Design of A Line of Assembly Under an Ergonomic Approach to Optimize its Operation

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***Abstract*— Describes a new design of manual assembly line. In the assembly line, the subject has a design problem with the stations, such as the design fault on the flow process, this is caused because of the wrong placement of materials and tools. The solution utilized, which in part came from a study by Chim (2014) in Hong Kong, where a systematic solution is used to calculate the potential risk of muscle/bone trauma. And also from a study by Sanchez Reyes et al. (2013) which proposes a study of shift and time managment to find apropppiate standard production times, a reduction of inventory, facilitate the scheduling of production and to find possible improvements in labor conditions**

***Index Terms*— prevention of occupational hazards; ergonomics; design of workspaces; process design**

I. INTRODUCTION

Organizations depend mainly on the work of employees to give value to their products and/or services, it is necessary to pay attention on the way in which the activities take place. This study will help manufacturing companies to detect areas of care and risk related to ergonomics and that affect directly and indirectly to production processes. On the other hand, addressing the ergonomic issues would be improved production processes reducing times and waste, thereby increasing productivity. The foregoing, together with the quality, represents the ideal pursued by all industrial processes.

II. THEORETICAL FRAMEWORK

2.1. Occupational risk prevention

The evaluation of occupational hazards is the process aimed to estimate the magnitude of risks that could not have been avoided, obtaining the necessary information so that the entrepreneur is in position to take a decision to appropriate the need to adopt preventive and, if so, about the kind of measures to be taken (Ministerio de trabajo, 2014).

According to Franco et al. (2014), the greatest challenge of prevention is to achieve that the dangers that may arise in an employment situation does not become risks. Therefore, it is necessary to implement different strategies to control the sources of risks. A strategy is the evaluation of occupational risks which is aimed to estimate the magnitude of risks that could not have been avoided, obtaining the necessary information so that the employer is in a position to take a decision to appropriate the need for preventive measures (Ministerio de trabajo). The National Institute of safety and health at work aims to analysis and study of the conditions of health and safety at work, as well as the promotion and support to the improvement of the same (Boletin Oficial del estado). On the other hand the technical guide published by the National Institute of safety and hygiene at work establishes rules which should be taken into account to you prevention of risks during working hours (Llorca).

Occupational risk factors can be seen in the following groups: factors or safety conditions; factors of physical, chemical or biological origin or environmental conditions; factors derived from the characteristics of the work, factors arising from the organisation of work(María and Díaz).

For Gangopadhy and Dev (2014), some risk factors can be a workstation not suitable for the physical characteristics of the workers, working procedures, as well as tools.

Actions on prevention of occupational risks are marked by their interdisciplinary and multidisciplinary character, and its necessary integration at all stages of the production process and in the Organization of the company. In this sense, any that is level and speciality who displayed an activity on it, must have a sufficient and appropriate training in order to successfully assume and guarantee the prevention in its scope and responsibility (Ríos & Beltrán, 2010).

The disciplines for the prevention of occupational risks are the following:

- **Safety at work :** The Mexican official standard NOM-019-STPS-2011, Constitution, integration, organization and functioning of the committees of safety and hygiene, aims to establish the requirements for the Constitution, integration, organization and functioning of the committees of safety and hygiene in the workplace (2011 STPS) . According to Hedlund et to the. (2016) unsafe work environments can be unhealthy for employees and costly for organizations yet. Safety is motivation essential for the improvement of safety among employees behavior.
- **Industrial Hygiene :** Industrial hygiene is considered a discipline essential to advance in the search for healthy, risk-free work environments, or, at least, with risks effectively controlled, so it becomes a strategic in services discipline (Varona et al., 2012).

For (Herrick & Goelzer, 2000) The profession that is specifically dedicated to the prevention and control of risks arising from work processes is the industrial hygiene. Industrial hygiene objectives are the protection and

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promotion of the health of workers, the protection of the environment and contribution to a safe and sustainable development.

 Occupational : Medicine of work, dedicated to the study of the health of workers, process contributes to the promotion of a culture that promotes the health risks that involves any work activity, for which require specialists with critical and reflective attitude that prioritize knowledge about other values, in pursuit of a better technical and human quality that avoid distorting their work (Sánchez et al., 2007).

The beginnings of the occupational medicine initially had a vision care directed to the provision of first aid and hospital specialized in the evaluation of the biological damage from a purely clinical or surgical perspective and treatment and rehabilitation in cases of invalidity, relegating the problems of prevention to medical evaluation (Zeballos, 2006).

 Hazards psychosocial : Factors psychosocial are conditions present in work situations related to the Organization of work, the type of position, the accomplishment of the task, and even with the environment; that affect the development of the work and health of workers. The origin of the problem in psychosocial risk situations is not on the individual, but it tends to be in the environment which is where come from such situations of risk due to a bad design and management of the work (Gil-monte, 2012). Psychosocial factors are factors present in all organizations with positive or negative results (Moreno, 2015). However the ILO considered to psychosocial risks as the game generated interrelations between work, the medium in which this takes place, the organizational conditions and, on the other hand, perceptions, interests and personal conditions of the worker out of work (Vargas et al., 2013).

2.2 Design of workspaces

Leškova (2014), says that when you are designing a workspace heights ranges must take into account: room to lower extremities, depth and range of adjustment for the descanzapies; size and variation of the dimensions of the parts to be handled; applied efforts; variation on the distances from vision; local specifications and aspects related to methodology, safety and efficiency.

The benefits provided by the application Assembly and bonding of ergonomics and design systems carry out the reduction of risks at work injuries and improve the physical conditions and psychosocial (Battini et to the.).

Organizational design increasingly takes on greater relevance. In the majority of situations, professionals are faced with the task of improving the management and performance of organizations of production or services already exist (Rodriguez, Gonzalez, and Noy). However according to Rivera, Cardona and Vasquez (2012), today the industrial environments are highly changing, so redistribution projects are becoming increasingly more common.

Gomez (2012) , indicates that there are different types and strategies of distribution of processes, the most common and important are: distribution by product/process and cell distribution.

2.3 Ergonomics

Ergonomics is the scientific discipline which is the understanding of the interactions between human beings and the elements that are part of a system (Hollnagel) , and Bridger (2003) , its importance lies in its application, since the benefits that can be obtained are: improvements in the design of the workstation, in the security of the Organization and compliance with the legal aspects of workplace safety and health regulations. For his part, Melo (2009), considers that the importance of ergonomics is that their direct approach is the adaptation between the middle and the worker.

Kushwaha and Kane (2016), point out that the basic goal of ergonomics is to fit man and machine together to improve worker performance, reduce stress and fatigue on the job. Here are two branches of ergonomics:

 Cognitive ergonomics: Cognitive ergonomics is interested in how and to what extent, the mental processes such as perception, memory, reasoning, and motor response affect interactions among humans and other elements of a system. Such as the ergonomic triad (human-machine - environment) (Kim).

 Organizational ergonomics or macroergonomia: Organizational ergonomics or macroergonomia, is concerned with the optimization of socio-technical systems, including their organizational structures, policies and processes. It has been shown that the performance of the systems of work in terms of productivity, quality, safety and health, quality of working life and satisfaction of the user, among others can be improved with the Macroergonomia (Rodriguez et al., 2016).

2.4. Ergonomic evaluation methods

For the analysis of the conditions of work are many methods that can be used, although not all are applicable to all situations, nor provide the same results (Ines. Dalmau and Nogareda). According to Asensio-cuesta (2009), choosing a method of ergonomic evaluation that is best suitable for the measurement of ergonomic hazards, is a complicated situation. There are currently 60 methods, so it is necessary to make comparisons between them, since at the time of trying to make an assessment, it tends to complicate the choice of the same (Lopez, la Vega, and Diaz).

Ergonomic evaluation aims to detect the level of presence, in workplaces evaluated, risk factors for the emergence, in the workers who occupy them, type disergonomico health problems (Period, "Ergonautas.com").

According to Inés Dalmau and Nogareda (2008) , methods for evaluation of multiple risk factors most commonly used are: method LEST (Economics and labour sociology laboratory), the Renault method, method FAGOR, method Ergonomic Workplace Analysis and the ANACT method (National Agency for the improvement of working conditions). Likewise, the authors mentioned above, note that the methods for evaluation of positions are: method OWAS Ovako Working Posture Analysis System () method using targeting (technique for recording the positions of labour), RULA method Rapid Upper Limb Assessment () method VIRA (National Council of safety and health), ARBAN method (Research Foundation for occupational safety and health) and method PEO (Portable ergonomic observation). Although generically talk about *"Ergonomic job evaluation"*, the reality is that what is assessed is the presence of ergonomic hazards (or disergonomicos) (period, "Ergonomics Portal developed by the Universidad Politécnica de Valencia, Spain.").

III. PROBLEMS

Research is carried out in an electronics manufacturing company established in Hermosillo, Sonora. Work is specifically a special use speaker assembly line. To perform a preliminary analysis of the work area, various negative conditions were both environmental and design of station, have been building for 10 years approximately. One of the problems is given in the basic system concept, since it has a flow of they manufactured in batches and not by unit as stipulated in process manuals, this causes bottlenecks, another important issue is the number and distance of travel operators during the process operators, which translates into greater labour fatigue.

In the Assembly line, object of study is the problem of design of the stations as of process flows, since the arrangement of material such as tooling are not adequate. Another problem is when it is concluded any operation of the product, there are no clearly defined places where to place it. Due to problems of design of the flow, the production is poor and the quantity of manufactured products is significantly smaller to indicate the production and quality standards established by the management.

Before this problem, the research aims to carry out the redesign of the production line, with the goal of optimizing the flow of products and productivity, all of this under ergonomic principles. The main benefits of this redesign will be reflected in the Elimination of unnecessary transfers of product in process, reduction of production time and actual production levels similar to the forecasts of the management. However, the most important benefit, will be reflected in the reduction of the ergonomic problems, accidents and disabilities of workers.

IV. PROPOSED SOLUTION

Most of the proposals of solution used in the literature are only correct ergonomic or design issues. None of the proposals of solution indicates an improvement in the two aspects where the flows and productivity are improved.

Is the proposal of Maldonado and Carlos (2009) , which is based on a design of a peripheral computer aimed at middle upper limb amputees, which facilitates the task of the management and control. The system was designed applying ergonomics in each of the stages of the process, looking to build a product with ergonomic quality. This study was not conducted an analysis of the process flow by stages, only he focused on finding the best way so that persons with disabilities were in an area of comfort, while people with their upper extremities do not enter in this design. The previous proposal is a bit rigid and focused to specific situation, it does not provide us enough to solve our problems.

The proposal of solution used, in part, is taken from a study conducted by CHIM (2014) in Hong Kong which provides a systematic solution to manage the potential risk of muscular skeletal disorders among users of computer equipment. This research proposes a program of ergonomics integrated office which considers (1) furniture evaluation and selection; (2) evaluation of the individual workstation; (3) training and education; (4) stretching exercises. Part of our proposal will also take ideas from Sanchez Reyes et al., (2013), which proposes a study of times and movements in order to find the standard time of production, reduction of inventories, facilitate the scheduling of production and find possible ergonomic improvements to improve working conditions. The project consists of the description of the strategic guidelines of the company, carry out documentation of the process, identify ergonomic conditions of operators, perform decision times and movements of the process analysis, consider the different diagrams to make a graphical analysis of the status of the processes and make the cost/benefit analyses of the implementation of the new practices and proposed job.

For the purposes of this research combined proposals of CHIM (2014) and Sanchez Reyes et al., (2013), which, in the future will continue being used in other production lines that have the same problems within the company's study.

4.1 phase 1: general survey of the line

It is important to know the company, their processes, workstations and staff who work in it. For this study, pictures of the processes, as well as videos of the production of each of the products shall be taken. Will be calculated production times to carry out a comparison between the current and established by the system. On the other hand also will take place the analysis of ergonomics of each operation by means of a format called ErgoCheck. This format is implemented in a visual way to detect the risks directly affecting operators. For the analysis of routes, operators offset distances shall be taken to produce different products. This survey is intended to detect serious problems of the Assembly line.

4.2 phase 2: analyzing the information for the detection and classification of risk

This analysis is based on the study conducted in phase 1. For every job or task, is required to identify the type of ergonomic risk present. Which, it is necessary to use methods of ergonomic assessment, depending on the conditions in the facilities found in the previous phase. The OCRA method, evaluates some groups of muscles such as: neck, shoulders, elbows, hands, wrists and fingers. This method will be taken by the repetitiveness of the operations and the characteristics of the same. This method will be applied using a software called IGEL, which will provide us with an accurate study and where we can classify the risks found in the Assembly line.

4.3 phase 3: make the redesign

For the preparation of the redesign will take place a thorough tour of the operations carried out in the Assembly, in addition to this line, it will continue the process flow as well as the distribution of machines and tools. Be interviewed informally operators to learn about their concerns and problems obtained in order to carry out its work. On the other hand, it will consult the opinion of the supervisor of the line which indicate that problems are identified in terms of costs, waste, diseases, etc. This information will be complemented by the results of phase 2 to do the redesign. In addition, you will be subject to the conditions of the Assembly according to costs and investments available line managers.

4.4 phase 4: implement the redesign

Implementation will take place according to the area that has been agreed by the management, and the benefits that each proposal, subject to installation costs. The implementation will be the participation of the engineers in charge of the area, as well as the supervisor and will be carried out by a company contracted to perform the installation. This company will be chosen according to budgets and choice of plant manager.

4.5 phase 5: evaluate the results.

Results will be evaluated using techniques that were conducted in the phase 1 and phase 2. Intends to conduct a

general study where, times, will again be taken to compare the two conditions (before and after). Intends to produce an analysis of travel, which will yield us the actual distances that operators run during working hours and in addition be conducted ergonomic analyses for the activities of the new design.

V. RESULTS

Photos of the line detected the following problems: excess of material raw material out of its location, area of finished goods away from the area of packaging material that can cause accidents by blocking part of corridors and misplaced material racks. In Figure 5.1, the current design of the production line is observed.

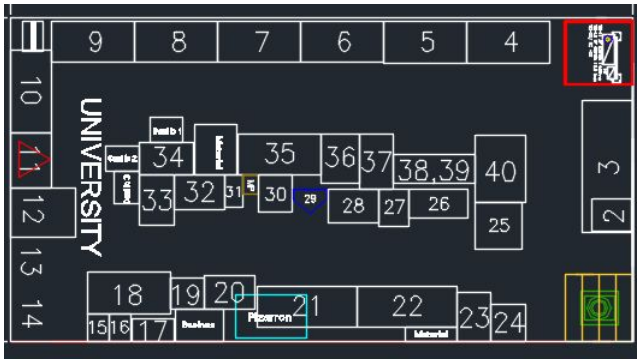

Figure 5.1. Current design. Source: Own elaboration

On the other hand, was the study of travel to know how much walking operators in a day of production. In table 5.1 we can observe the distance of tours per day of production

Part number	Current design Distance in meters.
A product	
A-1 product	76.5
Product A-2	49.0
Product B	72.3
Product C	62.0
Product D	63.3
Product E	30.0
Product F	79.1
G product	58.5

Table 5.1 analysis of distances travelled by product with modern design. Source: Own elaboration

Also through the ErgoCheck ergonomics studies were carried out and the results obtained were very unfavorable for workstations.

According to the findings in phase 1, by means of Visual activities, it was detected that there is a repetitiveness in the activities and the constant use of the hands, wrists, elbows, shoulders, neck, this has made the ergonomic study with IGEL software through the OCRA method and the following results were obtained:

4 purple color operations: the purple cells are awarded by applying too much force when performing the operation, also includes the Rotary movements of wrists or hands like bad posture of the neck.

26 red operations: the cells in red, are by movements of the arms above shoulders and rotating movements of wrists or hands.

21 operations of yellow: yellow cells, are by postures in which must take precautions.

3 operations of Green: green cells, are activities that do not have a health risk when performing the activity.

For the preparation of the redesign was carried out a thorough tour of the operations carried out in the Assembly as well as this line followed the process flow as well as the distribution of machines and tools. You were interviewed informally operators to learn about their concerns and problems obtained in order to carry out its work. On the other hand were consulted the opinion of the supervisor of the line which indicated us which problems are identified in terms of costs, waste, diseases, etc. and we took into account the results of the ergonomic study conducted in phase 2. The redesign was carried out using 2D AutoCad software and SolidWorks for 3D figure deployment 5.2 you can see the redesign in 2D and Figure 5.3 the redesign in 3D.

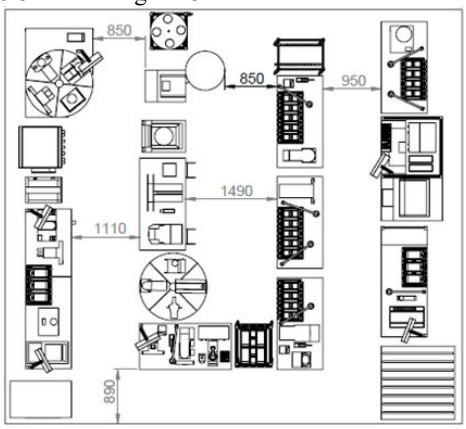

Figure 5.2. Redesign 2D

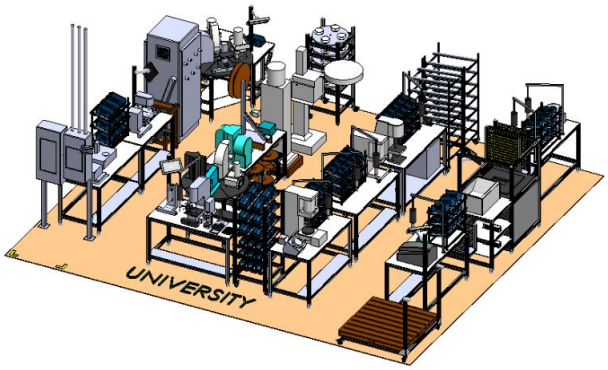

Figure 5.3. Redesign 3D

Benefits having up to this point are mainly reflected in a reduction of the physical area of the 48.54%; at the same time the proposed redesign is formed so that the flow is continuous for all products that are produced there and thus decrease distance traveled and time allowing daily production by programmers. On the other hand, the redesign was based on ergonomic approaches for reducing risks and accidents in the area. Similarly, table 5.2 Let us see the decrease in travel distances.

Part number	Current design Distance in meters.	Current design Distance in meters.
A product		
A-1 product	76.5	16.5
Product A-2	49.0	
Product B	72.3	19.2
Product C	62.0	17.2
Product D	63.3	20.2
Product E	30.0	20.1
Product F	79.1	17.6
G product	58.5	18.0

Table 5. 2 Comparison of analysis of distances travelled by two process designs product.

In this phase it was determined in which to install the new design line by management. The decision was taken into account according to the cost-benefit that is determined by the area of projects. Figure 5.4 shows the area where it was decided to install the redesign.

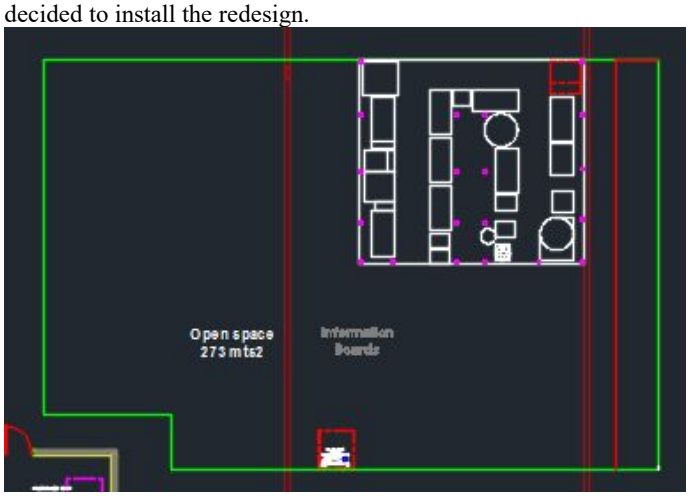

Figure 5.4 installation Area new design.

This area has a different temperature, is isolated from other lines by its high use of chemicals. After determining the area for the installation he was the determination of materials in new racks and in addition, was awarded a place and container to those materials that did not have one. The materials were organized according to the use and to the proximity of the station to which they are destined

CONCLUSIONS

Companies depend mainly on the work of operators, it is necessary to pay attention on the way in which the activities take place. This work helped to detect the red dots related to ergonomics and which in turn affect production processes. In the end this helped reduce accidents, injuries and costs associated with it. On the other hand, addressing the ergonomic issues improved flows of production processes by reducing time and waste, thereby increasing productivity. Always in all work, it is important to take into account both operators as to personnel working near processes such as supervisors and engineers in the area.

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