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Implementation of Digital Human Modeling (DHM) and Virtual Ergonomics (VE) for safer Agricultural Activities in India: Case Studies

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ABSTRACT

Ergonomics is an inherent part of product design. Involving ergonomics in workplace improves operator efficiency, reduces operating fatigue and improves productivity. Role of product designers has increased tremendous not only in developing successful functional products but also in addressing the ergonomical issues during its usage. Though many manual methods of ergonomic assessment tools are available, it is noticed that the use of modern CAD tools like DHM and VE workbenches have drastically reduced the development time without compromising the human factors in design. The present study is focused on the application of DHM and VE in the Indian agricultural environment as it enhances the human machine interface by providing platform for safer and effective design of tools and equipments. Some case studies related to the implementation of DHM and VE in agricultural fields have been summarized to appreciate its role in successful product development.
Agriculture is an important sector which plays a vital role in the development of Indian economy. Nearly 60% of the rural population is involved in the farming activity contributing approximately 16% GDP of the nation. In spite of its enormous contribution, agricultural sector is still considered as the most hazardous workplace leading to increased number of agricultural accidents. One of the reasons for this is poor involvement of human factors in design and use of traditional tools, methods for the farming activities thus leading to work related injuries. The advancement in CAD and its implementation in ergonomics give greater benefits for the designers and manufacturers to address this issue. Digital Human Modeling (DHM) and Virtual Ergonomic (VE) tools can be effectively used for the design of agricultural tools and equipments by providing comfortable working environment to the workers engaged in agriculture thus reducing Musculoskeletal Disorders (MSDs).

Keywords: *Agriculture, Ergonomics, Digital Human Modeling, Virtual Ergonomics, Musculoskeletal Disorders.*

1. INTRODUCTION

Agricultural sector is the main backbone of Indian economy; contributing approximately 16% of GDP and involving around 60% of the rural population. Though a large amount of population is involved in agricultural working segment, the attention towards the design of healthy farming environment is seldom noticed [1]. It is also observed that the working in agricultural field is considerably different when compared with working in private firms as the operational environment, tools and implements used, atmospheric conditions differ [2]. The unhealthy working culture, use of traditional non-human centric approaches in farming resulted in high rates of work related injuries. Human factors and its application in design is the key to a successful product in consumer market scenario. This is true even in agricultural working situations where the farmer is in continues interaction with tools, equipments and machinery. They are facing serious health issues due to poor socioeconomic conditions and less awareness towards safety aspects. The study related to the failure of most of the products in consumer market is observed to be the ergonomic mismatch between the user and the machine or the working environment

Ergonomics

Ergonomics is originated from two Greek words ‘ergon’ meaning work and ‘nomos’ meaning the law. It is the science related to human and their working environment. Ergonomics is the process of designing the workplace, products or systems to fit the person who uses them instead of fitting the person to the existing design of workplace, products or systems. Consideration of human factors in product or process design improves operator comfort, higher efficiency, increases productivity, decreases work related injuries and operator fatigue [4]. Though the effect of

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ergonomics is well known in various sectors, their implementation in the human centric environment is still at a lower level.

Ergonomics in agriculture

Agriculture is one of the most harmful working areas involving labor- intensive activities and displays high rates of musculoskeletal disorders (MSDs) in most of the countries [5]. The causes of MSDs in agriculture is result of heavy burden, repetitive motion, awkward working postures, long time working in sitting conditions and use of non ergonomically designed traditional tools and implements. Commonly observed MSDs in agricultural workers are tendinitis, bursitis, carpal tunnel syndrome and back pain as shown in Fig (1). These affect the body muscles, joints, tendons, ligaments, discs, nerves, etc [6]. Farmers play a major role in agricultural activities and an appropriate attention is needed to consider their abilities and limitations in the design of farm implements in achieving higher productivity, enhanced comfort and safety.

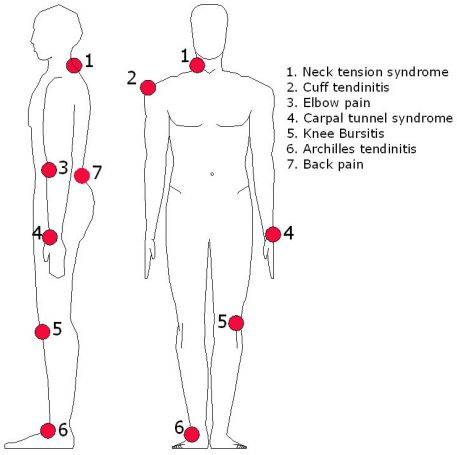

Fig (1) Commonly observed MSDs in agricultural workers

Ergonomics Assessment tools

Ergonomic risk factors involved in working environment can be measured by using various assessment tools to determine the worker's capabilities and limitations [7]. However in most cases the risk factors are gathered by

1. Self evaluation: The data is gathered by exposing to the real physical environment and recording it in the dairies, direct interviewing the person involved in activity or by using questionnaires.
2. Observations: Observing the physical task through pictures or videos and noting the working posture to assess the risk involved in job. Further the same thing can be achieved by community based studies.
3. Direct Measurement: The work related risks can be measured directly by using some of the scientifically proven assessment tools like RULA, REBA, NIOSH lifting equation, Snooks tables etc. Standard assessment worksheets or tables are used to evaluate the working posture during each operations or activities.

2. Virtual Ergonomics

Interaction of human with product, workplace or system in complex environment is difficult to predict. In earlier periods this was usually achieved through perception or using some thumb rule done by expert ergonomist. The advances in CAD systems and its enormous capabilities in the ergonomics have drastically changed the study related to man-machine environment [8]. Modern CAD has the ability to construct Digital Humans typically known as manikins and able to perform various virtual ergonomic analysis based on human working postures, human loadings,

and repetitive motions during working. These capabilities give greater flexibilities to the designers to consider human factors to design and develop human centric products [9]. The technologies also help the designers to simulate the human working environments and ergonomic performance between the human with the product or system in use like evaluating visibility, maximum reach, posture stress and fatigue etc [10]. Virtual ergonomics can be effectively and successfully utilized in workspace design, aerospace, automotive, product design and its utilization, healthcare design, fabrication and assembly processes, etc as shown in Fig (2).

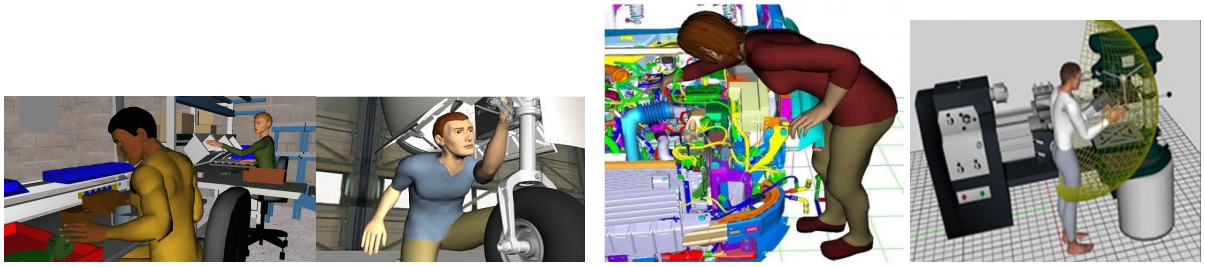

Fig (2) Application of Virtual Ergonomics

Ergonomics Assessment tools in Virtual Environment

Various virtual ergonomics assessment tools to evaluate man machine environment such as reach and fit checking, visibility, posture stress and fatigue, static and dynamic loadings are

1. Jack
2. SAFEWORK
3. ENVISION/ERGO
4. eMHuman
5. ERGOman
6. Delmia
7. Ramsis
8. ManneQuinPRO

These soft tools allow the designers to construct and analyze the complex computer 3D models and their use by the user in virtual environment. They give flexibility to the designers to simulate the real-time working conditions and study the man-machine behaviors in complex environments.

3. Case Study

The concept of Virtual ergonomics also has its wide application and impact in the agricultural scenario. The technology improves the overall performance in farming and its related fields. Some of the case studies are discussed in brief where the VE and DHM are utilized in the areas of agriculture are discussed below.

1. Ergonomic Assessment of Traditional Weeding Tools Usage using DHM and VE.

Weed growth is a major problem for both dry and wet land crops causing a significant lower crop yield [11]. In northern Karnataka most of the farmers having small holdings use the traditional tools for the weeding process. The commonly used tools are sickle, hoe, manual/animal driven weeders, manual tiller, etc. It requires enormous amount of labour force to perform the work. Postures adopted while performing these weeding tasks were mainly awkward in nature. Most commonly used traditional weeding methods in this region and their frequently practiced posture were observed. DHM and VE tools were used to analyze the working of various weeding postures using RULA ergonomic assessment tool in CATIA Ergonomics Human Posture analysis workbench. The results of analysis is

further used to suggest the improvements in working postures to reduce work related injuries and hence improve operator working comfort. Fig (3) illustrated below shows the harmful working posture during sickle usage in weeding operation.

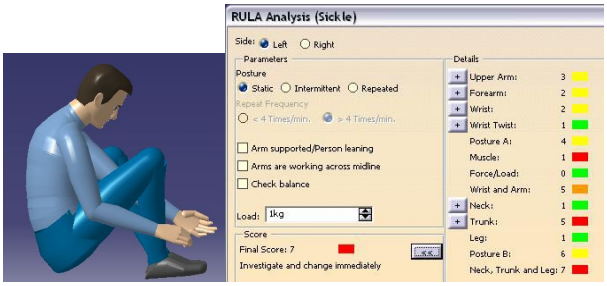

Fig (3) *VE analysis of posture and its RULA result*

Based on the virtual ergonomic assessment of these weed removal postures, which result in work related injuries many action-plans were suggested to the farmers. Some suggested action-plans are:

1. Prolonged squatting position should be avoided during weeding operation. This posture eventually results in musculoskeletal injuries. An adjustable stool of proper height is recommended to use during the sickle weeding process.
2. A regular halt of 10-15 minutes is necessary after every 15-20 minutes of weeding process.
3. Avoid sitting in the same position for more than 20minutes.
4. During dry-land and animal driven weeding process distribute body weight evenly on both hips.
5. Handles of the tools should be covered with smooth materials either plastic or rubber to avoid tools slipping from hands while weeding.

2. Analysis of maize seed sowing posture and minimization of MSDs using DHM and VE.

Maize is the third largest grown food cash crops in the world and India is the fifth largest producer of this cereal crop [12]. It shares nearly 9% in the national food basket. Maize serves as food for human, important animal feed, basic material for various products like oil, protein, food industries, textile, poultry feeds, papers industries, pharmaceutical, food sweeteners, etc. In Karnataka there is an increasing inclination towards the growth and cultivation of maize. It is the widely farming cash crop which is grown in all the three seasons of the year.

The basic working body posture during the maize seed sowing activity is studied and analyzed during the study. The examination is carried out on the farmers having small holdings and who basically use traditional method of seed sowing like manual sit-bend hand sowing Fig(4), walk-bend hand sowing Fig (5). The objective of the study was to determine the unsafe posture level in the above two sowing methods and to design hand operated simple sowing equipment for such formers to ease the sowing method and to reduce the work related injuries.

The body working postures were captures by manual posture measurements and were virtually built and analyzed for their effect on the body parts.

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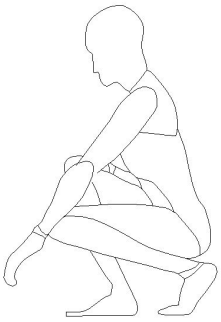


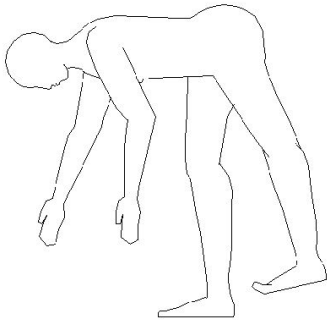
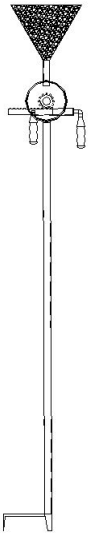


Fig (4) *Sit-bend hand sowing* *Fig* ***(5)*** *Walk-bend hand sowing*

From the ergonomic analysis using Computer Aided Ergonomics (VE and DHM) it was found that these two methods of manual hand operated sowing methods are risky for the formers and they develop work related injuries after some period of continuous working. The MSDs likely to develop are lower back pain, neck tension syndrome, knee bursitis and cuff tendinitis.

To reduce the effect of injuries because of these postures, a hand operated seed sowing equipment is developed Fig (6). The equipment is designed such that the farmer can sow the seed without bending forward or sitting. It can be used in standing posture and walking forward in the field to sow the seed in a row. The mechanism of the equipment delivers one seed at a time from the hopper by operating the lever provided to it Fig (7). As the equipment is handy and light weight, it can be operated easily in walking posture thus reducing the fatigue during sowing process and increasing the working comfort.



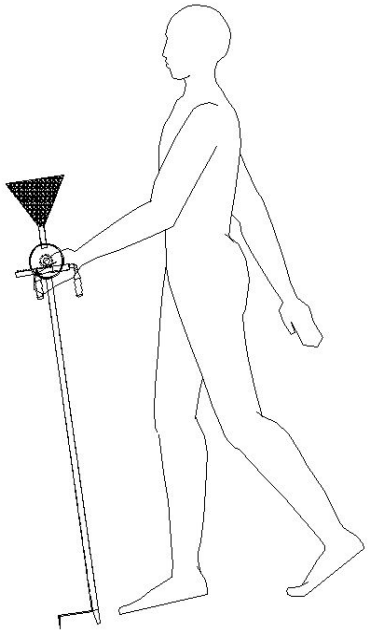


Fig (6) ***Fig (7) Equipment usage posture***

4. Conclusion

Agricultural sector is the reason for the development of country's economical status ensuring the food security to its society. In spite of its enormous contribution to the growth of country, it is still considered to be the hazardous

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working place. Large amount of land fragmentation and increase in the number of small holdings has resulted in the reduction of farming land per farmer. The farmers having small holdings still adopt the traditional approach of farming process as adaptation of mechanization is uneconomical. The development of modern CAD and its application in ergonomics has tremendous impact on the improvement in agricultural activities and ensuring the safe working environment and increasing agricultural productivity. DHM and VE tools are the platform for addressing these issues at faster pace. Product designers involving in the development of agricultural tools and implements should make use of these soft tools effectively to build the human centric agricultural environment to reduce the MSDs.

The investigations performed using DHM and VE on the above mentioned case studies in agricultural sector showed that these innovative tools successfully can be used in improving the safety in man-machine-workplace designs. The body postures of farmers can be tested and investigated thoroughly from various aspects so as to ensure the comfort of users.

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