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Designing Work Tools That Potentially Reduce Risk Of Musculoskeletal Disorders In Neutral Amine Filling Activities

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Abstract. *Petrochemical is a manufacturing company that uses automatic machines in its production process. However, there is also a production process that is carried out manually, namely the activity of filling 25L of neutral amine chemicals four times a day. Unergonomic work postures when filling neutral amine chemicals often cause musculoskeletal disorders such as pain in the waist and back. Based on the Nordic Questionnaire, data on the prevalence of musculoskeletal disorders in the last 12 months showed complaints in the right elbow, upper back, lower back and left knee had a percentage of 100% and in the last 7 days in the lower back had a percentage of 100%. This is evidenced by the examination of 100 screenshots of work posture images when filling neutral amine chemicals, which resulted in a RULA score of 58% for high risk and a REBA score of 59% for moderate risk. From the calculation results, the average of the five workers was a QEC assessment of 59% and a JSI assessment of 9.75. Based on QFD, it produces 6 target specifications, which are AODP pump, anthropometric data of the pelvic height dimension, palm width dimension, forward hand grip distance dimension, measuring cup lid and pipe interconnection. Based on the simulation results, there was a decrease in the score by 3 points, which proves that the design of neutral amine filling work tools has the potential to reduce the risk of musculoskeletal disorders.*

Keywords: *Job Strain Index (JSI), Musculoskeletal Disorders, Rapid Entire Body Assessment (REBA), Rapid Upper Limb Assessment (RULA), Quality Function Deployment (QFD), Quick Exposure Check (QEC).*

I. INTRODUCTION

One sector of the economy in Indonesia that sometimes shows growth is the manufacturing sector. Manufacturing businesses are involved in various processes to transform raw materials into completed products with high selling prices and direct consumer applications. The use of machinery, equipment, and cutting-edge technology is only one of the many things used by businesses engaged in manufacturing. The production process in the manufacturing industry that uses technologically advanced machinery and equipment makes electrical equipment in the manufacturing industry very numerous and complex. Large amount of energy sources needed from power plants as the effort to increase industrial productivity in factories. The construction of power plants in the manufacturing industry can increase cost savings in the energy sector which of course can produce enough electricity for factory needs.

Most of the production processes in petrochemicals have used automatic machines, but in the power plant process some still use human labour, which is when filling neutral amine chemicals manually by pouring jerry cans containing 25 L of neutral amine into a measuring cup with a volume of 5 L and then poured into a neutral amine tank. The frequency of filling neutral amine chemicals is four times a day. Based on observations, non-ergonomic work postures during manual filling of neutral amine often cause complaints of workers' health problems. One of the workers' health problems is musculoskeletal disorders in the form of pain in the waist and back.

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Figure. 1. Neutral Amine Filling Activity

Musculoskeletal disorders are injuries that occur in muscles, nerves, tendons, ligaments, joints, cartilage, or spinal discs that affect the level of productivity of a worker in carrying out their work. Good performance and high productivity levels of workers are things that the company wants to achieve simultaneously and sustainably. Signals that indicate the presence of musculoskeletal disorders are pain, anxiety, tingling, numbness, burning, swelling, stiffness, cramps, grip strength in the moved hand, shortened range of motion, changes in body balance, shortness of breath, and loss of flexibility.

Manual load transfer without proper ergonomics can cause acute or chronic back pain, and even damage to body tissues due to excessive lifting loads. Manual material handling is a job that has the potential to cause work accidents. Manual material handling is also the main cause of many lost working days. Data from the Health and Safety Executive states that approximately 1.6 million working days were lost from 2009 to 2013 because many of workers absent due to injury.

To determine the danger level of musculoskeletal injuries experienced by workers in the petrochemical section due to unergonomic work postures when performing manual material handling activities, measurements can be made using the Rapid Upper Limb Assessment (RULA), Rapid Entire Body Assessment (REBA), Quick Exposure Check (QEC) and Job Strain Index (JSI) methods. RULA is a survey method developed for the use of ergonomic investigations in the workplace, which identifies upper body muscle diseases due to work. It does not require any special equipment to measure the posture of the neck, back, arms and upper body as a function of muscles and external body loads. Therefore, several designs and tools were proposed to improve operators' performance.

The importance of adapting ergonomic principles in the workplace is the first step towards effective prevention of musculoskeletal disorders, such as conducting regular worker health monitoring. Finally, the methods compared in this study can be analyzed in greater detail to determine the influence or impact of each variable taken into an account when calculating risk levels. This information could be very useful for developing new or modified MSD risk assessment methods.

Based on this, it is necessary to design work tools that can flow neutral amine liquid automatically to reduce the risk of musculoskeletal disorders due to manual neutral amine filling. The process of designing work tools in this research uses the QFD method as the basis for product design. Based on the results of measuring the risk of work posture, it is hoped that this research can produce an ergonomic work tools design. The work tools can be applied in the neutral amine filling process with the aim of minimizing the risk of musculoskeletal disorders in workers. From the results of measuring the risk of work postures and the application of work tools, it is hoped that worker productivity can increase.

II. Research Method

Primary research resources are included under Materials and Methods, along with problem-solving strategies and analytical techniques. The Survey of Musculoskeletal Disorders, complaints for your information, the PGD department at Petrochemical has workers on a daily time system. Five males participated in the study to ascertain the incidence of musculoskeletal diseases as the partner business employees are responsible for filling neutral

amine. Each employee was required to complete a Nordic questionnaire to provide information on their identity, physical characteristics, and musculoskeletal symptoms.

Data processing was carried out by recapitulating the Nordic Questionnaire results, calculating three sections of questionnaires on twenty body parts, frequency and complaints/inhibition of worker activities during the last 12 months, and complaints/inhibition of worker activities felt during the last seven days to determine the prevalence of musculoskeletal disorders.

Work Posture Assessment, in the RULA and REBA methods, documentation of neutral amine filling activities is carried out which will later be assessed for work posture risk levels. The filling of neutral amine is documented using a Smartpatrol camera. Documentation of work postures in the form of videos with a sample of five people. From the video, 100 photos of work postures were selected to determine the least ergonomic work posture. Workers were also asked to fill out a QEC questionnaire based on the work activities performed that conducted by worker observers.

The work activity of neutral amine filling was also measured using the JSI with six assessment variables. A total of 100 work posture images taken from five worker samples were analyzed as part of the data processing procedure. Using the ErgoFellow 3.0 programme, the RULA and REBA methodologies were used to assess the risk level of the work position. After obtaining 100 work posture risk level scores, the percentage of the work posture risk level was calculated and the mode value of the overall work posture score was found to determine the final result of the risk level in neutral amine filling.

Another data processing method is to analyze the survey responses of the QEC questionnaire. Data from the QEC questionnaire are collected by employees and worker observers. QEC assessment can also be carried out using ErgoFellow 3.0 software. Then calculations were carried out with JSI to analyse the risk of musculoskeletal disorders due to neutral amine filling work. ErgoFellow 3.0 itself is software that has features to analyze workplace conditions,

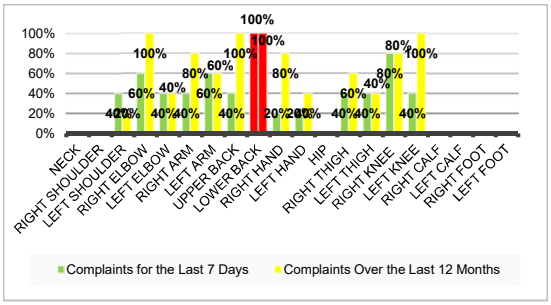

Figure 2. Diagram Prevalence of Musculoskeletal Disorders

evaluate workplace conditions, improve workplace conditions, reduce work risks, and increase productivity from various points of view, such as RULA, REBA, QEC, NIOSH, OWAS, Anthropometry, NOISE Exposure, etc.

Design of the Intervention, customer needs are part of QFD which contain data or information regarding things needed by users and still general. In order to learn more about the consumer voice, five respondents were interviewed and given a series of questions to answer. The list of questions are: (1) What is your opinion regarding the neutral amine filling that has been carried out so far?; (2) Do you agree that this work tools will be more helpful in the neutral amine filling process?; and (3) What do you expect regarding the advantages and specifications of the work tools design?

Designing work tools using the Quality Function Deployment (QFD) method starts from the process of recapitulating the results of Voice of Customer interviews as a basis for designing work tools that suit the user's needs and desires, followed by filling in a questionnaire with user interest and satisfaction data, then turning it into a House of Quality matrix.

III. RESULTS AND DISCUSSION

Analysis of the Prevalence of Musculoskeletal Disorders.

Based on the results of the musculoskeletal disorder diagram, it shows that the body parts that have the most complaints during the last 12 months and the last 7 days are almost all parts of the body. It is known that 100% of workers feel

Table 1. The Results of Risk Level Assessment for RULA, REBA, QEC and JSI Work Postures

Methods	Result		Description
	Most Value	Average	
RULA	7	-	High risk, make changes now/as soon as possible
REBA	5	-	Medium risk, requires further investigation and immediate changes
QEC	-	59%	Further investigation and action need to be taken immediately
JSI	-	9,75	Work activities carried out at extremely dangerous levels

low back pain. The factor causing the high prevalence of musculoskeletal disorder is due to excessive muscle performance. Manual material handling activities for neutral amine filling such as lifting 25L jerry cans from below in a bent position, carrying jerry cans from the ground floor to the top floor to be filled using a monkey ladder and pouring the jerry cans into the neutral amine tank require large muscle movements. Therefore, if a worker felt fatigue or pain in a part of the body, they should take a break immediately and not force the muscles to work excessively.

Table 1 shows that the neutral amine filling activity has a high work posture risk level based on the RULA method and a moderate work posture risk level based on the REBA method. This study assessed work postureson 100 photos. The purpose of collecting a large sample of work posture photos is to compare the results of the RULA and REBA method scores. Looking at the percentage results of each method in Table 1, the risk level of the RULA method work posture is in the high category, so changes need to be made now / immediately. Meanwhile, the risk level of the work posture of the REBA method is in the medium category, so the filling of this neutral amine needs to be further investigated and changes need to be made immediately.

From the calculation of the average QEC assessment of the five workers, a value of 59% was obtained. The average QEC result of the five workers is in the 51%-70% category. The interpretation of these values requires further investigation and changes need to be made immediately to avoid accidents. From the calculation of the average JSI assessment of the five workers, a value of 9.75 was obtained. This shows that the neutral amine filling activities carried out by the workers has been at a very dangerous level.

The high RULA, REBA, QEC and JSI scores are due to operators carrying out work in unnatural/not ergonomic working postures. The following are several factors that cause high RULA, REBA, QEC and JSI score results:

a. Body postures that are far from normal and forced to withstand the weight of neutral amine jerry cans which are quite heavy (25L) for quite a long time (± 1 minute);
b. The high neutral amine tank filling location and the presence of a monkey ladder made it difficult for workers to move jerry cans from the ground floor to the tank filling position on the upper floor.
c. The grip (coupling) is quite poor during the neutral amine filling activity.
d. The position of the measuring cup that was parallel to the filling floor made workers must bend their bodies when filling the measuring cup with jerry cans.

This is due to lack of ergonomics knowledge and awareness of workers. Thus, the workers are under moderate to high risk of musculoskeletal disorders as determined from REBA and RULA risk level. This study recommends the immediate implementation of ergonomics interventions with proper knowledge among workers and health education on common postural change, implementation and monitoring of laws among industries are recommended to take down morbidity due to MSDs.

This study highlighted the importance to inform and train the operators to perform gestures, postures and activities in accordance with the ergonomic principles. In this way, in addition to optimize the human–machine

interaction, it can be possible to intervene on the organization and management of the whole activity. The results show that the operators are working in an inadequate working environment with awkward postures the results are supported by the subjective assessment of discomfort.

The initial conditions for filling neutral amine, workers are used to lifting neutral amine jerry cans that have weight 25L with both hands without using other tools. In Figure 3 is one of the working postures when filling neutral amine using the old working method which produces a RULA score of 7. Thus, it is high risk and changes are needed immediately. Based on the above, RULA is more suitable for assessing postural load and its relation to MSDs.

Figure 3. The Process of Neutral Amine Filling Manually

The Tools Design Results, this set of filling equipment for neutral amine includes a number of different series of parts, including a 1000L volume kempu to replace 25L jerry cans, connecting pipes (pipes reinforced with fiberglass), valves (ball valves), AODP pumps (Air Operated Diaphragm Pumps), closed measuring cups (PVC clear sheet), and support for the pump, measuring cup, and AODP pump, as well as compressed air (air plant) as the AODP pump driver.

The anthropometric data used for the width of the tap handle is the measurement of hand width with the 50th percentile is 10 cm in length. And standing hip height is a reference in determining the height of the tap on work tools. The percentage used is the 50th percentile is 88 cm. The standing upper arm height dimension is used so that workers feel comfortable when operating the valve because the arm position forms an angle of <45 degree. According to the RULA dan REBA methods, the arm angle that does not caused injury is <45 degree from the body axis.

After the design of the new work tools has been completed, it is created using Solidworks AutoCAD software. Then a simulation was carried out to assess the worker's working posture when filling the neutral amine tank using the new work tools. Neutral amine filling simulation using Solidworks AutoCAD software to assess the Rapid Upper Limb Assessment (RULA) method using ErgoFellow 3.0 software.

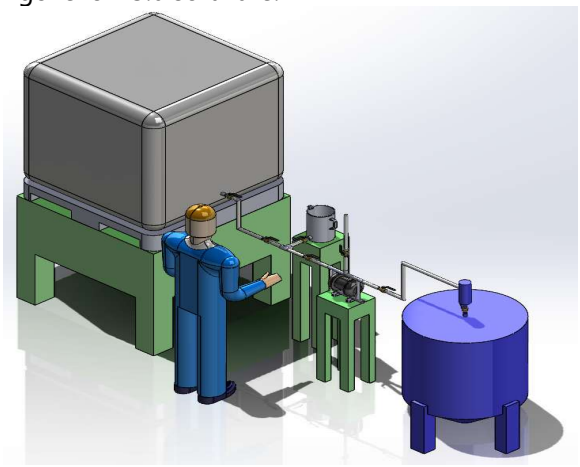

Figure 4. Work Posture Simulation Using Solidworks Software

Simulation the Use of Work Tools, the use of the new work tools design resulted in a RULA score of 4 (low risk), while during manual handling, the RULA assessment score for the job of manually filling neutral amine with jerry cans was 7 (high risk). This shows that there is a decrease in the risk level by 3 points, from high risk to low risk. This reduction in risk levels shows how this new work tool design may be used to prevent or alleviate musculoskeletal issues that employees have previously faced.

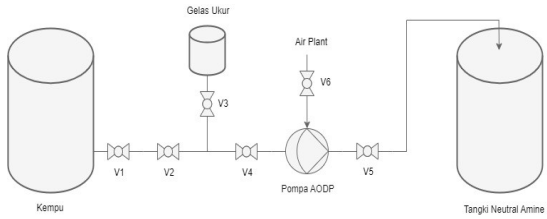

Figure 5. New Work Tools Design

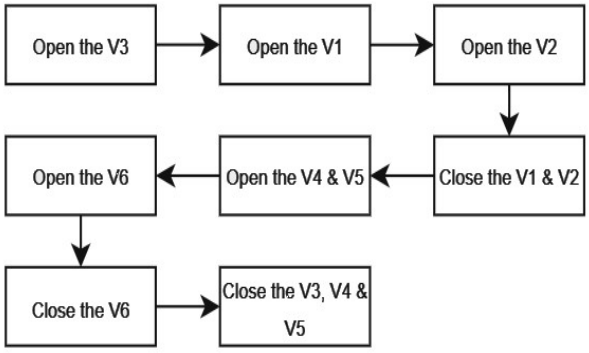

Figure 6. Block Diagram of New Work Tools Procedure

Some of the advantages of using this work tools are:

The use of this work tools will reduce the habit of bending, because these new work tools will minimize lifting and pouring postures.

Users no longer hold weight with their hands while lifting, carrying and pouring. Users simply stand to operate the valve on the new work tools.

It is more effective in filling neutral amine because it is directly connected to the pump to flow from the pump to the neutral amine tank immediately.

Safer for users. The neutral amine gas is contained by the measuring cup's cover, preventing the user from inhaling it directly.

Neutral amine will not spill or expose the user because it is connected to a pipe, while previously when filling it was easily spilled/exposed.

Based on observations at suspending agent workstations in the chemical industry, workers face unique challenges, such as dust exposure, high altitudes, and limited space, which can cause these individuals to assume awkward body postures. The simulation in Ergonomics Intervention Study of the RULA/REBA Method in Chemical Industries for MSDs' Risk Assessment research were run using CATIA software to evaluate the designs of a conveyor, a jack-adjustable table, and the overall work method. The systematic posture assessment shows that the awkward work postures that had the highest risk of causing musculoskeletal disorders occurred on average in the upper arm and wrist, twist, muscle and extreme load. The high prevalence of MSDs among large random samples of the general working population are most evident in the lower back, neck, and shoulders.

Based on systematic assessment results using (RULA/REBA) in suspending agent workstations, a RULA score of 7 indicates that investigation and changes are required immediately, and a REBA score of 13 indicates a very high risk and need to implement change. The method to follow up the results of existing measurements and reduce the risk of MSDs was to conduct an evaluation and to control work posture risks, revise the work-system process, and integrate ergonomic concepts with the work equipment. The result of strategic intervention in the suspending agent workstation is shown in the final column, with simulation CATIA score RULA 3 ('low risk, change may be needed'). Methods of ergonomic intervention include the creation of an integrated worker system, such as the addition of a conveyor, a jack-adjustable table, and an ergonomic method for pouring the chemical materials into the mixer.

The article a field study on ergonomic interventions of WMSDs prevention in a chemical company using an atlas that used to help improvement and Key Indicators Method (KIM) was used to evaluate the goodness of the improvement. Meanwhile to determine the level of danger of musculoskeletal injuries that felt by workers due to not ergonomic work posture when filling neutral amine manually can be measured using RULA, REBA, QEC, JSI, and QFD as the basis for product design to process designing work tools as the output of the research.

Previous research on the Chemical Industry was also conducted by Yayan Harry Yadi (2017) with the title Ergonomic Intervention Study of the

RULA/REBA Method in the Chemical Industry for MSDs Risk Assessment. The research has been conducted on chemical industry workers who operate suspending agent workstations, while this research was conducted on neutral amine filling workers. This shows that the topics taken in this study are both included in the chemical industry. In previous studies, workers faced unique challenges, such as exposure to dust, heights, and space limitations, which can cause the individual to have an uncomfortable posture. While the challenges faced by workers in filling neutral amine are carrying, lifting, and pouring loads weighing 25L with a frequency of four times a day with limited space conditions that can cause workers to be exposed by neutral amine chemicals due to un ergonomic work postures. The challenges faced by workers in both studies were almost the same, but in this research the challenge that faced by workers were more severe because the workers carried & lifted loads weighing 25L manually in an unergonomic working position so there was a risk that causing musculoskeletal disorders.

The simulation in Ergonomics at the previous research were run using CATIA software to evaluate the designs of a conveyor, a jack-adjustable table, and the overall work method. Meanwhile the simulation in this study uses ErgoFellow 3.0 software to analyze the state of the workstation, improve productivity, evaluate workplace conditions, reduce work risk and to improve workplace conditions from different points of view, such as RULA. In addition, the other software that used is Solidworks 2022 software for the three-dimensional design process. The researcher using ErgoFellow 3.0 because the software has supporting 17 features to analyze, evaluate and improve workplace conditions, and to reduce work risks and increase productivity from different points of view, such as RULA (Rapid Upper Limb Assessment), REBA (Rapid Entire Body Assessment), OWAS (Ovako Working Posture Analyzing System), Suzzane Rodgers, and Quick Exposure Check (QEC) which can support this research. Apart from that, Solidworks 2022 software helps researchers in creating 3D designs and assists in translating images into casting patterns/models which will reduce image reading errors in the resulting product. Meanwhile, CATIA is more complex software which is suitable to use in the car industry, however for product design for making machines or production equipment it will be better and faster to use Solidworks software.

The systematic posture assessment at the previous research shows that the awkward work postures that had the highest risk of causing musculoskeletal disorders occurred on average in the upper arm and wrist, twist, muscle and extreme load. The high prevalence of MSDs among large random samples of the general working population are most evident in the lower back, neck, and shoulders. While in this research, the data prevalence of musculoskeletal disorders on filling neutral amine manually in the last 12 months shows that complaints in the right elbow, upper back, lower back and left knee have a percentage of 100% which means that all workers have felt the pain. The right arm, right wrist and right knee have been felt by 80% of respondents (workers). In the left arm and right thigh have been felt by 60% respondents. From the results of processing the data prevalence of musculoskeletal disorders in these twenty parts of the body, it can be concluded that almost the workers felt the pain in all the body. This is caused by the heavy of loads that lifted by workers which are carried out repeatedly over a long period of time.

Systematic assessment results at the previous research using (RULA/REBA) in suspending agent workstations (Table 2), a RULA score of 7 indicates that investigation and changes are required immediately, and a REBA score of 13 indicates a very high risk and need to implement change. The method to follow up the results of existing measurements and reduce the risk of MSDs was to conduct an evaluation and to control work posture risks, revise the work-system process, and integrate ergonomic concepts with the work equipment. Based on the modus of recapitulation of work posture assessment by RULA and REBA at this research of neutral amine filling activity in the high and medium categories. This indicates that the activity needs for

investigation and changes in the work of filling neutral amine. So that awkward work posture due to the filling of neutral amine using jerry cans is the cause of musculoskeletal disorders that workers have felt so far. From these results, researchers designed work tools to reduce the risk of musculoskeletal disorders.

The result of the previous research that strategic intervention in the suspending agent workstation is shown in the final column, with simulation CATIA score RULA 3 ('low risk, change may be needed'). Methods of ergonomic intervention include the creation of an integrated worker system, such as the addition of a conveyor, a jack-adjustable table, and an ergonomic method for pouring the chemical materials into the mixer. Based on the simulation results of filling neutral amine, there was a decrease in score of 3 points, which proves that the design of work tools for filling neutral amine has the potential to reduce the risk of musculoskeletal disorders

Statistical hypothesis test results by RULA/REBA show that changing the design of ergonomic work systems automatically leads to improvements in workers' posture. Ergonomic interventions can also improve workers' welfare, increase productivity, and enhance the quality of the work produced. By using ergonomic interventions in the workplace, it is possible to reduce the risk of MSDs or prevent adverse health effects. Changes in working conditions must be promptly implemented to protect workers and installing appropriate equipment will improve their quality of life. Ergonomic interventions to improve worker conditions (e.g., through workstation design and work organization) can reduce the high prevalence of MSDs among these worker groups.

IV. CONCLUSION

The study concludes that musculoskeletal disorders (MSDs) are prevalent among workers, particularly in the Right Elbow, Upper Back, Lower Back, and Left Knee, with a 100% complaint rate over the past 12 months. Additionally, 80% of workers reported discomfort in the Right Arm, Right Wrist, and Right Knee. In the last seven days, the most frequently reported pain was in the Lower Back (100%) and the Right Knee (80%). Postural risk assessments using RULA, REBA, QEC, and JSI indicate that the neutral amine filling activity poses a high to moderate risk, necessitating further investigation and corrective measures. Poor working posture, particularly due to handling jerry cans, is a significant contributor to MSDs among workers.

To mitigate these risks, a work tool design was developed using the HOQ matrix with a QFD approach, resulting in six target specifications. The primary improvement includes the use of an AODP pump powered by compressed air, designed to accommodate Indonesian anthropometric data. The ergonomic intervention demonstrated effectiveness, as simulated assessments showed a reduction in work posture risk scores from 7 (high) to 4 (moderate) based on the RULA method. This indicates that implementing proper ergonomic solutions can significantly improve workers' posture and reduce the risk of MSDs.

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