEP (°C)	RH (%)	WBGT (°C)	Air Velocity (m/sec)	ET (°C)
32.50 ± 2.85	28.16 ± 2.86	31.94 ± 2.98	27.45 ± 2.99	4.33 ± 0.73	73.25 ± 4.00	28.80 ± 2.93	0.1 ± 8.8E-16	29.58 ± 2.49

Mean ± SD

Legend: WBGT: wet bulb globe temperature; ET: effective temperature;

Table 5 clearly reflects the environmental conditions of the working site. The close proximity of dry bulb temperature (32.50 ± 2.85°C) and wet bulb temperature (28.16 ± 2.86°C) at the work place, replicates humidity in the range of 73.25% and conditions in which air velocity at working site shows almost stagnancy (0.1± 0 m/sec). The ET in the working place is (29.58 ± 2.49°C).The mean NWBT value is 27.45°C and the mean WBGT value in the working site is (28.80 ± 2.93°C). According to the classification of environmental zone based on ET value (Mookherjee and Sharma) [2], the workplace falls under the very hot zone (Table 5).

The physiological condition of the electric arc welders reflects the job heaviness on them. It is discussed earlier about the task of the welders. They have to work in different awkward posture in a semi confined space in front of high temperature (electric arc welding temperature). From the observed mean value of WHR it is clearly seen that ‘very heavy’ workload may causes occupational discomfort among senior welders as per workload classification given by Astrand [11]. Especially for the senior group the NCC and RCC value is far above cut above line as per recommendation of Chamoux et al. [4] and Lablache-Combier and Ley [10] respectively. The EE value also lies in the danger zone (Ramanathan et al. [6]. The job heaviness becomes extreme when the environmental conditions of the working site merge with it. If we look at the ET value which is 29.58°C and it is above the recommended value for heavy workload condition suggested by WHO [7]. The WBGT value also crosses the threshold value as per recommendation of ACGIH [9]. The mean air velocity of the working site is 0.1 ms^{-1} i.e. there is almost stagnancy of air flow in the working place and the conditions i.e. job heaviness, physiological and environmental conditions reflect on the recovery heart rate pattern of the workers as per recommendation of renowned scientist Brouha [5] and in each and every cases the result is ‘No recovery’.

4.0 Conclusion

The working ambience along with job heaviness and ignorance of worker creates a hostile working environment which is reflected by the physiological data of the workers (Table 2). As per recommendation of eminent scientists Astrand [11], Chamoux et al. [4] and Ramanathan et al. [6] with reference of WHR, NCC and EE respectively the nature of job is heavy to very heavy in nature for the welders of the age group of above forty years of age. The environmental parameters also cross the threshold value as per guide line given by different international organizations like WHO, ACGIH etc. It is clear that the senior group is facing more physiological hazards than the junior but when the junior feels the problem of their counter parts and realizes about the coming future they are psychologically disturbed which plays like the retardation force and it may reflects on the production also.

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