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Ergonomic Assessment And Risk Reduction In A Refractory Industry

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Abstract - The refractory industry plays a critical role in various high-temperature industrial processes. However, the nature of work in this industry often involves physically demanding tasks that can lead to ergonomic challenges and occupational health risks for workers. The Purpose of this paper is to assess and reduce or eliminate Ergonomic risks using ARECC framework. It provides an overview of the importance of ergonomic assessment and risk reduction in the refractory industry.

Ergonomic assessment is essential in identifying and mitigating ergonomic hazards that workers in the refractory industry face daily. These hazards include heavy lifting, repetitive motions, awkward postures, and exposure to extreme temperatures, which can lead to musculoskeletal disorders, fatigue, and decreased productivity. Ergonomic assessments involve the systematic evaluation of workplace conditions, equipment design, and work processes to identify potential risks and areas for improvement. The findings recommend a necessary change to improve or even eliminate the ergonomic related issues. The result of the data opens an opportunity for the change to improve welfare and productivity of an organization or company.

Keywords— Ergonomics, Ergonomic Assessment, Risk score, Refractory industry, ARECC

I. Introduction

The field of ergonomics is, about optimizing the way humans interact with their work environment. Its goal is to improve both productivity and well-being. When assessing ergonomics, we systematically evaluate factors like cognitive and organizational aspects to identify potential risks that can lead to musculoskeletal disorders, stress, fatigue, and decreased performance. By understanding the core principles of ergonomics and implementing strategies to reduce risks organizations can create more efficient work environments.

The first section of this paper delivers the importance of ergonomic assessment in identifying and quantifying risk factors associated with occupational tasks.

The second section focuses on risk reduction strategy and intervention aimed at minimizing or eliminating ergonomic hazards.

In conclusion, ergonomic assessment and risk reduction are vital components of creating safe and healthy work environments. By promoting the principles of ergonomics and adopting proactive measures by anticipating identifying and mitigate ergonomic risks and reduce the incidence of work-related injuries and muscular skeletal disorder risks. This paper aims to contribute to the growing body of knowledge in this field and inspire further research and practical applications in the pursuit of optimized workplace ergonomics.

II. PROBLEM IDENTIFICATION

A. Cumulative risk score

For problem identification, the E Ergo Tool, an excel based assessment worksheet and Checklist of questionaries related to E Ergo Tool are used to assess and priories the ergonomic risk in the workstation. The E Ergo Tool contains number of tasks with respect to postures, force, motion, pushing, pulling, lifting, and carrying of loads. E-Ergo Score is formulated the score range as three categories of risk. They are score 8 denoted as green which means the redesign of workplace is not required, 84 as yellow risk which means redesign of workplace is recommended and 240 denoted as red risk which means the redesign of workplace is necessary. If any of risk assessments (Posture-Force-Motion, Pushing and Pulling & Lifting and Carrying) turns red risk score then the Synthesis risk score will turn to red risk and conclude as whole activity is in red risk and the redesign of workplace is necessary.

To identify the risk, The Assessment was carried out around 87 activities of 42 workstations. In that 9 activities were found as red risk region, and 16 activities were found as yellow risk region.

B. Consideration of feasible activity for risk reduction

On further analysis on above Synthesis risk chart of red and yellow risk, we have chosen the prior and feasible activity as Mould assembling activity in Jargal dipping station which is the one has yellow risk in pushing and pulling (Fig. 1) and red risk in lifting and carrying (Fig. 2). So that it had taken into consideration on further analysis and improvement measures to eliminate or reduce the risk.

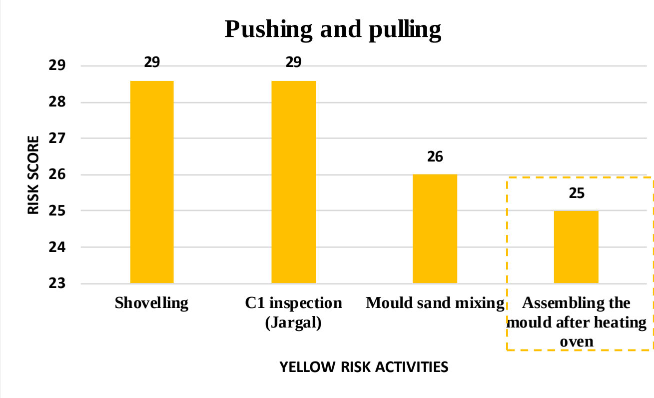

Fig. 1 Yellow risk score chart for pushing and pulling.

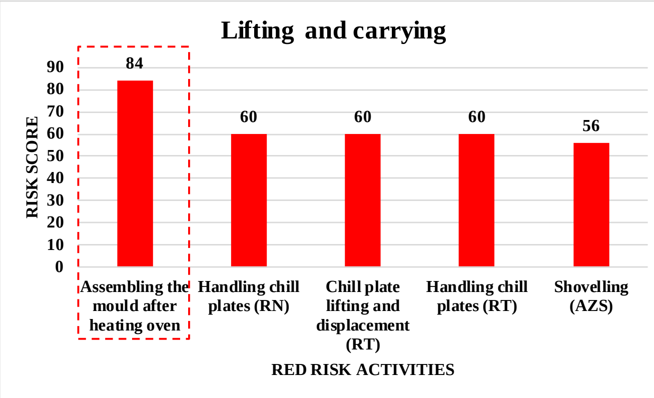

Fig. 2 Red risk score chart for lifting and carrying.

C. Mould assembly and its ergonomic hazard

The process of heating oven involves dismantle of graphite boards depends on size, dipping & draining from mono aluminium phosphate, then the moisture content on the graphite board is dried by heating oven process and finally the graphite board is assembled.

1). Posture-Force-Motion score:

While assembling the graphite boards, the operators will face posture risk of back bent of >20° or twist. For a shift the operator assembles about 10 moulds as maximum which has two L – Shape graphite boards and it is moved by pushing and pulling and lifting and carrying at the time operator bent more than 20° within 5 meters. On observing it is noted that, the time taken for moving 1 L – Shape graphite board for 2 minutes. On accounting 10 moulds which has 20 pieces of L – Shape graphite boards and the operators is in back bent of >20°of 40 minutes, which means 0.666 hrs the operator in awkward posture (Fig. 2). After placing the graphite boards on the pallet, assembling (Screwing) is initiated, one mould takes time of 3 minute and on accounting 10 moulds, 30 minutes to finish the job at that time the operator is working in bending posture of >20° forward and forearm rotation. Finally, it is found that not so much of risk as mentioned in E Ergo Tool and it has green score (redesign of workplace is not necessary as mentioned from the table I).

TABLE I
RISK ASSESSMENT SCORE FOR POSTURE-FORCE-MOTION

Risk Assessment	Risk score
Posture - Force - Motion	0

Fig. 3 Back bent forward >20° while pushing and pulling of graphite board

2). Pushing and pulling score:

From this pushing and pulling of graphite board up to distance of 5 meter has yellow risk as score of 25 as considerable that recommendation needed (Table II).

For a shift the operator assembles about 10 moulds as maximum which has each of two L – Shape graphite boards and it is moved by pushing and pulling. On observing it is noted that 20 No's of L – Shape graphite boards with weight of 25 kgs moved for up to 5-meter distance (Fig. 4). Finally, it is found that pushing and pulling has yellow risk score of 25 (the redesign of workplace is recommended).

TABLE II
RISK ASSESSMENT SCORE FOR PUSHING AND PULLING

Risk Assessment	Risk score
Manual Handling (MH) of loads: Pushing and Pulling	25

Fig. 4 Pushing and pulling of graphite board.

3). Lifting, carrying and displacement score:

In graphite boards assembly activity, the lifting and carrying of graphite board has red risk score of 84 as maximum which indicates, the redesign of workplace is necessary (Table III).

For a shift the operator assembles about 10 moulds as maximum which has each of two L – Shape graphite boards and it is lifted & carried to the pallet. On observing it is noted that 20 pieces of L – Shape graphite boards with weight of 25 kgs (Fig. 5) were lifted and placed on the pallet. Finally, it is found that lifting and carrying has red risk score of 84 which implies the synthesis score as 240 (the redesign of workplace is necessary).

TABLE III
RISK ASSESSMENT SCORE FOR LIFTING AND CARRYING

Risk Assessment	Risk score
Manual Handling (MH) of loads: Lifting and Carrying	84

Fig. 5 Lifting and carrying of graphite board.

4). Synthesis score for the mould assembling activity:

The synthesis score represents the cumulation score of Risk assessments (Posture-Motion-Force, Pushing and Pulling & Lifting and Carrying), if any one of assessment has either red or yellow risk score, then the Synthesis score will change with respect to that red or yellow risk score (Table IV). In this mould assembling activity involves the risk score of red (84) and yellow (25), and the synthesis score changes to red risk score (240) which indicates the redesign of workplace is necessary.

TABLE IV
SYNTHESIS FOR FINAL RISK SCORE

Workplace	Activity	Posture-Force-Motion	Lifting and carrying	Pushing and pulling	Final Risk Score
JARGAL Dipping Station	Assembling the Mould after heating Oven process	0	84	25	240

III. OBJECTIVE

The primary objective of ergonomic assessment and risk reduction in fused cast refractory is to identify and reduce or eliminate the risk of Musculoskeletal Disorders (MSDs) and its related disorders. Fused cast refractory manufacturing often involves physically demanding tasks, such as awkward posture, force, motion, pushing, pulling, lifting, carrying of loads, and operating machinery, which can lead to ergonomic hazards and contribute to the development of MSDs. The purpose of this assessment is to systematically identify and evaluate these ergonomic risks, as well as potential risks associated with exposure to certain materials, with the aim of implementing targeted measures to mitigate these risks. This includes optimizing workstations, introducing ergonomic equipment, providing proper training, and enforcing ergonomic work practices to minimize the risk of MSDs and related injuries.

The goal is to identify ergonomic risk factors, analyse and quantify them, to then come up with measurable improvements to the workplace. This will ensure that jobs and tasks are within workers' capabilities and limitations. The best approach for doing that is to make ergonomics an ongoing process of risk identification and risk reduction based on an objective and specific analysis of our jobs.

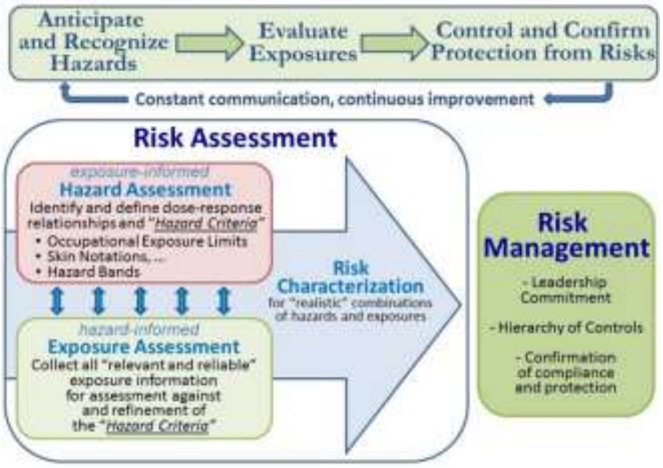

Fig. 6 Objective of Ergonomic Assessment and Risk Reduction Using ARECC Framework

IV. METHODOLOGY

The Methodology is shown in Fig. 7, A Competency framework for the occupational exposure assessment. This provides an organized summary of the collective knowledge and skills necessary for persons conducting occupational exposure assessments. This Body of Knowledge (BoK) will be used by AIHA to establish a framework for the development of education programs and knowledge/skill assessment tools, and for the improvement of the state of professional industrial hygiene (IH) knowledge.

The knowledge and skills in this BoK are one approach in assessing exposures and hazards through the identification, characterization, estimation, and evaluation of workplace hazards. This BoK establishes the core knowledge elements of the industrial hygiene process in harmony with the convention of Anticipate, Recognize, Evaluate, Control, and Confirm (ARECC).

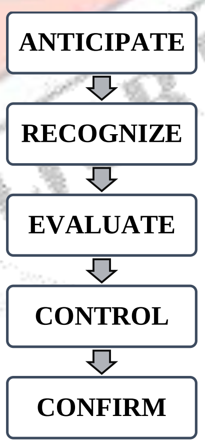

Fig. 7 Methodology

The ARECC framework is a five-step methodology for conducting ergonomic assessments and reducing ergonomic risks in the workplace.

1). Anticipate: This step involves anticipating potential ergonomic hazards before they occur by using ergonomic assessment checklist. This can be done by conducting a job hazard analysis, which involves breaking down process into individual activities and identifying potential hazards associated with each activity. The goal of this step is to anticipate any potential ergonomic risks and take proactive measures to prevent them from occurring.

2). Recognize: After the workstation process is breaking down into activities and from each activity the existing and upcoming ergonomic hazards in the workplace were identified. These are done by observing the activity which includes hazard in posture, force, motion, lifting, carrying, pushing, and pulling loads as mentioned in E Ergo Tool worksheet. Recognize ergonomic hazards to prioritize and determine which hazards require immediate attention.

3). Evaluate: Once the ergonomic hazards have been identified and recognized, the next step is to evaluate the severity of risk in that activity by observing and obtaining the data as “How many times does the activity done for a shift and how much time it takes for each time” like that data is noted down. After that collected data is feed into the E Ergo Tool and it shows the severity of the activity.

4). Control: The fourth step is to implement controls to reduce or eliminate the ergonomic hazards that have been identified. Controls can be either administrative, engineering, or personal protective equipment (PPE). Examples of controls include ergonomic redesign of workstations, job rotation, use of ergonomically beneficial tools and equipment, and providing training to workers on ergonomically standard operating procedure.

5). Confirm: The final step in the ARECC framework is to confirm that the solutions implemented in the control step are effective in reducing or eliminating ergonomic hazards. This can involve conducting follow-up evaluations, monitoring injury and illness data, and gathering feedback from the workers.

V. Data collection

Data collection through process observation in the refractories industry, coupled with evaluation using the "E Ergo Tool," an Excel-based assessment tool, offers a powerful means to enhance workplace safety. Observing work processes allows for a firsthand understanding of ergonomic challenges and potential risks faced by workers. The required crucial data such as posture, force exertion, and repetitive motions were obtained during these observations, the "E Ergo Tool" simplifies the analysis of this data, enabling the calculation of ergonomic risk scores and identification of critical areas that require attention. It also helps us to pinpoint ergonomic hazards accurately and implement targeted measures for risk reduction, thereby fostering a safer and more efficient work environment for their employees while minimizing the potential for workplace injuries and discomfort.

This risk evaluation process needs to be as simple as possible. The evaluator should focus only on the most critical ergonomics risks that operators are exposed to and their associated tasks.

The durations of exposure reported should be the duration during which the operators are exposed to these risks for each task. To list the tasks will help the observer, prioritizing the work and to find adequate control measures, as necessary.

A). Ergonomic Assessment Checklist

From the E Ergo Tool’s pinpointed tasks the ergonomic risk analysis questionaries checklist is prepared. This involves questionaries based on categories as posture, force, and motion, pushing & pulling of loads and lifting, carrying and displacement of loads.

Ergonomic Assessment Checklist

Date & Shift:

Dept. & Workstation:

SL. No.	Risk Factors	Yes	No
1	Is they Working with the back bent > 20° or twist?		
2	Is they Working with the neck bent forward >20° or back bent > 5°?		
3	Is they Working with the hand(s) above the head or the elbow (s) above the shoulder(s)?		
4	Working with the wrists bent in flexion >20° or in extension >30°?		
5	Is they working in Squatting or kneeling?		
6	Is they Working with Gripping 5 kg or more weight?		
7	Is they Working with Pinching 1 kg or more weight?		
8	Is they Working with Finger pressing?		
9	Is they Working with Mechanical local stress?		
10	Is they Working with the hand as a hammer?		
11	Is they Working with Fast forearm Rotation?		
12	Is they Working with Repeating the same motions of the upper limbs every 15 seconds or less?		
13	Is they Working with Hand-Arm or whole-body vibration?		
14	Is they Working with Temperature in the workplace < 15°C?		
15	Is they push or pull over short distance or frequent stopping?		
16	Is they Working with Pulling for long distance?		
17	While pulling/Pushing, Is Trunk upright, not twisted?		
18	While pulling/Pushing, Is Trunk slightly bending forward or slightly Twisted?		
19	While pulling/Pushing, Is Body inclined low in direction of motion Squatting, kneeling, bending?		
20	While pushing/Pulling, Is they involve combination of bending and twisting?		
21	While pulling/Pushing, Is Good floor or other surfaces level firm, smooth, dry / No inclined Surface?		
22	While pulling/Pushing, Is Restricted floor or uneven inclined up to 2°?		
23	While pulling/Pushing, Is Difficult or unpaved or rough paved roadway, path hole/Inclined up to 2 to 5°?		
24	While pulling/Pushing, Is complicated steps or stairs/ Inclined >5°/ combinations of indicators from "Restricted' to "difficult"?		
25	Is holding a Load for long time?		
26	Is there good ergonomic condition (Sufficient space., No obstacle within workplace, sufficient lighting, no vibration, no extreme temperature, and good gripping conditions)?		
27	Is they carrying load upright, not twisted, while lifting, holding, carrying, lowering, and the load near to medium to body?		
28	Is they carrying load with slight bending or twisting trunk, while lifting, holding, carrying, lowering, and the load near to medium to body?		
29	Is they low bending of far bending forward, slightly bending forward with simultaneous twisting of trunk, Load far from the body or above shoulder height?		
30	Is they bending far forward with simultaneous twisting of trunk, load far from the body, restricted stability of posture when standing, kneeling, or squatting?		

Fig. 8 Checklist for ergonomic assessment

B). E - Ergo Tool

Ergonomic risk assessment tool designed to identify and prioritize the most critical situations for which improvements are needed. The ergonomics risk factors we selected are a combination of factors used in well-known and approved methods (KIM, OSHA-US, OSHA-EUR). This combination allows us to cover most of the critical situations we encounter at our sites.

1) *Postures, Force and Motions*

In this we evaluate 5 Factors ergonomics: The necessary force, the posture of the collaborator, the repetitive motions, the vibrations, and the temperature. For each factor it is necessary to assess the time of exposure and to choose the corresponding score.

TABLE V
RISK SCORE CRITERIA FOR POSTURE, FORCE AND MOTIONS

Risk score for Posture, Force and Motions	
0-2	Redesign of workplace is not needed
3-4	Redesign of workplace is recommended
>=5	Redesign of workplace is necessary

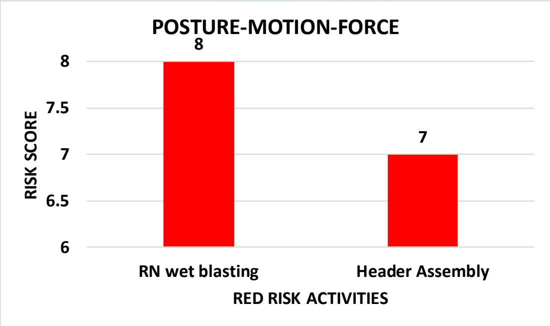

Fig. 9 Red risk chart for Posture, Force and Motion

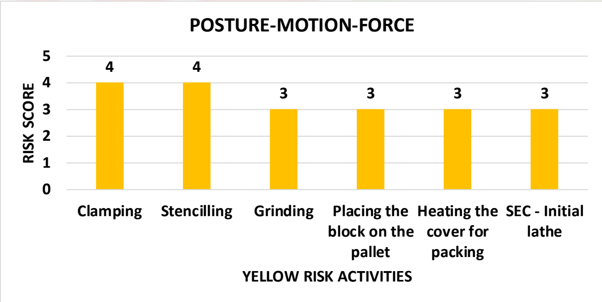

Fig. 10 Yellow risk chart for Posture, Force and Motion

2) *Lifting and Carrying*

Determine the execution time of lifting and carrying the loads. Then determine the working conditions, the weight of load and the loading posture.

TABLE VI
RISK SCORE CRITERIA FOR LIFTING AND CARRYING

Risk score for Lifting and Carrying	
0-24	Redesign of workplace is not needed
25-49	Redesign of workplace is recommended
>=50	Redesign of workplace is necessary

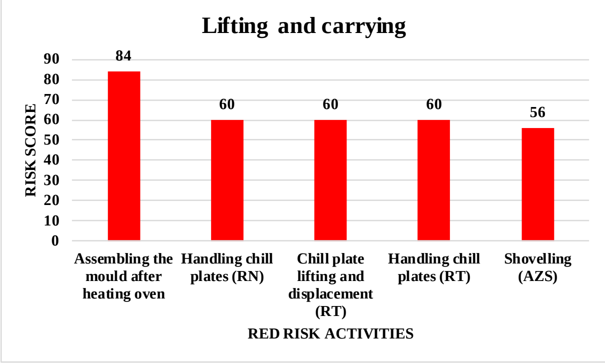

Fig. 11 Red risk chart for Lifting and Carrying

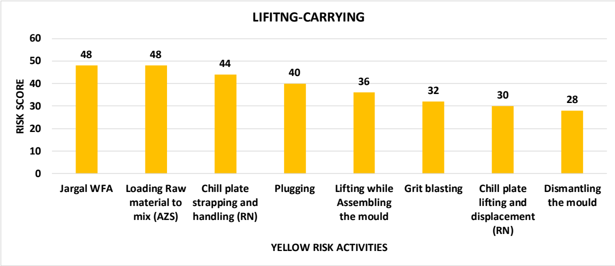

Fig. 12 Yellow risk chart for Lifting and Carrying

3) *Pushing and Pulling*

Determine the time of execution of the movement. Then determine the mass, speed and accuracy of execution, posture and working conditions.

TABLE VII
RISK SCORE CRITERIA FOR PUSHING AND PULLING

Risk score for Pushing and Pulling	
0-24	Redesign of workplace is not needed
25-49	Redesign of workplace is recommended
>=50	Redesign of workplace is necessary

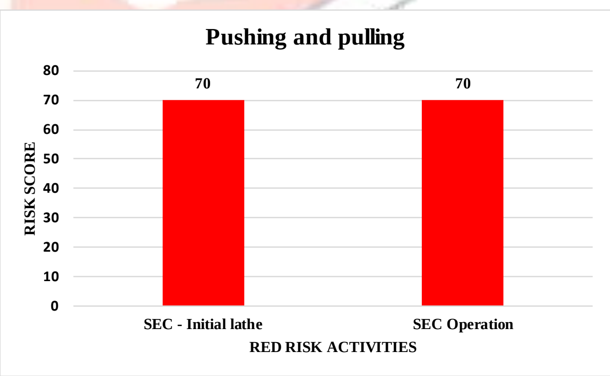

Fig. 13 Red risk chart for Lifting and Carrying

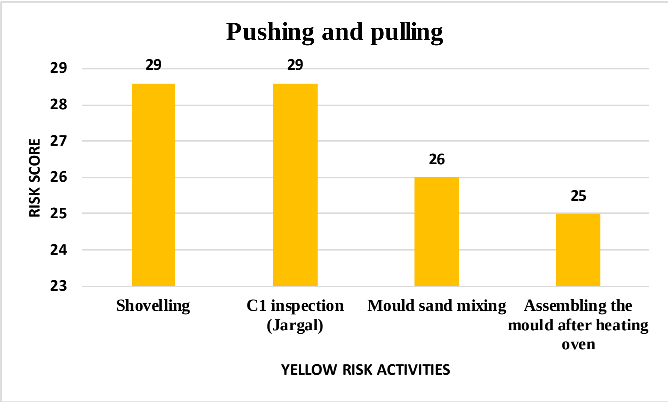

Fig. 14 Yellow risk chart for Pushing and Pulling

4) *Synthesis risk rating*

The synthesis score represents the cumulation score of risk assessments (Posture-Motion-Force, Pushing and Pulling & Lifting and Carrying), if any one of the risk assessments has either red or yellow risk score, then the Synthesis score will change with respect to red or yellow risk score (Fig. 15 & 16). But the red risk score is prior one so that if activity has both yellow and red risk score, then the score will change to red score. And the activity is concluded as red risk zone with the risk score of 240 which indicates the redesign of workplace is necessary.

TABLE VIII
SYNTHESIS RISK SCORE CRITERIA

Synthesis risk score	
0-8	Redesign of workplace is not needed
9-84	Redesign of workplace is recommended
85-240	Redesign of workplace is necessary

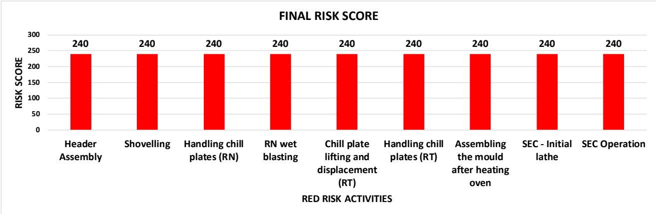

Fig. 15 Synthesis score chart for red risk

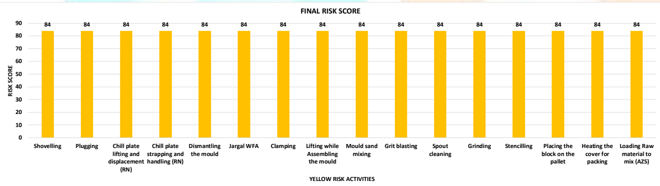

Fig. 16 Synthesis score chart for yellow risk

VI. RESULT AND DISCUSSION

In our investigation focused on ergonomic issues which has both lifting and carrying & pushing and pulling heavy loads, we recognized a significant concern that had the potential to lead to musculoskeletal injuries among the operators. The manual lifting and carrying of heavy materials placed excessive strain on employees' backs, shoulders, and arms, posing a substantial risk to their health and well-being. To mitigate this issue, we devised a risk reduction solution by fabricating a specialized lifting clamp that could be utilized in fitted with our existing EOT (Electric Overhead Traveling) crane system (Fig. 17).

Fig. 17 Fabricated clamp for lifting and carrying.

The lifting clamp was designed to securely holding the adjustable grip setting and lift heavy loads, and thus eliminate the physical effort required from workers (Fig. 18).

Fig. 18 Adjusting / Tightening the clamp.

The implementation of lifting clamp had a significant impact on our workplace. Workers reported reduced fatigue and discomfort, which led to increased job satisfaction and overall well-being.

Moreover, this solution underscored the importance of hierarchy of controls as engineering controls in addressing ergonomic concerns within industrial settings. It is typical example of how a thoughtful design approach, in this case, the fabrication of a specialized lifting tool, could have a profound effect on employee safety and health. Going forward or Concern step as mentioned in ARECC framework (Fig. 7), we remain committed to ongoing monitoring and improvement of our ergonomic solutions to ensure the continued well-being of our operators while also promoting best practices in ergonomics across the organization.

Before the implementation of control measures on ergonomic hazards, the risk score in lifting & carrying was 84 (red risk), the score in pushing and pulling was 25 (yellow score) and the synthesis score was 240 which indicates the operators often struggled with the physical demands of these activities, leading to musculoskeletal disorders, and strains, and redesign of workplace was necessary (Fig. 19).

Fig. 19 Before implementation of clamp

However, after the implementation the pushing and pulling and lifting & carrying activities were eliminated. So that red and yellow scores were also eliminated and comes to zero.

But still have small ergonomic hazard as 20 degrees forward bending motion while adjusting the clamp (Fig. 18), but it was observed that has green score.

Fig. 20 After implementation of clamp

The comparison of before and after implementation of engineering controls shows the ergonomic risk score in mould assembly activity with respect to posture-force-motion, lifting-carrying and pushing-pulling as mentioned below the chart Fig. 21.

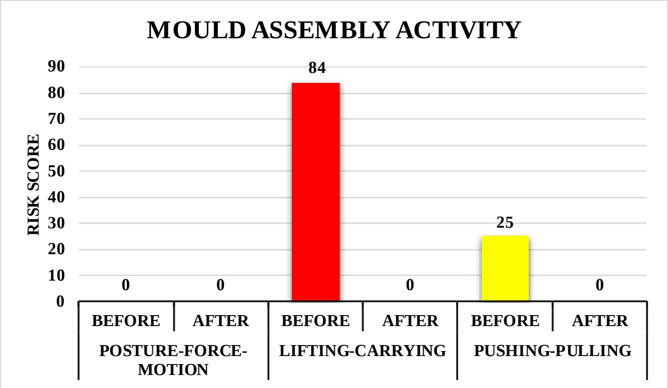

Fig. 21 Comparison of before and after risk score of mould assembly activity

VII. Conclusions

In conclusion, our comprehensive ergonomic risk assessment on 87 activities has been contributing in our commitment to creating a safer and healthier work environment. Through this extensive evaluation, we successfully identified six red-risk activities and 16 activities with yellow ergonomic risks. A major achievement was the effective control of one red-risk activity involving both lifting, carrying, and pushing and pulling tasks which was chosen as prior and feasible risk to reduce and was accomplished by the implementation of a fabricated clamp for lifting graphite moulds in mould assembly in mould dipping station. So that red risk in lifting and carrying and yellow risk in pushing and pulling were eliminated and becomes zero in graphite mould assembly after heating oven in dipping station.

However, after the implementation of such a control measure still have small ergonomic hazard as 20 degrees forward bending motion while adjusting the clamp (Fig. 18), but it was observed that has green score.

VIII. SCOPE FOR FUTURE WORK

As mentioned before, our comprehensive ergonomic risk assessments, which covered an extensive 87 activities of 43 locations, have been pivotal in promoting the safety and well-being of our workforce. Within this extensive evaluation, we identified 6 activities classified as high-risk and 16 activities as having a moderate level of risk. Notably, we achieved a significant milestone by effectively controlling one of these high-risk activities through the implementation of targeted control measures, showcasing our commitment to fostering ergonomic excellence in our workplace.

Looking forward, our scope for future work is both ambitious and focused. Firstly, our dedication to maintaining the controlled high-risk activity remains unwavering. Continuous monitoring and refinement of our ergonomic control measures will ensure that potential hazards are effectively mitigated, preserving a safe working environment.

Expanding our horizons, we intend to extend our ergonomic risk assessments to encompass the remaining high-risk and moderate-risk activities. Building upon the valuable insights gained from our extensive assessments, we will apply a meticulous approach to identify and address potential ergonomic risks, contributing to a healthier and more productive workforce.

Furthermore, we are eager to embrace innovation in our ergonomic risk assessment process. The integration of cutting-edge technology and data-driven analytics will empower us to identify ergonomic concerns with precision and agility, allowing us to proactively address issues and further enhance the comfort and efficiency of our employees.

In summary, the future scope of our work in ergonomic risk assessment revolves around sustaining the safety and well-being of the controlled high-risk activity, extending our assessments to encompass the remaining high-risk and moderate-risk activities, and harnessing technology to amplify our ergonomic risk management capabilities. Through these initiatives, we remain steadfast in our commitment to creating a work environment that prioritizes the health and safety of our employees across all activities.

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