AN ERGONOMIC STUDY OF CASTING INDUSTRY USING FUZZY DOMINANCE AND ANALYTICAL HIERARCHY PROCESS

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ABSTRACT

This paper presents a study which was carried out in the city of Taj. Basic objectives of study were to improve the worker's productivity in general and the overall productivity in particular. Ten foundry industries of small and medium in nature were selected. Nominal group technique (NGT) and idea Engineering was used to gather the basic information. Various physiological parameters of workers were measured. Eight tasks/postures were selected and their improved methods were analyzed. The Fuzzy dominance method & A.H.P assessment were carried out for final results.

Key Words*: *A.H.P, Fuzzy Dominance Order, Musculoskeletal Disorder, MSD, Productivity

I INTRODUCTION

The role of casting in manufacturing industries cannot be denied. Agra is a well known cluster of casting industry in Uttar Pradesh surrounded by the three major states of country like Madhypradesh, Rajsthan, Haryana. The global export market of casted products is up to $5 billion annual. Agra exports different casted products in Saudi Arab, South Africa, Bangladesh, Myanmar, Srilanka, Iraq, United Arab Emirates, Iran etc. Musculoskeletal disorder, repetitive work, poor working conditions and wrong postures cause poor worker's productivity. Physical conditions of workers were not very good in the foundries. They were working with severe threats to their physical health due to lack of unscientifically method, information and training of ergonomics. Awkward working postures are one of the important factors emanating from ergonomic deficits that are endemic of casting industry. "Working posture" is a term that is encompassed with in physical ergonomics domain refers to the alignment and orientation of the human body and its segments in the working environment (Vieira and Kumar, 2004). Any working posture that is adopted by an individual is a direct expression of the interaction between the task demands, the individuals factors like

height, weight, design of work station, and the tools being utilized (Chung et al; 2001). In view of the above, the following are the objectives of the present study.

1. To identify the potential postures.

2. To identify the worker's problems in selected postures.

3. To identify the improved/modified postures.

4. To improve worker's productivity in general and the overall productivity in particular by fuzzy dominance matrix and Analytical hierarchy process assessment.

II METHODOLOGY

In Agra region, around 250 casting industries are in working conditions. Due to the Taj Trapezium zone some industries have been shifted in nearby locations. In the present study 10 small and medium scale industries were visited in the city of Taj. Initially a very minute and detailed study about existing postures/conditions was observed. For assessment of various Ergonomic and economic parameters of existing and improved tasks/postures, following methodology were used.

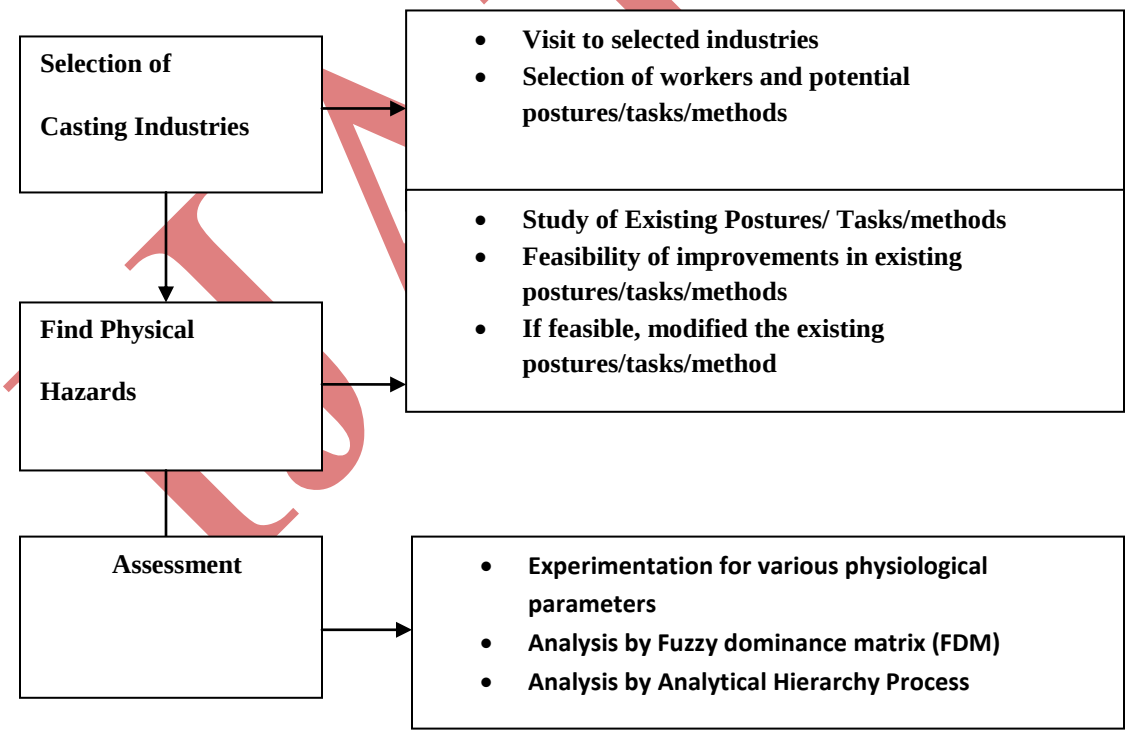

Fig. 1: Methodology of proposed work

In the first phase various interactive session were conducted with the employee of industries. Brain storming session was also conducted in various groups of workers. Idea Engineering and Nominal group technology were used to identify the potential postures. Following triggering question was asked to workers.

"Which problem has the maximum negative impact on your health?"

In all 25 responses were collected, they were edited, merged and key worded, finally eight postures have been selected on the basis of this exercise.

In the second phase of the workshop the same exercise was carried out to identify the improved /modified tasks. In all 16 improved/modified tasks have been identified by using idea engineering and nominal group technology.

Table 1 depicts a list of 8 selected postures/tasks. The following important processes/tasks were studied during visit, lead to musculature work and caused their severe illness like stomach pain, Back pain, headache, cervical pain, vomiting, mussels pain, neck pain and muscles stretching caused MSD. These physical problems lead to huge absenteeism, lack of concentration, rejections in casting, in turn, loss of overall productivity of these worker and process. Here PE denotes existing posture.

Table 1: Existing Task/postured lead to physical hazards

SN.	Task	Description
1,	P_1E	A pattern maker set on his feet. The pattern positioned at ground. The pattern maker hold pattern by his left hand and scraping pattern by right hand. Whole body weight lay on his feet. The knee of that worker in bent position.
2.	P_2E	The workers were preparing sand in sand preparation section by adding various contents for desired properties. After added all contents the fine meshing is done by using wire meshing. The posture opted by workers for this operation was very awkward. The one end of wire mesh on the ground and center of upper end was stick by a bamboo. A worker filled wire mesh by putting sand on it and then two workers stand behind the wire mesh. They bent from the waist. The trunks of the workers in inclined position. Both hands swinging down on wire mesh for fine meshing of sand. The neck and head both were oscillating with hands. This was very typical awkward posture of repetitive work leading severe musculoskeletal disorder.
3.	P_3E	A worker was filling pig iron and sponge iron of spherical ball shapes in the bin by hand. The bin placed on the ground. The worker set on his feet. After filling he lifted bin above shoulder height and placed on head leading excessive severe stress.

4.	P_4E	At molding section four workers lifted pattern from ground with help of long wooden handles fitted in it. After lifting from ground they put it on their shoulders and walking near the bed then they lowered the pattern on the sand by exerting force of the weight of pattern and after a minute they lifted pattern, putted it on the shoulder and again placed on the ground from where they lifted it. This process exerted physical stress on the workers.
5.	P_5E	In fettling shop workers were doing fettling work. The casted parts placed on the dusty ground. The workers set on the ground and hammering casted part by one hand and rotating it by another or both hand. Another worker was using vibratory chisel to clear surface of the casted part, holding bulky vibratory chisel in hands and driving it on the surface in bent position lead to excessive LBP in turn to severe MSD.
6.	P_6E	A worker was doing surface grinding on the casted parts which lay down on the ground. The worker hold a grinder of 8 -10 kg weight, rotated at 1200 r.p.m with vibration due to rotations of the motor. The worker was in bent position to perform the work. He was bent from waist holding full weight of grinder. This posture of worker leads excessive physical stress and lead to musculoskeletal disorder.
7.	P_7E	In painting shop a worker was brushing paint on the final casted part ready to shipment. He was set on his feet folding his Knee to perform this operation. This operation leads to excessive tire out in this posture.
8.	P_8E	In assembly section the different parts of the product (Generator, Pump and coolers) stacking. The body of that product was lying on the ground. The workers were assembling their parts, in sitting position on feet or in many times standing position by bent their trunk. This operation leads to excessive wear (tire out).

At this stage task group conducted various brain storming session to find out the modification of existing task. For this collected data were analyzed by core team of researchers, engineers, and supervisors.

III DATA COLLECTION AND IMPROVEMENT IN THEIR MAN METHODS AND MACHINE

After studying these typical postures we have studied the effects of these awkward postures on the productivity of workers and process. For this we studied the methods and observed the operations in the foundry [2 3 4 5]. Several hours and days spent to analyze the reasons of the problems. For analyze the fuzzy information gathered from workers and monitoring various postures of workers, we shoot photographs and videos to find exact cause and use some medical technology like measurements of their B.P and Pulse rate during working. After this detailed analysis, some groups of supervisors, engineers and workers with our research team were made to find the right methods. Again after many experiments finally some improvements suggested and validate our results by comparison of new

data. FDM method and AHP techniques were used to validate the results of study. Under following table showing improvement did by the team in existing postures/methods of workers.

Table 2: For Improved or modified Tasks/posture

SN:	TASK	DESCRIPTION
1	P_1I_1	Pattern positioned at ground. A stool (provided to the worker to sit comfortably in comparison to P_1E. But his knees are in bent position.
	P_1I_2	Now pattern was put on a bench. A stool of long height provided to the worker with foot rest. Now pattern was in front of his chest and his feet rest at foot rest provided in the stool.
2.	P_2I_1	The wire mesh lay down on four blocks of bricks at each end of wire mesh. Stool provided to the workers on which they sit comfortably on each side. The position of wire mesh is such that they can mix and mash sand finer.
	P_2I_2	With above arrangements (PI2), two wipers types tool of wooden were provided to mesh the sand.
3.	P_3I_1	A worker was provided to fill the bin by Shovel. After filling both workers lift the bin and place on the head of one worker.
	P_3I_2	The bin was placed on a foundation of bricks. A worker provided to fill the bin by Shovel. After filling both workers lift the bin and place on the head of one worker
4.	P_4I_1	Pattern was put on foundation 3 to 4 feet above from ground. After lifting from foundation they put it on their shoulders and walking near the bed then they lowered the pattern on the sand by exerting force of the weight of pattern and after a minute they lifted pattern, putted it on the shoulder and again placed on the foundation from.
	P_4I_2	A remote operated crane was provided. The workers bind the handles of pattern by steel rope. The crane carried pattern at desired location. Workers held the weighted pattern then they lowered the pattern on the sand by exerting force of the weight of pattern and after a minute they lifted pattern and then again crane carried and put it on the foundation
5.	P_5I_1	The casted parts were placed on the dusty ground. A work station had designed above the floor on which the worker set in comfortable position and hammering casted part by one hand and rotating it by another or both hand. Casted part put on a foundation. Worker used vibratory chisel to clear surface of the casted part in less bent position lead to less LBP.
	P_5I_2	The casted parts were placed on the bench. Workers set on the long height bench designed above the floor and hammering casted parts using gloves. Casted part was put on a foundation. Worker used vibratory chisel to clear surface of the casted part in less bent position lead to less LBP. Gloves were provided to better holding of the vibratory chisel.
6.	P_6I_1	The casted part was put on a foundation 3 to 4 feet height. Now worker in less bent position.

	P_6I_2	The casted part put on a foundation. The grinder holds by Chain kopi device hang from ceiling.
7.	P_7I_1	Parts were put on a foundation. Worker brushed paint in standing position.
	P_7I_2	Parts putted on a foundation. A long height stool provided with foot rest in it.
8.	P_8I_1	Parts were put on a foundation of a steel garter, 3 feet above from the floor. Workers did assembly operations in standing position.
	P_8I_2	Parts were put on a foundation of a steel garter, 3 feet above from the floor. A long height rotary stool provided with foot rest in it.

IV DATA ANALYSIS FOR DECISION MAKING

Decision making is the method of identifying and choosing alternatives based on the values and preferences of the decision maker. Decision making is the most vital step in many real applications such as critical disease diagnosis, inventory planning, financial planning, and risk assessment. As the situation demands, decision can be taken by a single decision maker or a group of decision makers. Actually in a complex situation, when numbers of alternatives, criteria or objectives are more, then only a group of decision makers can provide better solutions. A number of researchers have contributed to develop various decision making methods to support human for making decisions under complex situations.

Here we introduce a new concept to represent the decision making system with the help of fuzzy dominance and A.H.P. we have used fuzzy decision matrix to present the opinions of individual or group of decision makers.

For FDM and A.H.P assessment of existing task (PE) and improved task (PI_1 and PI_2), a Decision making group (DM) and interdisciplinary expert group was formed. They consist of three teams.

Table 3: Expert Group

Team A (Expert 1)	Managers	4
Team B(Expert 2)	Engineers	6
Team C (Expert 3)	Supervisors & Experienced workers	10

4.1 First Method: Fuzzy dominance Matrix Application

We have used fuzzy decision matrix to present the opinions of individual decision makers. This matrix is formed with a finite set of alternative and criteria, where opinion of a decision maker is presented using a fuzzy value.

Fuzzy dominance matrix is used to find the dominance degree of an expert or task group over other expert on a set of alternative attribute pair [12].

Let P = {PE, PI_1, PI_2}be a set of existing and improved tasks/postures and EP = {ease of operation (EOO), Work efficiency (WE), Fatigue (F), Satisfaction(S), Productivity, Overall cost. be the set of parameters (attributes), given by, EP = {EOO, WE, F, S, P, OC}. A set of decision making and expert group E = {E_1, E_2, E_3} want to evaluate the best posture as per their knowledge and experience. Fuzzy decision matrices of expert E_1, E_2, E_3 are given in table 4, table 5, and table 6 respectively. Fuzzy dominance matrices are calculated in table 7, table 8 and table 9, Where table 7 shows the fuzzy dominance relation of E_1 and E_2, and table 8 shows the fuzzy dominance relation of the E_1 and E_3 and table 9 shows the relation between E_2 and E_3. These fuzzy dominance relations are aggregated in table 10, where the choice values of various alternatives were calculated.

Table 4 (Expert E_1)

	EOO	WE	P	OC	S
P_1E	0.25	0.36	0.47	0.23	0.54
P_1I_1	0.37	0.42	0.57	0.21	0.78
P_1I_2	0.61	0.68	0.69	0.19	0.84

Table 5 (Expert E_2)

	EOO	WE	P	OC	S
P_1E	0.30	0.33	0.44	0.27	0.64
P_1I1	0.41	0.53	0.58	0.25	0.65
P_1I_2	0.54	0.62	0.69	0.22	0.7

Table 6 (Expert E_3)

	EOO	WE	P	OC	S
P_1E	0.26	0.32	0.42	0.24	0.59
P_1I_1	0.35	0.42	0.54	0.23	0.61
P_1I_2	0.48	0.47	0.59	0.20	0.65

Table 7 FDM of opinion of Expert E_1-E_2

	EOO	WE	P	OC	S
P_1E	-0.05	0.32	0.42	0.24	0.59
P_1I_1	0.35	0.42	0.54	0.23	0.61
P_1I_2	0.48	0.47	0.59	0.20	0.65

Table 8 FDM of opinion of Expert E_1-E_3

	EOO	WE	P	OC	S
P_1E	-0.01	0.04	0.05	-0.01	-0.05
P_1I_1	0.02	0.0	0.03	-0.02	0.17
P_1I_2	0.13	0.21	0.1	-0.01	0.19

Table 9 FDM of opinion of Expert E_2-E_3

	EOO	WE	P	OC	S
P_1E	0.04	0.01	0.02	0.03	0.05
P_1I_1	0.06	0.11	0.04	0.02	0.04
P_1I_2	0.06	0.15	0.1	0.02	0.05

Table 10 Aggregate FDM of expert E_1, E_2 and E_3

	EOO	WE	P	OC	S	Aggregate
P_1E	0.04	0.04	0.05	0.03	0.05	0.21
P_1I_1	0.06	0.11	0.04	0.02	0.17	0.4
P_1I_2	0.13	0.21	0.1	0.02	0.19	0.65

Dominance Ranking P_1I_2 – I, P_1I_1 – II, P_1E – III

Here, we see the aggregate fuzzy dominance matrix of opinion of experts team E_1, E_2 and E_3 which clearly show the P_1I_2 (second modification of posture P_1E) is more dominant over existing and first modification. So we prefer P_1I_2 as final improvement in existing task.

Similarly the overall dominance matrixes for remaining seven tasks were obtained and summarized the results as under following.

Table 11: Dominance Ranking

	Dominance Ranking		
Task	I	II	III
2	P_2I_1	P_2I_2	P_2E
3	P_3I_2	P_3I_1	P_3E
4	P_4I_2	P_4I_1	P_4E
5	P_5I_2	P_5I_1	P_5E
6	P_6I_2	P_6I_1	P_6E
7	P_7I_2	P_7I_1	P_7E
8	P_8I_1	P_8I_2	P_8E

4.2 Second Method: AHP Process Assessment

The AHP has been applied in various complex decision making situations with its unique features of choice selection of one alternative from a set of alternatives. Prioritization/evaluation for determining the relative merit of a set of alternatives and benchmarking of processes or systems with other, known processes or methods [10] Analytical hierarchy Process, introduced by Thomas Saaty (1980), is an effective tool for dealing with complex decision maker to set priorities and make the best decision. By reducing complex decisions to a series of pair wise comparisons, and then synthesizing the results, the AHP helps to capture both subjective and objective aspects of decisions.

For pair wise comparison of activities a preference scale shown as under following table 7

Table 12 Preference Scale for Pair wise comparison

Intensity of weight	Definition	Explanation
1. 1	Equal importance	Two activities contribute equally to the objective
2. 3	Moderate importance	Ease of operation and productivity slightly favor one over other
3. 5	Strong importance	Ease of operation and productivity strongly favor one over another
4. 7	Very strong importance	An activity is strongly favored and its dominance is demonstrated in practice
5. 9	Absolute importance	the importance of one over another affirmed on the highest possible order
6. 2,4,6,8	Intermediate Values	Used to represent compromise between the priorities listed above

Each method [PE, PI_1, PI_2] of selected 8 task/postures were rated and ranked on the basis of following criterion.

1. Ease of operation, 2. Productivity, 3.Overall cost

AHP assessment was done for all identified tasks/postures (existing and modified) on the basis of above criterion. The procedure as described by Satty [5] for AHP assessment has been utilized for the all tasks and its modification. The AHP provides a means of decomposing the problem in to a hierarchy of sub- problems which can more easily be comprehended and subjectively evaluated. The subjective evaluations are converted in to numerical values and processed to rank each alternative on a numerical scale [T.L Satty]. As an example the findings of task 1 is given below. Similar findings were obtained for all the tasks. Table shows the result of AHP assessment for remaining tasks.

Table 13 Criteria 1: Ease of Operation

Method	Ease of operation		
	P_1E	P_1I_1	P_1I_2
P_1E	1	1/5	1/6
P_1I_1	5	1	1/2
P_1I_2	6	2	1
	12	3.2	1.6666

	Ease of operation			
	P_1E	P_1I_1	P_1I_2	
P_1E	0.083333	0.0625	0.100004	0.245837
P_1I_1	0.416667	0.3125	0.300012	1.029179
P_1I_2	0.5	0.625	0.600024	1.725024

$$\begin{bmatrix} P_1E \\ P_1I_1 \\ P_1I_2 \end{bmatrix} = \begin{bmatrix} 0.245837 \\ 1.029179 \\ 1.725024 \end{bmatrix}$$

Table 14 Criteria 2: Productivity

Method	Productivity		
	PE	P_1I_1	P_1I_2
P_1E	1	1/6	1/4
P_1I_1	6	1	1/2
P_1I_2	4	2	1
	11	3.1666	1.75

Method	Productivity			
	P_1E	P_1I_1	P_1I_2	
P_1E	0.090909	0.052632	0.142857	0.095466
P_1I_1	0.545454	0.315789	0.285714	0.382319
P_1I_2	0.363636	0.631579	0.571429	0.522215

$$\begin{bmatrix} P_1E \\ P_1I_1 \\ P_1I_2 \end{bmatrix} = \begin{bmatrix} 0.095466 \\ 0.382319 \\ 0.522215 \end{bmatrix}$$

Table 15 Criteria 3: Overall Cost

Method	Overall Cost		
	P_1E	P_1I_1	P_1I_2
P_1E	1	½	1/3
P_1I_1	2	1	1/2
P_1I_2	3	2	1
	6	3.5	1.8333

Method	Overall cost			
	P_1E	P_1I_1	P_1I_2	
P_1E	0.166667	0.142857	0.181818	0.163781
P_1I_1	0.333333	0.285714	0.272727	0.297258
P_1I_2	0.5	0.571429	0.545464	0.523809

$$\begin{bmatrix} P_1E \\ P_1I_1 \\ P_2I_2 \end{bmatrix} = \begin{bmatrix} 0.163781 \\ 0.297258 \\ 0.523809 \end{bmatrix}$$

Table: 16 Ranking of Criteria

	EOO	P	OC
EOO	1	6	3
P	1/6	1	1/3
OC	1/3	3	1
	1.5	10	4.33333

	EOO	P	OC	
EOO	0.666667	0.6	0.692308	0.652991
P	0.111111	0.1	0.076923	0.096011
OC	0.222222	0.3	0.230769	0.250997

$$\begin{bmatrix} P_1E \\ P_1I_1 \\ P_1I_2 \end{bmatrix} = \begin{matrix} 0.245837 & 0.095466 & 0.163781 & 0.652991 \\ 1.029179 & 0.382319 & 0.297258 & \times 0.096011 \\ 1.725024 & 0.522215 & 0.523809 & 0.250997 \end{matrix}$$

$$\begin{bmatrix} P_1E \\ P_1I_1 \\ P_1I_2 \end{bmatrix} = \begin{bmatrix} 0.227617 \\ 0.783362 \\ 1.308038 \end{bmatrix}$$

Dominance Ranking for Ease of operation, Productivity and overall cost is (P_1I_2 – I, P_1I_1 – II, PE_1 – III)

Here we see the aggregate fuzzy dominance matrix of opinion of experts team E_1, E_2 and E_3 which clearly show the P_1I_2 (second modification of posture P_1E) is more dominant over existing and first modification. So we prefer P_1I_2 as final improvement in existing task.

Similarly the overall dominance matrixes for remaining seven tasks were obtained and summarized the results as under following.

Table: 17 Ranking

Task/posture no.	Fuzzy dominance Ranking			Analytical Hierarchy process Ranking		
	I	II	III	I	II	III
2.	P_2I_1	P_2I_2	P_2E	P_2I_2	P_2I_1	P_2E
3.	P_3I_2	P_3I_1	P_3E	P_3I_2	P_3I_1	P_3E
4.	P_4I_2	P_4I_1	P_4E	P_4I_2	P_4I_1	P_4E
5.	P_5I_2	P_5I_1	P_5E	P_5I_1	P_5I_2	P_5E
6.	P_6I_2	P_6I_1	P_6E	P_6I_2	P_6I_1	P_6E
7.	P_7I_2	P_7I_1	P_7E	P_7I_2	P_7I_1	P_7E
8.	P_8I_1	P_8I_2	P_8E	P_8I_2	P_8I_1	P_8E

V RESULTS

Table 16, show the comparison of result after applying FDM and AHP method for finding the best task/method, which clear that second modification of most tasks rated first, in improved and existing method. Second improvement of most tasks found more productive, ease in operation. But some task differ the opinion between both methods. So the overall productivity has increased and the company has benefited in terms of less absenteeism, least loss of material, least medical expense and more worker's productivity.

5.1 Assessment of absenteeism Record before and after improvement period

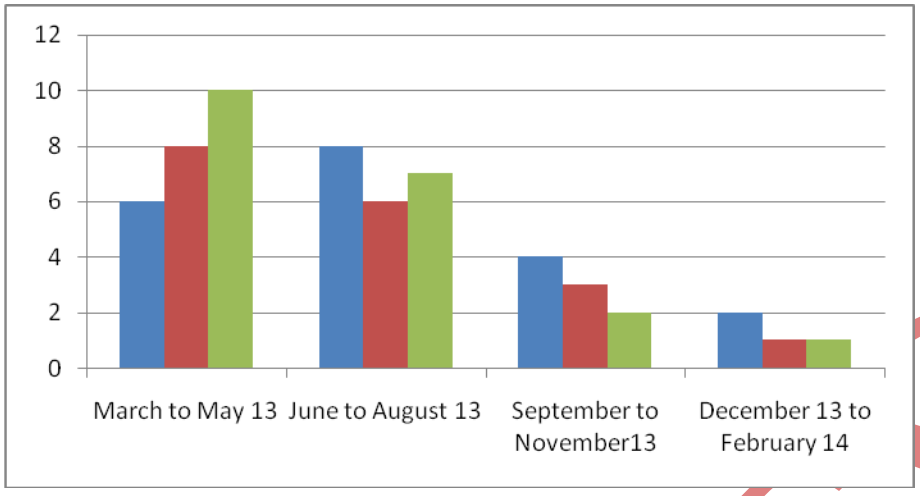

Chart 1: Absenteeism records of workers in days in a month

Below chart showed the number of days of absenteeism in a month due to illness of the workers. March to May 13 was the period of study of existing postures without any improvement. Entire research team worked from June to August 13 for improving these existing postures on paper. From September to November 13 was the period of implementation of improved postures/ methods. Period from Dec 13 to Feb 14 was the period of analysis the result. So here the result became in rapid decrease in absenteeism rate of workers due to illness.

5.2 Assessment of loss of castings rejected due to excessive stressed postures/ methods

Below chart showed the loss and reduction in loss before and after the improvement of postures. Here we see the tremendous change in loss due to less rejection after improvement in postures/methods. After the implementation of improved postures company minimize its loss from $750 to $90 in a month.

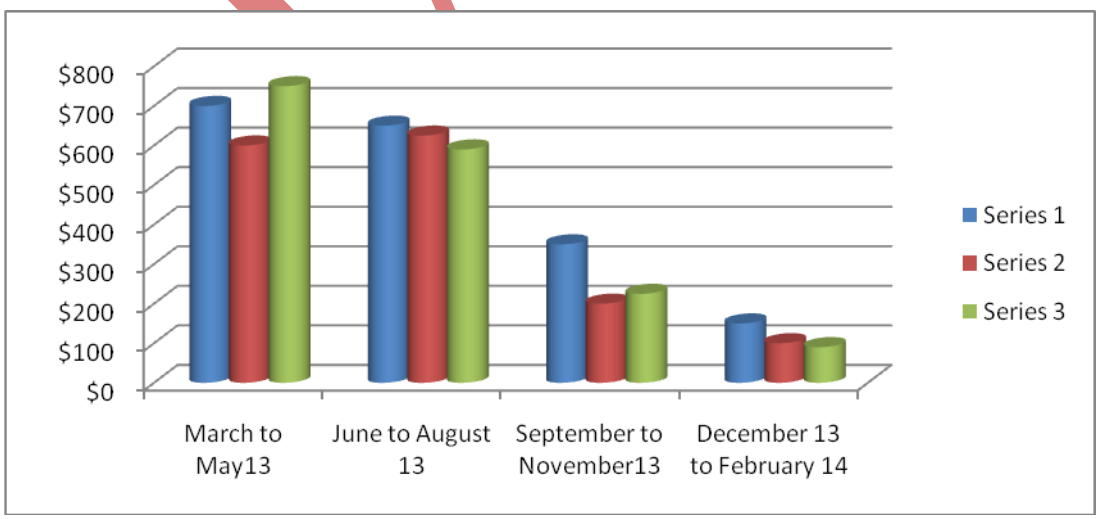

Chart 2: Assessment of loss before and after modification of task/process

VI. CONCLUSION

From the study of the various tasks / methods used by foundry workers it can be concluded that these workers were working in various awkward situations. This situation ruined their life due to several disorders in their bodies. They were suffering due to wrong selection of postures/ methods and directly lost the money of company in terms of their illness expenditure and huge amount of rejections of casting. Improvement in their existing task/ postures in keeping view of ergonomic parameters result a great reduction in the absenteeism rates as well as rejection of the casting. So the overall productivity of company has increased which is prime motive of this study along with the happy life of workers.

VII. VARIOUS POTENTIAL POSTURES OF WORKERS IN CASTING INDUSTRIES




REFERENCES

1. Dickinson CE, Campain K, Foster AF, Newman SJ, Thomas PG. Questionnaire development: an examination of the Nordic Musculoskeletal Questionaire. Apple Ergon 1992; 23(3): 197-201

2. Wilson JR, Corlett EN; Evaluation of human work; a practical ergonomics methodology. 2nd ed. London, UK; Taylor and Francis; 1995

3. Upahyay Rajeev Kumar, Das Padam; Physiological and AHP assessment of improved working conditions of certain occupation related musculoskeletal disorders, in HWWE, 2005

4. Gurunath Shinde V, Prof. V.S Jadhav; Ergonomic analysis of an assembly workstation to identify time consuming and fatigue causing factors using application of motion study. IJET Vol 4, Aug- Sept 2012

5. Upadhyay Rajeev Kumar, Das Padam, Gaur S.K and Mishra D.S; Fuzzy Dominance for various ergonomic parameters for task selection in an industries environment. HWWE, 2005

6. Gangopadhyay Somnath, Das Banibrata, Das Tamal, Ghosal Goutam; An Ergonomic study on posture- Related discomfort among preadolescent Agriculture workers of Best Bengal; JOSE 2005, Vol 11, no:3 315-322.

7.Triantis, K. and Vanden Eeckaut, P; Fuzzy Pairwise Dominance and Implications for Technical Efficiency Performance Assessment, " Journal of Productivity Analysis, Vol. 13, no.3, 203-226, May 2000.

8. George J. Klir and Bo Yuan; Fuzzy Sets and Fuzzy logic: Theory and application, PHI, 1997

9. Edger Ramos Vieira and Shrawan Kumar; Working postures; a literature review", journal of occupational Rehabilitation page Vol 28, 143-159

10. Dr. Rainer Haas and Dr. Oliver Mexiner; An illustrated guide to the Analytical hierarchy process", Institute of Marketing & Innovation, University of Natural Resources and Applied Life Sciences, Vienna, http://www.boku.ac.at/mi/

11. Satty, T.L., "The Analytical Hierarchy Process", McGraw-Hill, New York, 1980

12. Gope Sulekha, Das Sujit; Fuzzy dominance matrix and its application in Decision making problems", International Journal of soft computing and Engineering (IJSCE) ISSSN:2231-2307,Volume 4, Issue-1, March-2014