International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 04 Issue: 10 | Oct -2017 www.irjet.net p-ISSN: 2395-0072

ERGONOMICS IMPROVEMENTS IN A PAINT MANUFACTURING COMPANY

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Abstract: *The work environment has a potential of adversely affecting staff's performance in diverse ways ranging from displeasure, fatigue, frustration, and minor or major injuries that decrease the workers' ability to accomplish the daily tasks, and even deaths in extreme cases. Also known as human factors engineering, the goal of ergonomics is to fit the job to the worker, not the worker to the job. This paper examined the role of ergonomics in manufacturing, and the results of its application in a paint manufacturing company. The frequent cases of Work-related Musculoskeletal Disorders (WMSD) were tackled by the installation of sit-standing variety of chairs and new ergonomic chairs with many adjustable functions to enhance convenience. To achieve illumination of up to 1000 lux in order to easily see and address quality issues, more fluorescent light tubes were installed to attain uniform illumination level, while 1.438 were calculated as the average total noise the machines subject the operators for 8 hours of use each day. This was resolved by the installation of sound insulating covers for many processes to improve oral communication. Also, the ambient noise level at the workstations was decreased from around 78 to 62 dBA, thereby enabling the workers to discuss freely without undue interference. The application also achieved 21%, 22%, and 24% improvements in throughput, workers' productivity, and injury reduction respectively, and 62,300 dollars total cost reduction in six months. However, the firm was unable to record appreciable waste detection and possible elimination during the period under review, hence the introduction of Five-S housekeeping practice was advocated.*

Keywords: manufacturing; ergonomics; musculoskeletal disorders; safety; shop floor; work station; operators; productivity; throughput; human factors engineering

1. INTRODUCTION

Fatigued, sick and frustrated workforce are some of the consequences of poorly designed plant layout and work station which leads to decrease in productivity, income and efficiency, low product quality, increased medical claims, musculoskeletal disorders, as well as disabilities. Hence, the need for ergonomics in the manufacturing industries. Wolfgang and Joachim (2017), explained that ergonomics "examines not only the passive ambient situation but also the unique advantages of the human operator and the contributions that can be made if a work situation is designed to permit and encourage the person to make the best use of his or her abilities."

As the science of studying people's efficiency in the work environment and the modalities and processes to be added to enhance their health and productivity all through the working hours, ergonomics entails proper designing of a job to fit a worker in order to ensure more efficient and safety work. Also known as human factors engineering, ergonomics is defined by Middlesworth (2016), as "the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design, in order to optimize human well-being and overall system performance." It encompasses other scientific disciplines like psychology, mechanical/industrial engineering, industrial and information designs, kinesiology, industrial safety, biomechanics, as well as anthropometry, and instead of physically compelling the worker to fit the job, it fits the job to the worker.

To optimize man-machine integration in order to enhance precision and rate of work is the main objective of ergonomics. It involves the design of a favourable workstation, the increasing of efficiency by reducing mental and physical strain of workers. The objective is aimed at optimizing the integration of man and machine, so as to improve the work rate and accuracy, as well as the organization of daily tasks at work. Other objectives are the improvement of machines and equipment at the early or design stage of production, profit enhancement and cost reduction by reduction or possible elimination of accidents, fatigues, mistakes and death without tampering with the product quality.

2. LITERATURE REVIEW

According to Sanchez (2015), Industrial ergonomics can be defined as the branch of science that aims at achieving an optimal fitting of the work environment and job activities to the worker. He noted that the work environment can affect a worker's accomplishment in many different ways varying from health damage to effects that reduce the individual's capacity to perform a task or those that cause dissatisfaction and uncooperative attitudes. However, The International Ergonomics Association (2000), defined ergonomics (or human factors) as "the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance."

The scope of ergonomics in manufacturing industries include but not limited to pushing and drawing of loads, physical work load, staff posture at work, man-machine interaction, noise, visibility, environmental stress, analysis of human capabilities and weaknesses, fatigue, dynamic forces acting on the human body while at work, the tools used by workers to perform various tasks, etc. Godwin and Okpala (2013), observed that "work-related health problems are experienced by workers across all types of jobs and work sectors, and to many, it has become a fact of life." However, they explained that some types of work groups seem to be particularly at higher risk when compared to others.

Identifying the risk factors in a manufacturing company is fundamental in eliminating or reducing hazards and enhancing the overall workers' safety. Working for over eight hours, strenuous repetitive works, firm grips on working tools when combined with faulty machine, equipment, work station, and tool design, create physical stress on workers, thereby leading to injuries like musculoskeletal disorders.

According to Pinnacleoffice (2016), an ergonomic study is conducted to ascertain if an employee is working to their full efficiency with the office supplied to them currently. They pointed out that "if the study concludes that productivity would increase and the employee would benefit from a change in supplies such as a different chair, desk, mouse, monitor, etc., the needed changes are made to ensure the employee doesn't sustain any injury and is able to work at full productivity level from then on."

Body aches and muscular strains which result from improper seating and working postures are daily experiences in manufacturing companies, as most of the operations are executed by workers in standing or seating positions over a long period of time. Ergonomics is aimed at promoting sound health for operators in industries in order to achieve a comfortable, safe, and protected work environment.

According to Marilyn and Andrew (2014), "The need for ergonomics can arise in a number of circumstances, including changing demographics, changing technology and job demands, fear of consequences of human error, high demand for creativity and accuracy, high workers' compensation and insurance costs, and highly competitive markets."

The ability of manufacturing companies to ergonomically design conducive shop floors and plants that enhance good health by allowing reduced motions, better posture and less exertion will lead to more effective and productive work force, as well as the production of high quality products with reduced defects. According to Middlesworth (2015), "When the job task is too physically taxing on the worker, they may not perform their job like they were trained," he explained that an employee may not fasten a screw tight enough due to a high force requirement which could create a product quality issue if he is not comfortable.

Another importance of ergonomics is production cost reduction; this is because a properly designed ergonomics friendly workstation will drastically reduce all risk factors that may lead to fatigue, strain, injuries, musculoskeletal disorders, as well as other exorbitant indirect costs.

Other benefits include: improvements in throughput, productivity, sustainable workforce, savings, product quality, employees morale and engagement, as well as safety which leads to fewer injuries and compensation claims.

3. METHODS

D. O. Onyia International Limited was established in 2009 in Enugu, initially as a modest enterprise that manufactures Doil and Joytex brand of emulsion, and texcote paints. However, through dedication, specialized craftsmanship, market knowledge, and production of high quality paints, the company has increased its range of products and also established itself as one of the best known brands in the city.

The first step in paint making entails mixing the resin with pigment, other additives and solvents resulting to a thick paste, it is later passed through a big cylinder which tosses small particles of silica that break up the pigment particles throughout the mixture after grinding them. As it is a physically demanding activity, paint manufacturing in the newly established company alongside its production processes exposed workers to diverse ergonomic challenges. This is mainly because the company's work tasks, machines and equipment did not inculcate ergonomic principles in their design setup. As a result, undue physical stress, strain, and over-exertion, which include vibration, awkward postures, forceful exertions, repetitive motion, and heavy lifting adversely affected the workers at the shop floor.

To guarantee the success of the exercise, the team insisted that the entire workforce must be involved in the exercise, in order to ensure that the individual needs of employees are met and that there is a match between workers and their activities, equipment, tools and systems. Also, written assessments and evaluation of all factors before follow up were also advocated and implemented.

As training is a very important element of successful ergonomics, an ergonomics seminar was organized for the entire workforce with the collaboration of the company's management. The purpose of the seminar was to ensure that the workers and operators are empowered to achieve predetermined roles and responsibilities through identifying and eliminating the risk factors, by achieving practicable and economical shop floor improvements. The seminar highlighted practical trainings and user friendly solutions to problems that will enable them to easily confront their day to day shop floor problems effectively, and also encourage them to exceed their goals and expectations.

As occupational ergonomics must deliver proper design modifications of a plant layout and shop floor, as well as the arrangement of work to match the workers in order to enhance safety, profitability, productivity, and quality, and also decrease injuries, the adverse effects of the condition which include injuries, musculoskeletal disorders, low productivity, low product quality, loss of man-hours, and reduced profitability forced the management of the company to approach the ergonomics team for solution.

The knowledge of manufacturing choices that can enhance productivity as well as how ergonomics application can be affected by the decisions taken on equipment, technical system, process layout, machines, and communication routes among workers is very vital. This is because verifiable improvements in ergonomics cannot be possibly achieved without including the manufacturing processes.

A detailed analysis of the company's production processes revealed to that numerous factors like uncomfortable chairs that are either too high or too low without adequate leg clearance, noise pollution, work surfaces and equipment positioned at wrong heights, out of reach tools, bins and shelves, poor light effects, as well as hand tools that lack proper gripping efficiency are to be blamed for the ergonomics problems, injuries, musculoskeletal disorders, and losses bedeviling the manufacturing firm.

To properly assess the circumstances of the company, the team involved the entire workforce, and sought for information from different sources which include:

- The management. The company's management provided detailed information of the perceived ergonomics problems facing the company.
- Managers and Supervisors: consisting mainly of promoted shop floor workers and machine operators; the information they provided on the "good old days" of the company and the recent ergonomics problems are very vital for the success of the exercise.
- Shop floor workers: questions here bordered on the difficulties encountered on the shop floor which include the weights of the raw materials they usually lift, high noise rate, as well as the duration of mastering a new job.
- Shop floor inspection and observations: all the manufacturing processes were properly examined and ergonomics problems and possible solutions identified.
- Measurements: Evaluation of the shop floor's illumination and noise, as well as Recommended Weight Limit (RWL).

An ergonomic assessment to appraise the rapport between the staff and their work environment revealed the following: unhealthy relationship between the various departments and their workers, abysmally low morale, as well as poor safety culture. As happy employees are productive workers, the need to boost the workers morale, improve their engagement and happiness cannot be over-emphasized, as healthy staff are a firm's most valuable asset. This is because creating and fostering the wellbeing and safety culture of an organization will lead to a better human performance for it.

According to Anderson (2012), the first step to correcting problems is to understand the key workplace ergonomic risk factors and review work tasks in an operation to see which ones that apply, as this can make a tremendous difference, since occupational safety professionals estimate that reducing physical stresses could eliminate as much as half the serious injuries that happen each year.

However, the first approach to reducing ergonomics problems is by predicting what might go wrong and modifying tools and the work environment to make tasks safer for the staff.

The key risk factors and the injuries each may cause are shown in Table 1.

Table 1 – MSD Risk Factors

Force	Exerting excessive force can cause a variety of injuries.
Repetition	Excessive repetition of movements can irritate tendons and increase pressure on nerves.
Awkward postures	Positions that stretch physical limits can compress nerves and irritate tendons.
Static postures	Positions that a worker must hold for long periods of time can restrict blood flow and damage muscles.
Quick motions	Increased speed or acceleration when bending and twisting can increase the amount of force exerted on the body.
Compression or contact stress	Grasping sharp edges like tool handles can concentrate force on small areas of the body, reduce blood flow and nerve transmission, and damage tendons and tendon sheaths.
Recovery time	Inadequate recovery time due to overtime, lack of breaks, and failure to vary tasks can leave insufficient time for tissue repair.
Vibration	Excessive vibration from tools can decrease blood flow, damage nerves, and contribute to muscle fatigue. Whole body vibration can affect skeletal muscles and cause low-back pain.
Cold temperatures	Working in cold temperatures can adversely affect a worker's coordination and manual dexterity and cause a worker to use more force than necessary to perform a task.

Source: Adapted from Ergonomics: The Study of Work, U.S. Department of Labor, Occupational Safety and Health Administration, OSHA 3125, 2000.

The illustration of Ergonomics Risk Factors is shown in figure 1.

Figure 1: Illustration of Ergonomics Risk Factors. Source: Anderson (2012)

A detailed and comprehensive appraisal of the entire manufacturing processes, as well as the workers' tasks was achieved through questionnaires, observations and measurements. The findings revealed substantial improvement opportunities.

4. RESULTS

Although the ideal thing would have been to eliminate all manual lifting operations in the company, however, since it is not realistic, the best possible control strategy is ergonomic redesign which is aimed at decreasing job demands leading to reduction of over-exposure to traumatic movements of the body and hazardous loading and lifting conditions. The proposed ergonomics redesign entails complete overhaul of the entire plant layout, adjustments of weight, size and physical properties of raw materials and other lifting objects, and considerable decrease of lifting frequency.

The adopted work station design principles are shown in Table 2.

Table 2 – Work Station Design Principles	
Make the work station adjustable	Large and small people should be able to fit comfortably and reach materials easily.
Locate materials to reduce twisting	Give enough space for whole body to turn.
Avoid static loads, fixed work postures	Avoid long periods of leaning, extending limbs, tilting heat, and supporting body on one leg.
Set work surface according to type of task	Above elbow height for fine visual work. Below elbow height for tasks needing downward force or heavy physical effort.
Provide adjustable chairs	Include adjustments to seat height, back rest, lumbar support. Padding shouldn't compress more than an inch. Chair must be stable (5-leg).
Allow workers to alternate between standing and sitting	Floor mats for prolonged standing.
Support the limbs	Provide elbow, wrist, arm, foot, back rests as needed.
Use gravity	Consider ways to move materials using gravity rather than lifting.
Design for proper arm movements	Arm movements should be continuous and curved. Movements should pivot around the elbow rather than shoulder. Minimize movements or extensions more than 15 inches.
Consider computer monitors	Should be adjustable to eye level.
Provide simple dials and displays	Make sure they are easy to read, reach, and operate.
Consider environmental conditions	Minimize excessive noise, heat, humidity, cold, poor lighting.

Source: Adapted from Elements of Ergonomics Programs, A Primer based on Workplace Evaluations of Musculoskeletal Disorders. Adapted from checklists developed by Applied Ergonomics Technology

The National Institute for Occupational Safety and Health (NIOSH) lifting equation and procedures were adopted to isolate the ergonomic problems and also appraise the redesign solutions. Here any of the job factors that have the most reduction in the load constant is adjudged the first priority for job redesign. The lifting equation describes a Recommended Weight Limit (RWL) for distinctive job liftings, which the workers can conveniently perform within an eight hour normal working day without the danger of acquiring injuries or lower back pain.

The Recommended Weight Limit (RWL) equation is given in equation 1.

$$RWL = LC * HM * VM * DM * AM * FM * CM \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where the six task variables LC, HM, VM, DM, AM, FM, and CM are Weight of the lifted object, Horizontal distance of hands from midpoint between the ankles, Vertical distance of the hands from the floor, Vertical travel distance between the origin and the lift destination, Angle of asymmetry or angular displacement of the load from the sagittal plane, Average frequency rate of lifting measured in lifts per minute, and A value derived from lifting frequency and vertical displacement of the lift respectively.

Also, the Lifting Index (LI) which provides a relative estimate of the physical stress associated with a manual lifting job and applied to estimate the relative magnitude of physical stress for a job is giving as:

$$LI = \frac{weight\ of\ load\ in\ pounds\ or\ kilograms}{RWL} \ldots\ldots\ldots\ldots\ldots 2$$

Here, the bigger the Lifting Index (LI), the smaller the fraction of workers capable of safely sustaining the level of activity.

As improper work posture leads to injuries, fatigue, poor quality, and defective products, the work processes and workstations at the shop floor were redesigned to enhance better work posture, well-being and convenience. Improper sitting arrangements, sitting positions, as well as the design of two mixing machines were equally improved upon to forestall the frequent cases of musculoskeletal disorders and injuries. For the operators, the sit-standing variety of chairs was installed for ease of operation, while new ergonomic chairs with many adjustable functions to enhance convenience were mounted for the inspectors.

To address the inadequate illumination which contributes to low product quality, and also induces stress at the shop floor, as workers tend to stress their eyes to take sample measurements, more fluorescent light tubes were installed to achieve uniform illumination level. Also, some light bulbs that were turned off to save energy were all switched on, while light fixtures in the ceilings were lowered closer to the workstations, as the aim was to attain illumination of up to 1000 lux in order to easily see and address quality issues. This eventually became one of the best measures, as safety hazards are properly seen and correct measurements easily taken.

As the workers complained about the unacceptable noise level at the shop floor which could be irritating, interferes with verbal communications, adversely affect productivity and throughput, and may also lead to hearing losses, the noise exposure of diverse intensity were added with the Occupational Safety and Health Administration (OSHA) formula, which gives the allowable noise dose (D) as:

$$D = {}^{Ci}/_{Ti} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

Where the allowable noise dose (D) should be 1,
Ci is the duration of exposure to a noise level i (in hours), and
Ti is the permissible duration of exposure to noise level i (in hours).

The average total noise the machines subject the operators for 8 hours of use each day were calculated accordingly with equation 3 to give 1.438. As the noise is far greater than the allowable noise dose of 1.0, it shows that the shop floor exposes the workers to an excessive noise level that is not permissible. Although many factories adopt hearing protectors like ear muffs and plugs which are designed with different materials to occlude the ear canal, the team advocated for and installed sound insulating covers for many processes to improve oral communication. Also, the ambient noise level at the workstations was decreased from around 78 to 62 dBA, thereby enabling the workers to discuss freely without undue interference.

Another factor that hampers the quality of the products was that some of the operators were staying in enclosures in the shop floor, thereby limiting exposure and communication. To achieve open access with other operators and also improve verbal communication and feedback among the co-workers, all enclosures were removed, thereby improving free communication, safety, and job satisfaction which subsequently also improved the product quality.

Based on the nature of paint industry, projections were made on improvements (in percentage) and cost reduction (in dollars), enormous benefits have been realized within the period under review, the actual recorded improvements and cost reduction as shown in Table 3 are not quite close to the projected values. However, with 21%, 22%, and 24% improvements in throughput, workers' productivity, and injury reduction respectively and 62,300 dollars total cost reduction in six months, it has been proved that ergonomics plays a vital role in improvements and cost reduction in manufacturing.

Table 3: Improvements and Cost Reduction

	IMPROVEMENT (%)		**COST REDUCTION ($)**	
	PROJECTED	ACTUAL	PROJECTED	ACTUAL
THROUGHPUT IMPROVEMENT	32	21	50,000	17,000
WORKERS' PRODUCTIVITY	34	22	54,600	36,800
INJURY REDUCTION	31	24	12,800	8,500
TOTAL			117,400	62,300

The other benefits of the successful ergonomics process implementation are reduction in injuries, treatment and absentee costs, enhancements on throughput, profitability, product quality, etc.

The automation of a repetitive and monotonous operation that does not offer job satisfaction in order to enhance efficiency and throughput was recommended. However, this was not achieved as the management explained that they will continue with the manual processes pending when the fortune of the firm improves considerably, as automation is quite expensive.

5. CONCLUSION

The introduction of Ergonomics to the paint manufacturing company led to the analysis of the root causes of the losses that resulted from injuries, absenteeism, compensation, and labour costs, as well as the collaboration with the management and staff for workable solutions. The assessment of the company's performance after six months of ergonomics introduction showed remarkable improvements in all the departments, as it improved the productivity of the workers; this is because the workstations were redesigned to offer better posture, enhanced illumination, less movements, little exertion, reduced noise, and enhanced reaches, thereby leading to less fatigue and more effective workforce.

The employees were very important in the successes recorded in the company. As the workers realized the far reaching changes and solutions to their health and safety challenges offered by ergonomics, their level of commitment and morale were improved with considerable decrease in the rate of absenteeism. This is because comfortable workers that are less fatigued are more productive.

Other achieved benefits of ergonomics in the company include the prevention of the work related musculoskeletal disorders, considerable reduction in the following: ergonomic related injuries, workers' compensation costs, fatigues, defects and scraps, maintenance downtime, absenteeism, as well as maintenance downtime. Others are improved efficiency, and labour relations.

However, the firm was unable to record appreciable waste detection and possible elimination during the period under review, hence the need for the introduction of Five-S housekeeping practice.

REFERENCES

- Anderson, J. (2012), "Four Simple Ergonomic Steps to a More Productive Workplace" [Online], Assessed on 5 Octoberber 2017, from http://www.listaintl.com/resource-center/white-papers-and-case-studies/white-papers/four-simple-ergonomic-steps-more-productive-workplace

- Elements of Ergonomics Programs (1997), A Primer based on Workplace Evaluations of Musculoskeletal Disorders, U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health

- Godwin, H. and Okpala, C. (2013), "Ergonomics of Musculuskeletal Disorders From Load-Lifting Activities in Building Construction" International Journal of Advanced Engineering Technology, Vol. iv, Iss. iv.

- Marilyn, J. and Andrew, J. (2014), "The Business Benefits of Ergonomics" [Online], Assessed on 13 October, 2017 from www.adlittle.com/downloads/tx_adlprism/1996_q1_23-26.pdf

- Middlesworth, M. (2016), "The Definitions, Domains, and Applications of Ergonomics" [Online], Assessed on 13 September 2017, from http://ergo-plus.com/ergonomics-definition-domains-applications/

- Middlesworth, M. (2015), "Five Proven Benefits of Ergonomics in the Workplace" [Online], Assessed on 22 September 2017, from http://ergo-plus.com/workplace-ergonomics-benefits/

- OSHA (2000), "Ergonomics: The Study of Work" Department of Labour, Occupational Safety and Health Administration, 3125, 2000. United States of America (Revised)

- Pinnacleoffice (2016), "The Importance of Ergonomics in the Workplace" [Online], Assessed on 13 September 2017, from

https://www.pinnacleoffice.ca/importance-ergonomics-workplace/

- Sanchez, S. (2015), "The Importance of Ergonomics in Industrial Engineering" [Online], Assessed on 13 September 2017, from https://www.omicsonline.org/open-access/the-importance-of-ergonomics-in-industrial-engineering-2169-0316.1000e121.php?aid=23221

- The International Ergonomics Association (2000), "The Discipline of Ergonomics" [Online], Assessed on 14 October 2017, from www.iea.cc

- Wolfgang, L, and Joachim V. (2017) "Encyclopedia of Occupational Health and Safety" Fourth Edition. [Online], Assessed on 12 September 2017, from http://www.ilocis.org/documents/chpt29e.htm