Ergonomic Analysis Of The Assembly Of Monoblock Pump

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Abstract

Workers suffer from fatigue and injury during long hours of monotonous work when proper workplace/working environment is absent. This may indirectly contribute to decreased productivity in an industry. Human factor issues arise in simple systems and consumer products as well. Hence the ergonomic principles have been widely used in the design of both consumer and industrial products. Past examples include screwdriver handles made with serrations to improve finger grip, by increasing the friction between the skin of the hand and the handle surface. One of the most prevalent types of work-related injuries are musculoskeletal disorders. Work-related musculoskeletal disorders (WRMDs) result in persistent pain, loss of functional capacity and work disability, but their initial diagnosis is difficult because they are mainly based on complaints of pain and other symptoms. Hence a proper workplace is to be designed to overcome the above issues or to reduce them considerably. Ergonomics and Anthropometric considerations are made to aid the cause. In this research, the designing of the workplace for the assembly of mono block pump is considered. The existing workplace is designed, complicated body postures are identified and the stress level at various parts of the worker's body is calculated. Based on the results, the improved design of the workplace is suggested.

Keywords*: Ergonomics, Anthropometry, Monoblock pump.*

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1. Introduction

Human factors and Ergonomics (HF&E) is a multidisciplinary field incorporating contributions from psychology, engineering, industrial design, graphic design, statistics, operations research and anthropometry. In essence it is the study of designing equipment and devices that fit the human body and its abilities. The International Ergonomics Association defines 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.

HF&E is employed to fulfill the goals of health, safety and productivity. It is relevant in the design of such things as safe furniture and easy-to-use interfaces to machines and equipment. Proper ergonomic design is necessary to prevent repetitive strain injuries and other musculoskeletal disorders, which can develop over time and can lead to long-term disability.

Human factor and ergonomics is concerned with the 'fit' between the user, equipment and their environments. It takes account of the user's capabilities and limitations in seeking to ensure that tasks, functions, information and the environment suit each user. To assess the fit between a person and the used technology, human factors specialists or ergonomists consider the job (activity) being done and the demands on the user; the equipment used (its size, shape, and how appropriate it is for the task), and the information used (how it is presented, accessed, and changed). Ergonomics draws on many disciplines in its study of humans and their environments.

1.1. Domains of ergonomics

According to the International Ergonomics Association , within the discipline of ergonomics there exist domains of specialization such as,

A. Physical ergonomics

It is concerned with human anatomy and some of the anthropometric and physiological characteristics as they relate to physical activity.

B. Cognitive ergonomics

It is concerned with mental processes, such as perception, memory, reasoning, and motor response, as they affect interactions among humans and other elements of a system. (Relevant topics include mental workload, decision-making, skilled performance, human-computer interaction, human reliability, work stress and training as these may relate to human-system and Human-Computer Interaction design.

C. Organizational ergonomics

It is concerned with the optimization of socio-technical systems, including their organizational structures, policies, and processes.(Relevant topics include communication, crew resource management, work design, design of working times, teamwork and quality management.

D. Environmental ergonomics

It is concerned with human interaction with the environment. The physical environment is characterized by climate, temperature, pressure, vibration, light etc.

1.2 Anthropometry

Anthropometry refers to the measurement of the human individual. It is the science that defines physical measures of a person's size, form, and functional capacities. Today, anthropometry plays an important role in industrial design, clothing design, ergonomics and architecture where statistical data about the distribution of body dimensions in the population are used to optimize products. Changes in life styles, nutrition and ethnic composition of populations lead to changes in the distribution of body dimensions (e.g. the obesity) and require regular updating of anthropometric data collections.

A basic philosophy in ergonomics is to design workstations that are comfortable, convenient and productive to work. Ideally, workstations should fit both the body and mind of the operator. Our research focuses only on the body, which certainly is easier of the two problems. It discusses about how the adjustability of chairs, stools, benches and task arrangements can help to accommodate people of different sizes. Using anthropometric design principles it is possible for a variety of people to find physical comfort at a work station.

2. Literature survey

Prior to 1980, the industrial application of ergonomics in the United States largely focused on defining physical capabilities of workers and physiological responses to various working conditions. Companies supporting these early ergonomic efforts, mainly through applied industrial research activities included E.I. DuPont de Nemours & Company and Eastman Kodak Company (Eastman Kodak Company, 1983).

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In 1987, OSHA (Occupational Safety and Health Administration in the United States) issued its first ergonomics directive that established regional ergonomics coordinators to provide technical assistance to OSHA area offices, mandated training for compliance staff, and directed compliance safety and health officers to consider ergonomic violations under what is known as the ''General Duty Clause''. The General Duty Clause requires an employer to ''furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employees''. Without a specific rule or regulation related to ergonomics, OSHA's compliance personnel used (and continue to use) this General Duty Clause to develop ergonomics related citations—often leading to the development of settlement agreements that involved the development of an ergonomics program. In addition to the efforts in the area of compliance, the late 1980s and early 1990s saw OSHA involved in the development of ergonomics assistance materials to help industry deal with the growing problem of work related musculoskeletal disorders.

OSHA (1990) published the Ergonomics Program Management Guidelines for Meatpacking Plants, which defined basic elements of formal ergonomics programs, and served as a template for the meatpacking industry, as well as general industry. Since then, several case studies of ergonomics programs in other industries located in the United

States and other countries have been published. Industries identified in these reports included the beverage, cosmetic, telecommunications, electronics, financial planning, automotive, light manufacturing (abrasive products and shoes), health care, utilities and food industries, as well as office environments (Gauf, 1995; US Government Accounting Office, 1997; Perry, 1997; Hignett, 2001; Munck-Ulfsfa¨ et al., 2003; Butler, 2003; Smyth, 2003; Joseph, 2003; Moreau, 2003). These case studies generally demonstrated effectiveness with pre- and post implementation data, such as reductions in injury rates, compensation costs, work days lost, etc.

Despite the numerous reports of ergonomics programs in a variety of industries, there are no reports of implementing an ergonomics program in the assembly of monoblock pumps. The assembly environments pose challenges to implement the ergonomics principles.

3. Motivation and approach

As seen from the above literature review, one of the important considerations to be given in today's industries is the physical comfort of the worker in his/her working environment which indirectly leads to growth of the industry and in such a scenario, ergonomics plays a vital role. One important cause for undertaking this project is that there is no aid for conducting ergonomic analysis for the people relating to Indian origin as some software packages like CATIA, PRO-E, etc., provides support to perform ergonomic analysis for the people relating to a different origin (like Canadian but not Indian). Hence, the anthropometric data relating to Indian origin is to be fed into the software and then analysis is to be done. Thus, the project is divided into three phases of work.

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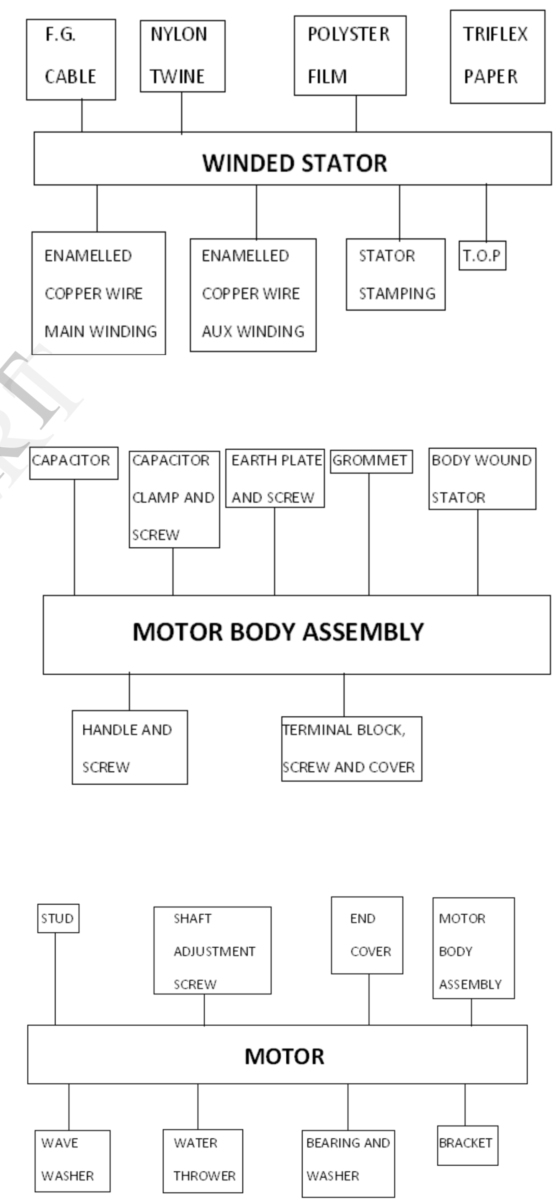
The first phase involves visiting mono block pump industries and getting to know the assembly process. The second phase of this project aims at designing the existing workplace for the assembly of mono block pump using CATIA software. The third and final phase involves ergonomic analysis of the existing workplace and to provide suggestions for improvement in working conditions of the assembly of mono block pump.

3.1. Discomfort survey

A number of pump manufacturing industries have been visited in order to get a clear view regarding the assembly of mono block pump. The age group of the employees was in the range of 26 to 37 years, experience of 3 to 8 years with working time of 7 hours per day. The discomfort survey was conducted. The areas where the employees had pain while assembling the components included elbows, wrists, hands, neck, limbs, knee joints, shoulders, upper and lower back.

4. Stages in mono block pump assembly

The details of various stages involved in the mono block pump assembly, represented by the fishbone diagram is given below.



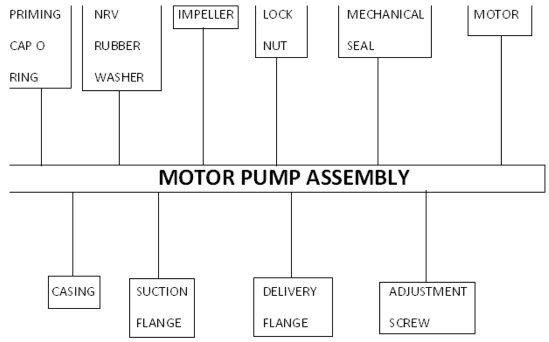


Figure 1.Stages in assembly of mono block pump

5. Anthropometric data collection procedure

The procedure for collecting the necessary anthropometric data needed a great care. The user population has to be characterized. The available anthropometric data was collected and also verification of the existing anthropometric data to check whether it can be used with the present population was done. If there were no valid data, creation of a database by obtaining measures of the existing workforce was considered. The percentile range to be accommodated in the workstation design was determined. The workforce was dominated by men in our case hence it would make sense to design for the predominant gender. Let the small person reach and let the large person fit. The reach dimensions (5th percentile) and clearance dimensions (95th percentile) for the work situation was determined. It is sometimes difficult to illustrate a work situation using an anthropometric model. Anthropometric measures are static, and in the real world there are many dynamic elements.

5.1. Anthropometric measurements

The following table provides the anthropometric measurements relating to workers of Indian origin that are to be used in creating the manikin using CATIA software.

Table 1.Anthropometric Measurements

S.NO	DESCRIPTION	VALUE (cm)
1	Elbow height	107.5
2	Knuckle height	78.4
3	Shoulder height	145.8
4	Stature	165.6
5	Functional forward reach	82.5
6	Thigh clearance	45.2
7	Sitting elbow height	35.3
8	Sitting eye height	79.6
9	Sitting height	91.2
10	Elbow to elbow breadth	40.7

6. RULA analysis

The Rapid Upper Limb Assessment (RULA) provides an analysis of the manikin's upper limbs based on variables such as weight, distance and frequency. It is used to analyze many facets of manikin posture based on a combination of automatically detected variables and user data. Using data derived from the RULA equations, this analysis considers multiple variables such as object weight, lifting distance, lowering distance, task frequency and action duration. It gives the option of adding task-specific variables such as whether the manikin is externally supported, if the manikin's arms are working across the midline of the body during a task, and whether the manikin's feet are balanced and well supported. This analysis creates a summarized report of the task and provides a quantified set of results noting whether the task and posture are acceptable or it should be investigated further or it should be investigated further but changed soon or should be investigated further but changed immediately. Hence, with the RULA Analysis we can optimize manikin posture in the context of a manual task and therefore design better, and more widely accepted, products and workplaces.

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6.1. Interpretation of results of RULA analysis

The RULA analysis examines the risk factors like the number of movements, static muscle work, force, working posture, and time worked without a break. All these factors combine to provide a final score that ranges from 1 to 7. The data displayed in this mode is the final score accompanied by a colored zone. The color of this zone changes from green to red according to the final score. The score report consists of two modes namely basic mode and advanced mode.

In the basic mode, the scores 1 and 2 (Green color) indicates that the posture is acceptable if it is not maintained or repeated for long periods of time. The scores 3 and 4 (Yellow color) indicates that further investigation is needed and changes may be required. The scores 5 and 6 (Orange color) indicates that investigation and changes are required soon. The score 7 (Red color) indicates that investigation and changes are required immediately. The score indication of advanced mode for different body parts is given below.

Table 2.The score indication of advanced mode

Segment	Score Range	Color associated to the score					
		1	2	3	4	5	6
Upper arm	1 to 6	Green	Green	Yellow	Yellow	Red	Red
Forearm	1 to 3	Green	Yellow	Red	Grey	Grey	Grey
Wrist	1 to 4	Green	Yellow	Orange	Red	Grey	Grey
Wrist twist	1 to 2	Green	Red	Grey	Grey	Grey	Grey
Neck	1 to 6	Green	Green	Yellow	Yellow	Red	Red
Trunk	1 to 6	Green	Green	Yellow	Yellow	Red	Red

7. Ergonomic analysis of existing workplace

The assembly process involving some of the complicated postures of the worker was identified and designed using CATIA software for ergonomic analysis. The manikin was created using the anthropometric measurements that have been taken.

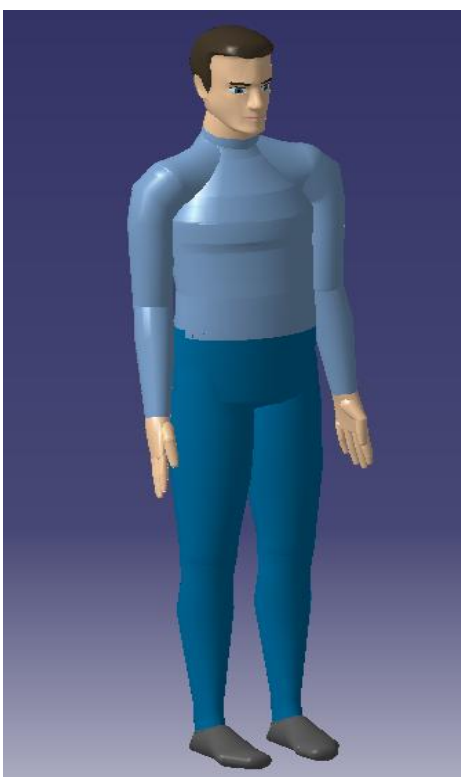

Figure 2.Manikin created using CATIA software

7.1. Existing workplace

The following image shows the existing workplace with worker in front of the assembly table (on the left) and the packing area (right).

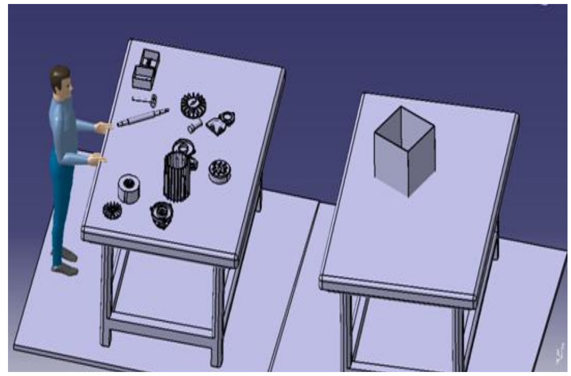

Figure 3.Existing workplace

The RULA analysis for different body postures while assembling the components is given below. The RULA analysis for the posture of manikin while picking up Motor body shows a final score of '7' indicating the need for immediate changes.

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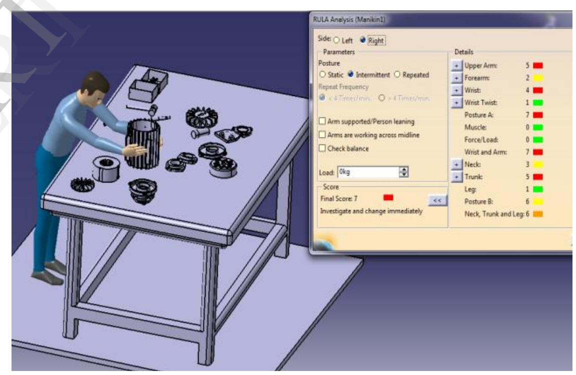

Figure 4.RULA Analysis for picking up the motor body

7.2. Reach envelope

A reach envelope is a surface that represents all the possible positions the manikin can reach using only the arm and forearm. We can create two reach envelopes; one for the right hand and other for left hand. The reach will also be influenced by the arm's angular limitations and preferred angles. The reach envelope representing the comfort zone for the given task is shown in the figure 5 and 6.

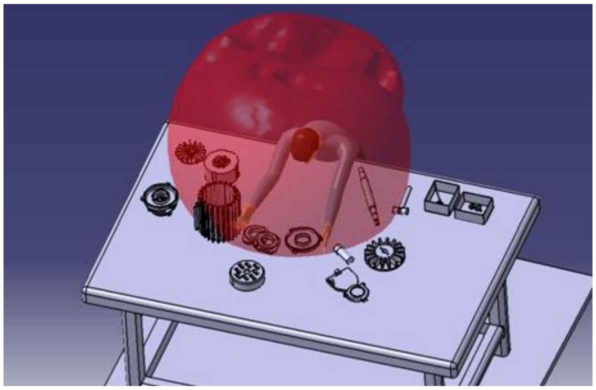

Figure 5.Reach envelope of right hand

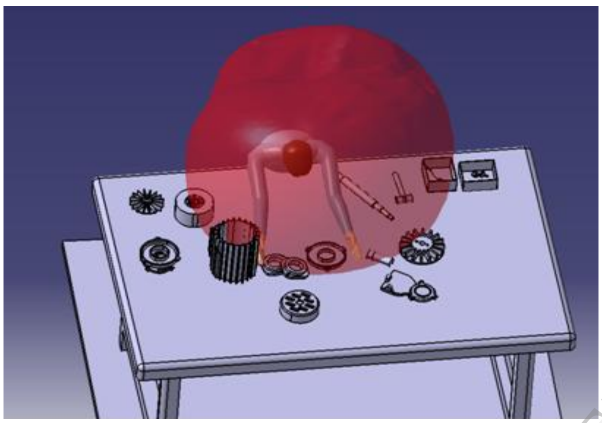

Figure 6.Reach envelope of left hand

7.3. Fixing of capacitor clamp

The figure shows the capacitor clamp being screwed into the motor body. The RULA analysis for the posture gives the score of '7' for both hands. The analysis is done in 'Repeated' mode i.e. the action is performed more than 4 times a minute.

Figure 7.Fixing the capacitor clamp

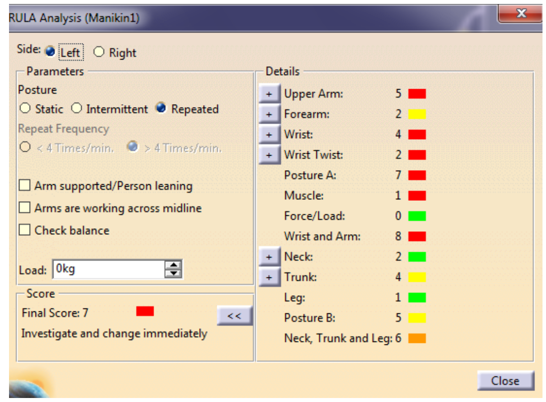

Figure 7.1.RULA analysis of left side

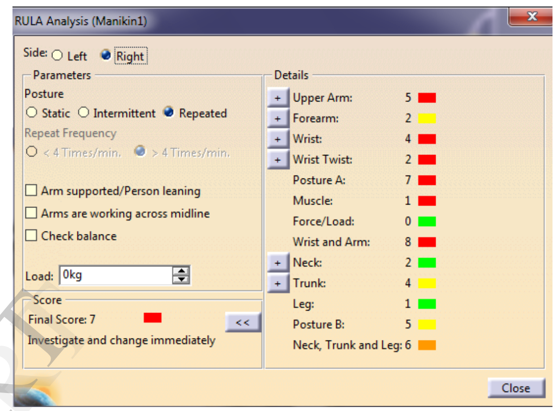

Figure 7.2.RULA analysis of right side

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7.4. Moving the assembled component to packing area

The figure shows the worker carrying the assembled pump from the assembly section to the packing area manually. The RULA analysis gives the score of '7' as the worker carries the pump which weighs around 5 kg, intermittently the whole day.

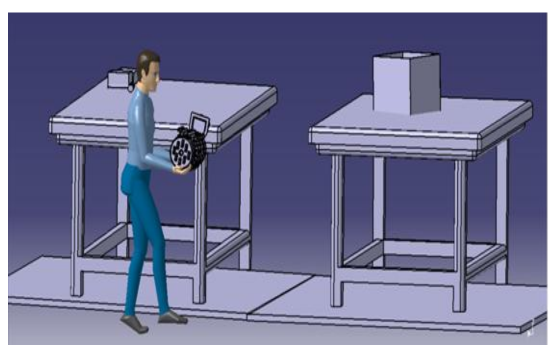

Figure 8.Moving the assembled pump to the packing section

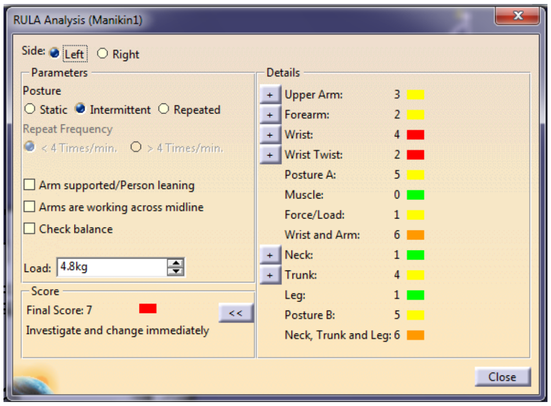

Figure 8.1.RULA analysis of left side

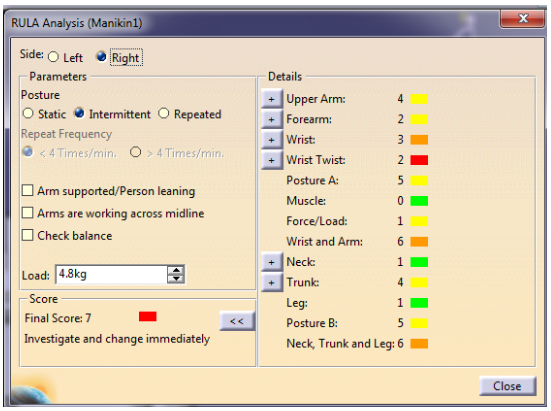

Figure 8.2.RULA analysis of right side

8. Results and discussions

As seen from the results of the RULA analysis, it is clear that some investigation and changes should be made to the existing workplace in order to save the worker from musculoskeletal disorders. Some possible modifications that can be made efficiently are as follows.

The dimension of the worktable can be changed so that it suits the worker of 5th percentile. As the workers of 5th percentile can work effectively in the worktable, it automatically suits the workers with 95th percentile easily. Some identification marks are made on the worktable indicating the maximum reach envelope of the worker so that the worker can lift the components with ease as all the components lie within the functional forward reach of the worker. A manually operated roller conveyor can be used to carry the assembled pump to the packing section. This eliminates the stress acting on both sides of the worker. The conceptual improved design with the reach envelope and with attached conveyor is shown in the figure 9.

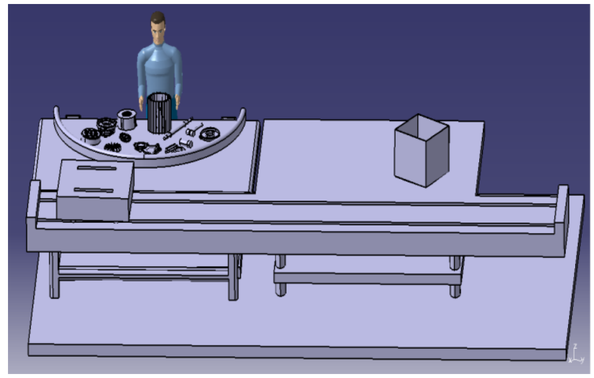

Figure 9.The conceptual improved design

9. Conclusion

The above improved design is one preferable case though there may be variety of solutions to the problem depending upon the economic conditions of the industry. For further improvements, the use of a hydraulic press for fixing of stator, use of screw gun to screw the capacitor clamp, use of the automatic conveyor to move the pump to the packing section can be done. Although the initial investments may be high, it would lead to better working environment for the shop floor employees thereby improving the efficiency of the assembly process.

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