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Static Analysis of Biomechanical Load in Foundry Workers while Performing Floor Molding Operation

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A B S T R A C T

The casting industry in India comes after the railways in employing a large share of the country's population. Since most of the workforce is exposed to manual operations, it turns into a potential hotspot for health risks that can result in musculoskeletal problems (MSDs). Musculoskeletal diseases could be caused by a number of things, including uncomfortable postures, powerful motions, and manual tasks that must be done quickly and repeatedly. A common technique is floor molding, which is using sandboxes to create sand castings on the ground or floor. The key distinction from other casting techniques is the use of green sand or resin sand and manual molding rather than machine molding. Although it is an ancient and traditional molding technique, China and other countries still utilize it extensively. Sand is used in floor molding because it is inexpensive, simple to make moulds from, and suitable for both small and large production volumes. Therefore, the fundamental technology for producing castings has been floor molding. Green sand and resin sand are frequently used as molding ingredients in the long-established floor molding industry. Present work gives an insight into the working culture responsible for fatigue and pain in the bodily structures of humans exposed to floor molding operations in a foundry. The result is based on the static evaluation of postures and biomechanical load thus encountered while carrying out the tasks. This would help diagnose the various factors responsible for musculoskeletal skeletal disorder and look over the possible ergonomic interventions, leading to a sustainable workplace design. This result is achieved by taking a survey of a certain number of workers through which it concludes that the highest pain area in the human body while performing floor molding is the shoulder part. Then after suggesting some position in terms of angle and analysis of the shoulder under different angles (30 degrees, 65 degrees, and 90 degrees) done in a static situation which results in that angle being 65 degrees more painless than the other two angles. As a future extension, sensors are for accurate reading by attaching them to the part of the body which have to be measured. All the mathematical calculation is done by computer software which is connected through a force sensor.

Keywords: Foundry workers, Musculoskeletal, Ergonomics.

1. INTRODUCTION

The Indian foundry industry forms the backbone of Indian economy in manufacturing sector. It has been determined through the recent census that India stands at second position in world in the production of various grades of castings in million tonnes. There are approximately forty five hundred units from which major percentage is acquired by the small scale units and only a small share is possessed by medium and large scale units. A considerable amount of population is employed in these industries. A major part of work done in small scale industries is manually in spite of the fact that it gives rise to hazardous problems for the workers at floor job. The processes are being performed manually which is done without the assistance of other objects. Further the manual carrying involves a combination of twisted and awkward postures which forms the major source of musculoskeletal disorders. The common symptoms of MSDs are fatigue in nature with pain in limbs caused due to iterative movement in limbs causing strain in ligaments and muscle fibers. The iterative work comprised of work nature like lowering, pulling, pushing, lifting etc. In foundry industries, most of the works like lifting the mould, pouring the molten metal, fettling etc. are iterative in nature causing and overexertion muscle fatigue. The poor techniques of manual handling of objects and operations are one of the major causes behind injuries. Workers are reported to possess personal protective equipment in inadequate quantities and they are being subjected to poor work practices. MSDs do not only affect the health but also the productivity and hence indirectly the economy of the country. The practice of total quality management of the firm goes wrong due to job stress resulting in fall of concentration, amnesia and lack of trust in management.

Researchers have played a vital role in determining the various causes of MSDs. They have done a commendable work in taking the feedbacks and observation qualitatively as well as quantitatively too. Questionnaires and survey format have been devised to record the reading manually. The methods like Right Upper Limb Assessment and REBA have been introduced in practices of data collection and improving the postures of workers as per the ergonomic design. MSDs have also been reported to be gender biased where it influences women more than the men. The ergonomic design of the workplaces and work study of various operations in a foundry industry has been recommended by the researchers.

2. RESEARCH GAP

After conducting thorough research through various renowned journals and online publications and platforms, it was found that there exist only sporadic instances and mentions of a report of mathematically based load calculations from any researcher as of yet. Hence, it has been determined and concluded that although this subject is not entirely unknown and has been discussed, yet, extensive studies have not yet been conducted to determine which movement angle is the least painful. Therefore, as there are no existing relevant studies about specific movement angles and their impact, there was no precedent and no pre-determined calculations to form the basis of this study that focuses on 30, 65, and 90-degree angles and suggests the 65-degree shoulder angle as the least painful.

2.1 OBJECTIVE

The following goals have been suggested in the current work based on the research gap that was discovered throughout the exhaustive literature evaluation.

- The goal of this study was to investigate the biomechanical and musculoskeletal stresses that foundry workers endured while doing floor molding.
- With the use of a survey, the objective was to establish a baseline understanding of sitting posture, muscular movements, and subjective assessments of stress during routine jobs. The shoulder muscles were discovered to be the human body part where pain occurs most frequently as a result.
- Shoulder movement analysis at different angles is done in static situations to find which is more painless than others.
- The aforementioned calculations are to be done with three angles in focus: 30, 65, and 90 degrees to the end of determining which of the three is the least and most painful.

3. METHODOLOGY

3.1 Workers (Subjects)

Sixty people who work in the foundry industry provided input for the study, which was conducted using their data. The study's participants' ages ranged from 20 to 50 years old, with the average age of the group being 32.5 years. The average height and weight of the participants was 1.64 meters and 67 kg, respectively. Table 1 lists t

he specifics of the employees who served as the study's subjects.

Table 1- Basic information about the workers.

S. NO	NAME	AGE (Year)	HEIGHT (in m)	WEIGHT (in kg)	EXPERIENCE (in Year)
1	RAMBABU	37	1.76	71	7
2	IQBAL	25	1.64	63	5
3	AMAR	38	1.82	79	8
4	SHAMLAL	37	1.72	74	6
5	RAM NIWAS	39	1.79	78	5
6	RANJEET	26	1.55	61	5
7	GULI	26	1.64	64	7
8	SONU	37	1.76	78	6
9	BADRI	37	1.69	63	8
10	ANAND	28	1.68	60	6
11	KAPIL	32	1.72	66	7
12	MAHADEV	29	1.73	65	8
13	RAVI	27	1.68	61	7
14	SHANKAR	39	1.64	63	6
15	ROHIT	35	1.68	72	5
16	DEV	29	1.73	67	5
17	IMRAN	24	1.80	75	6
18	MOHAN	33	1.69	60	8
19	RAMSI	37	1.73	73	7

20	RAGHAV	35	1.72	65	8
21	SUMIT	34	1.66	64	8
22	SURENDRA	24	1.56	59	4
23	RAJU SINGH	44	1.65	68	7
24	PRAKASH	28	1.53	66	8
25	SURESH	47	1.52	65	4
26	RAMESH	25	1.75	71	5
27	VIJAY	28	1.68	64	8
28	DILIP	23	1.50	62	6
29	BIJAY	41	1.62	68	7
30	GOVIND	34	1.56	64	8
31	MANISH	29	1.80	73	7
32	HARI PRASAD	23	1.76	67	5
33	SANJAY	22	1.65	60	8
34	ANIL	32	1.66	63	3
35	RAMA CHAND	26	1.50	67	6
36	KAMAL	43	1.62	69	4
37	ASHOK	30	1.56	66	6
38	MAHESH	33	1.70	71	6
39	RAJEEV	41	1.69	67	5
40	MUKESH	27	1.55	61	6
41	BHASKAR	46	1.60	75	8
42	JAGDESH	32	1.55	61	9
43	ARUN	26	1.60	62	2
44	RAVINDRA	25	1.72	75	7
45	BHAGWAN	30	1.60	69	8
46	VISHNU	49	1.60	63	9
47	SHIVA	31	1.58	66	6
48	BALRAM	39	1.60	74	8
49	MOHIT	45	1.58	59	5
50	SHIV NAYAN	33	1.53	63	6
51	NANAK DEV	35	1.58	69	9
52	MAHESH	38	1.65	73	7
53	DEVENDRA	38	1.52	67	5
54	SANJEEV	24	1.50	68	5
55	PAPU	22	1.59	63	8
56	NARESH	28	1.58	62	7
57	BHOLA	40	1.65	74	6
58	GOPAL	30	1.55	68	9
59	BADAL	29	1.51	65	8
60	BABULAL	26	1.62	73	7

The personnel participated in the current study out of personal curiosity. The goal of this study was presented to the workers and the supervisors before to the study. The manufacturing was often scheduled for one 8-hour shift. The eight-hour workday was broken up into two quick breaks of 10 minutes each and one longer break of 30 minutes.

3.2 Methods and Measures

In this study, a questionnaire was used as the data collection tool to record the individuals' responses. The questionnaire has ten questions and a human body graphic identifying the various body parts. In addition, certain additional causes of musculoskeletal discomfort were found in the literature. These include the type of work and amount of effort, job rotation, rest periods, job repetition, posture, work environment vibration, and rest periods.

The following conclusions on the musculoskeletal pain elements in foundry environments were drawn from Table 2. As was already indicated, there were 60 subjects in total for this study. The research shows that 56.67% of the workforce reports having "pain in neck" almost daily. Similar to this, 50% of employees report having "pain in upper back" and 68.34% in “pain in shoulder” virtually daily as a result of their jobs. Because there is "less work space," the employees are also susceptible to discomfort. Nearly 80% of employees work in congested areas, which limit their ability to move around freely. A further 83% of workers express dissatisfaction with the "lack of planned break and rest during work," which causes discomfort because of inadequate recovery time. Other sources of discomfort are also examined, and it becomes clear that workers in the foundry environment have musculoskeletal discomfort virtually daily. This resulted in the calculation of the subjects' average level of discomfort. This demonstrated a situation in which the employees were in pain practically every day. Additionally, there are other discomforts that the personnel must endure. This investigation shows that workers in the foundry environment frequently experience musculoskeletal discomfort. This survey result there is high number of employees having pain in shoulder.

Table 2- Average of worker’s body parameter.

S. NO	MUSCULOSKELETAL FACTORS	SOMETIMES	RARELY	NEVER
1	PAIN IN NECK	34	16	10
2	PAIN IN SHOULDER	41	17	2
3	PAIN IN UPPER ARM	28	14	18
4	PAIN IN LOWER ARM	15	28	17
5	PAIN IN UPPER BACK	30	18	12
6	PAIN IN MID BACK	32	22	6
7	PAIN IN LOWER BACK	35	21	4
8	PAIN IN BUTTOCKS	14	29	17
9	PAIN IN THIGHS	31	10	19
10	PAIN IN LEG	27	23	10

The Average of Discomfort Score in Musculoskeletal Factors of all workers is provided in the Table 3. It shows that the musculoskeletal discomfort score is higher than the average score or 2.5. This shows a situation in which the workers were in pain practically every day. Also, there are other discomforts that the personnel must endure. This investigation shows that workers in the foundry environment frequently experience musculoskeletal discomfort.

Table 3- Average of discomfort score in musculoskeletal factors of all workers

S. NO	MUSCULOSKELETAL FACTORS	AVERAGE SCORE (Out of 5)
1	PAIN IN NECK	2.9673
2	PAIN IN SHOULDER	3.8334
3	PAIN IN UPPER ARM	2.8832
4	PAIN IN LOWER ARM	2.9672
5	PAIN IN UPPER BACK	2.6501
6	PAIN IN MID BACK	2.8000
7	PAIN IN LOWER BACK	2.9167
8	PAIN IN BUTTOCKS	2.8334
9	PAIN IN THIGHS	2.8589
10	PAIN IN LEG	3.0667

3.3 STATIC ANALYSIS OF SHOULDER

3.3.1 SITUATION 1

- Muscle force acting at an angle of 30 degrees to the arm.

FM sin30 (0.08H) - 0.05W (0.2H) - 0.01W (0.4H) = 0

FM = 233.458 N

Jx - FM cos30 = 0

Jx = 202.1802 N

Jy + FM sin30 - 0.05W - 0.01W = 0 Jy + FM sin30 – 33.35 – 6.6708 = 0

Jy = -76.7082N

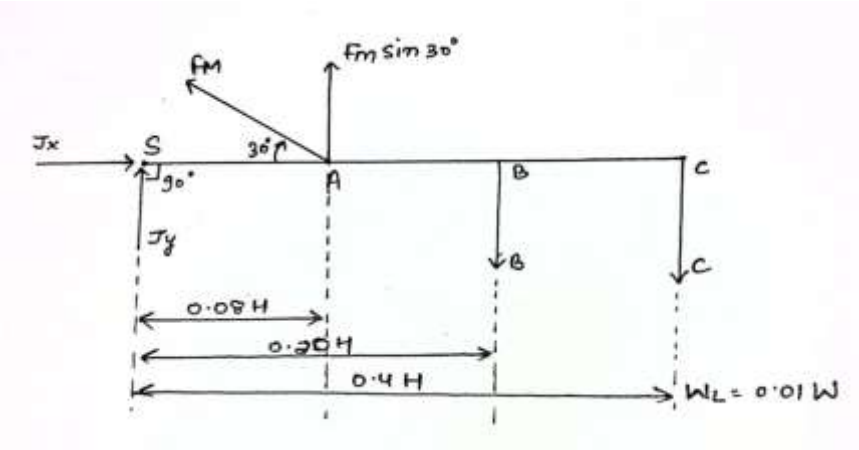

Fig. 1 – Free Body Diagram of Muscle force acting at an angle of 30 degrees to the arm

That means the muscle exerts a force is about 34.99% of the person's body weight which is a high force. After a while, a person finds it hard to keep it in this extended position. Results: The arm slowly brings the load closer to the body's midline.

3.3.2 SITUATION 2 - Muscle force acting at an angle of 65 degrees to the arm

Changing the angle from 90 degrees to 65 degrees reduces the external moment.

FM sin25 (0.08H) - 0.05W (0.2H sin65) - 0.01W (0.4H sin65) = 0

FM = 251.2450 N

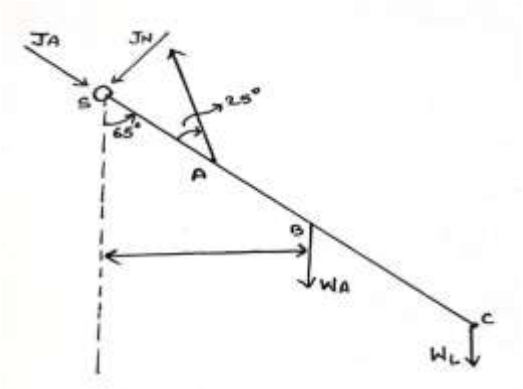

Fig. 2 – Free Body Diagram of Muscle force acting at an angle of 65 degrees to the arm

Moving the load closer by reducing the moment arm of the load increased the load on the muscle slightly.

3.3.3 SITUATION 3 - Muscle force increases slightly because of the disadvantageous insertion angle

F_M sin30 (SA) – (W_L - W_{LA}) (0.2H) - W_{UA} (0.1H) = 0

FM = 475.2718 N

The range of motion at the shoulder joint is the highest among the joints in the human body. The gain in motion results in loss instability.

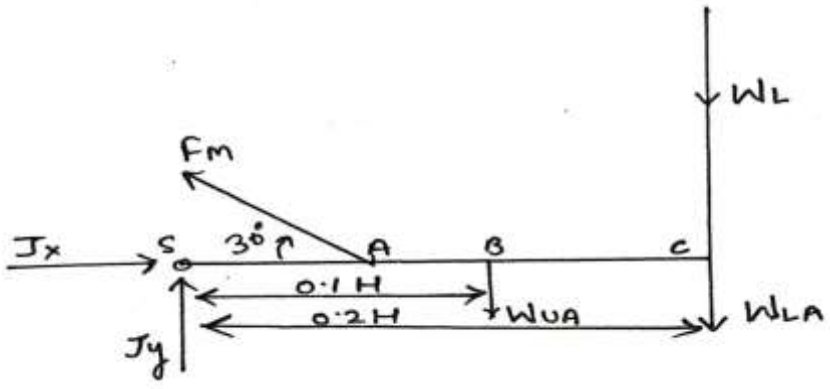

Fig. 3 – Free Body Diagram of Muscle force increases slightly because of the disadvantageous insertion angle

4. CONCLUSION AND RECOMMENDATIONS

- Working in the foundry sector carries a high risk of contracting various health-related issues which develop due to wrong postures of work handling and improper design of the workplace.
- While visiting, many workers in the industry make unknowingly irregular postures while performing foundry operations such as pouring, sand ramming, placing the cavity in the die, and several other operation and occupational disorders comprised of injuries, skin disease, pain, and various other musculoskeletal disorders.
- With the aid of a survey, establish a basic mastery of sitting posture, muscular movements, and subjective assessments of stress during routine jobs.
- The shoulder muscles were discovered to be the human body part where pain occurs most frequently as a result.
- Shoulder movement analysis at different angles is done in static situations to find which is more painless than others.
- Then after suggesting some position in terms of angle and analysis of the shoulder under different angles 30 degrees, 65 degrees, and 90 degrees should be done in a static situation to determine which of the three is the least and most painful.
- Analysis of movement on the angle at which we found angle 65 degrees the more painless than others so the aim of our thesis was fulfilled.

5. FUTURE SCOPE

As a future extension to static analysis of biomechanical load in foundry workers, while performing floor molding, force sensors are used for accurate reading by attaching them to the part of the body which have to be measured. All the mathematical calculation is done by computer software which is connected through a force sensor.

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