Design And Simulation Of DPM & Ergonomic Analysis In Automated Deburring Section

Abstract – Digital Process Manufacturing (DPM) is applied in this virtual proposal to verify the viability of conversion of manual deburring process to automatic, using articulated robots. As an advanced stage, simulation technology is applied in the DPM concept to enhance the accuracy and precision in the deburring process also the errors and rejection of the component could be reduced.

Currently the work is being carried out manually in the existing deburring section of the industry, which involves high human labor, high human body Musculoskeletal Disorders (MSD) and also results in routine economic investments. Postural analysis tool using Rapid Upper Limb Assessment (RULA) is applied for assessment which indicates that the workers are working within the secure limit of the MSD. So, by automating this section using robots, the high human labor is reduced and also the virtual ergonomic analysis carried out in software reduces the human MSD and direct implementation economy wastage.

Index Terms – Anthropometry, CATIA, DELMIA, DPM, MSD, Postural Analysis, RULA

I. INTRODUCTION

For productivity improvement in manufacturing industries, industrial automation and efficiency of worker plays an important role. Initially the purpose of automation was to increase productivity, since automated systems can work uninterrupted for 24 hours a day, and to reduce the cost associated with human operators (i.e. wages & benefits). However, in this project the focus of automation is extended to increasing quality and flexibility in deburring process. Productivity of worker greatly depends upon ergonomic design of workstation. Efficient ergonomics in workstation design shows better interaction between man-machine systems. Lot of research has been done on analyzing, implementing automation solution, improving ergonomics of workstation, facility layout and tool & fixture design. Workstation may function with less efficiency, if anthropometry data mismatches with workstation design. Effect of workstation design, process design, fixture design and working postures on operation shows industrial automation have most significant effect on the deburring process. Study of discomfort experienced by operators during process has been studied and analysis of working postures has been done in DELMIA V5 software to find out awkward postures.

The study is conducted on existing manual deburring operation cell which has large human labour and high cycle time. Objective of this study includes performance evaluation of workers during deburring process. In primary phase study regarding workstation layout, process design been carried out. Further motion study is done for the articulated robot and human ergonomic study by capturing motion film of automated deburring process in DELMIA software itself. Robot motion for each position of the robot was analyzed for each motion element of worker’s body postures and movement of other body members. Results of human simulation revealed various fatigue causing and time consuming factors related to worker and workstation layout.

II. LITERATURE REVIEW

A. Digital Process Manufacturing

A series of research works have already been done on the DPM process, the available literature reveals that DPM is the use of an integrated, computer-based system comprised of simulation, three-dimensional (3D) visualization, analytics and various collaboration tools to create product and manufacturing process definitions simultaneously. Many of the long-term benefits from product lifecycle management (PLM) cannot be achieved without a comprehensive digital manufacturing strategy. Wolfgang Kühn proposed a work on Digital Factory – Simulation Enhancing the Product and Production Engineering Process which emphasizes that the digital factory concept offers an integrated approach to enhance the product and production engineering processes and simulation is a key technology within this concept. Different types of simulation, such as discrete event or 3D motion simulation can be applied in virtual models on various planning levels and stages to improve the product and process planning on all levels. The focus and key factor is the integration of the various planning and simulation processes. In an advanced stage simulation technology can be applied in the digital factory concept to enhance the operative production planning and control as an integrated process from the top level to the factory floor control.

B. Ergonomic Analysis

Based on the work of Mr. Gurunath V Shindle Ergonomics plays an important role in workers’ productivity. Workstation layout and work design are two major factors of ergonomics of worker’s efficiency. Now, manufacturers found that instead of investing lots of money on man, machine, material, method (4m), improving ergonomics of workplaces is cost saving. Ergonomics found great need when market demand is high and manufacturers need more output within short period. His study was conducted on assembly workstation of welding shop. Ergonomic study of
this assembly workstation was done by using motion study. Observations were made by studying each element of motion film recorded by video recorder. Results from this study reveal that there is need to modify workstation layout according to ergonomic principles.

C. Anthropometric Dimensions
The anthropometric dimensions of the Indian Man were inculcated from the work of Chakrabarti, D.,1997: Indian Anthropometric Dimensions for Ergonomic Design Practice which focuses that the compiled data (with relevant descriptions of population) forms in the sequence of illustrative anthropometric terminology and illustrative measurement land marks, brief of dimensions! measurements descriptions with the respective measurement and the data table. Dimensional reference numbers as 'R. No.' landmarks) are presented herewith as INDIAN shown in illustrations and referred both in definitions and in ANTHROPOMETRIC DIMENSIONS separately for data tables simultaneously. All dimensions (except body Males, Females and Combined (males and females weight in Kg) are in millimeters (mm). both considering a single study

D. Rapid Upper Limb Assessment
The ergonomic analysis is based on the working postures of the human in the shop floor. The analysis method used is RULA analysis since in this proposed work the man works with a maximum stress in his upper body portion with the mid line on his arms. Hence the work Ergonomic Evaluation of Industrial Tasks in Indian Electronics Industries proposed by Tarwinder Singh is added as a reference for the analysis which states that Rapid Upper Limb Assessment (RULA) is used for ergonomic investigations of workplaces where work related injuries are reported. RULA is a simple diagnostic tool that allows surveying various tasks involving the upper limbs at workplace with focuses on use of arms, wrists, position of the head and the posture of the upper body. Mc Atamney and Corlett (1993) introduce RULA, or Rapid Upper Limb Assessment. It is developed to observe the operators who suffered upper limb disorders due to the musculoskeletal loading. The RULA is used without need for advanced and expensive equipment that’s why it is one of the most popular ergonomic investigation tools in industry.

E. Fixture Design
The fixture required for this proposed work was designed with reference to the work done by Dr.Yadavalli Basavaraj in Modeling and Analysis of Support Pin for Brake Spider Fixture by Fem Using Ansys Software in which he states that A fixture is designed and built to hold, support and locate every component to ensure that each is drilled or machined with accuracy and manufactured individually. A fixture can be designed for a particular job. A brake spider includes a spider body with a central opening and a slot for receiving a camshaft and bracket assembly. The brake spider is attached to axle housing via the central opening. The form to be used depends on the shape and requirement of the work piece to be machined. In the existing fixture, used for modeling brake spider component, only five components were machined per hour. In the present work, detailed study of brake spider component is carried out and design is modified to increase the productivity. The new fixture design is carried out by using CATIA V5 modeling software and it is critically evaluated for the failure of support pin component, by finite element method (FEM) using ANSYS software. This modified design is adapted in the fabrication of fixture and is tested for its productivity. It is found that there is a considerable enhancement in the productivity to seven components per hour with required accuracy

F. Industrial Automation
The design and analysis approach of the articulated robots in the DPM simulation is done with reference to the base work of S.Pachaiyappan in the field of Design And Analysis Of An Articulated Robot Arm For Various Industrial Applications. His work is based on design & analysis of a Generic articulated robot Arm. Articulated robot has been noted for application in traversing and performing manipulation in nuclear reactor facilities. Some aspects of the articulated Robot that are anticipated as useful are its small cross section and its projected ability to change elevation and maneuver over obstacle. The small cross section and the loads associated with suspension of the Robot while changing elevation or maneuvering over obstacles require large joint torque to weight rations for joint actuation. A novel joint actions actuation scheme is described and its implementation detailed in this project.
2. Ergonomic Simulation

B. DPM Simulation
• The available area for the automation layout was measured manually from the existing work cell.
• Then the virtual work environment was developed with the robotic work cell environment using CATIA V5R20 Software.
• All robotic safety accessories such as fence, controller, pedestal, Fork lift layout base were modeled in 3D using CATIA V5R20 Software.

C. Ergonomic Analysis
• The main tool used for the Human ergonomic analysis was DELMIA V5R20.
• There 4 main modules in this software as follows, that are used to perform ergonomic analysis.
  a) Human Measurements Editor
  b) Human Task Simulation
  c) Human Activity Analysis
  d) Human Posture Analysis
• In this proposed work, the ergonomic analysis is performed on 50th percentile male of Indian Anthropometric Dimensions.
• The manikin is created in the Human Measurements Editor module and the dimensions are modified to Indian Anthropometry.
• Then the manikin is simulated for his activity such as pick, place, walk, climb up & climb down stairs in the Human Activity Analysis module.
• This created human activity are then merged with human postures like bending, twisting, stretching, etc., in Human Postural Analysis module.
• Finally, the created human activity and the postures are simulated in the Human Task Simulation module for the identification of the following.
  a) RULA Score of each posture of manikin
  b) Reach Envelope analysis of the manikin
  c) Job Hazard Score analysis of the manikin.

V. RULA SCORE CALCULATION

A. Description
The RULA Score, Reach Envelope analysis and the Vision analysis of the manikin was performed in this proposed work cell using the DELMIA V5R20 Software.

B. RULA Analysis

<table>
<thead>
<tr>
<th>POSTURE</th>
<th>RULA SCORE</th>
<th>JOB HAZARD SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>3</td>
<td>11</td>
</tr>
</tbody>
</table>

Fig. 4 – Rula Score for PICK operation.
### C. Reach Envelope Analysis

In this analysis, the manikin is analyzed for his distance of access from his position to the component and accessories in the layout. The aspects like easy reach, reach path with no obstacles are the main consideration.

<table>
<thead>
<tr>
<th>REACH POSTURE</th>
<th>REACH VALUE</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>18 cm</td>
<td>Normal</td>
</tr>
<tr>
<td>2</td>
<td>23 cm</td>
<td>Normal</td>
</tr>
</tbody>
</table>

![Reach Envelope Analysis](image)

### D. Vision Analysis

This is a software analysis method using DEIMIA V5R20.

In this method, the vision window of the manikin with a binocular vision is used to avoid the obstacles in the work envelope.

<table>
<thead>
<tr>
<th>VISION</th>
<th>OBSTACLES</th>
<th>REMEDY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nil</td>
<td>Nil</td>
<td></td>
</tr>
</tbody>
</table>

![Vision Analysis](image)

### VI. JOB HAZARD SCORE CALCULATION

#### A. Description

The Job Hazard Score was calculated for both the existing and the proposed cell using the below procedures.

#### B. Procedure

1. First step is to calculate the Transfer brief score of the human labor for different parts of the body such as,
   a) Left & Right hand
   b) Left & Right wrist
   c) Left & Right Elbow
   d) Left & Right Shoulder
   e) Neck
   f) Back
   g) Legs

<table>
<thead>
<tr>
<th>Transfer BRIEF Scores</th>
<th>Hands and Wrists</th>
<th>Elbows</th>
<th>Shoulders</th>
<th>Neck</th>
<th>Back</th>
<th>Legs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left</td>
<td>Right</td>
<td>Left</td>
<td>Right</td>
<td>Left</td>
<td>Right</td>
<td>Neck</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

![Transfer score table](image)

2. Then the corresponding conversion factor for each Transfer score is replaced for each above-mentioned part of the body the data table below.

<table>
<thead>
<tr>
<th>Determine Conversion Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Find each BRIEF Score in the table at right and determine the conversion</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BRIEF Score</th>
<th>Conv. Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

![Conversion Factor replacement table](image)

3. The cumulative conversion factor for the Transfer score is calculated by summing the above replaced values.
4. Then the physical stress based on transfer score is determined for the following stresses, a) Vibration 
b) Low Temperature 
c) Soft Tissue compression 
d) Impact stress 
e) Glove issues.
The value for the physical stress is the determined by substituting a value of 2 for all stresses mentioned above. In case of absence of that stress the value is substituted to be 0.

5. The cumulative physical stress value is calculated.

6. Calculate Job risk factor is the sum of Cumulative Physical stress and Cumulative Conversion factor.

7. The time exposure multiplier is the Job Hazard score to be determined, it is calculated by multiplying the Job Risk Factor with the Multiplier factor from the below data table based on the working time of operation per week.

8. The Standard Hazard Score table is used to identify the fatigue issues in the work posture.

VII. FIXTURE DESIGN

A. Description
Initially the components were hand held and the operation was carried over with the component in hands. For this automation work cell the job cannot be hand held, hence a fixture was designed using CATIA V5R20 software, that can hold two components simultaneously, the components are held up in the fixture by the Toggle clamp mechanism.
The fixture is designed in such a way with POKA YOKE which helps even the unskilled labour to work with full efficiency.
CONCLUSION

Simulation is a very important key technology in the overall concept and can be applied in virtual models on various planning levels and stages to improve the product and process planning.

In the first phase the focus is on integrated product engineering. The second phase includes the work cell design and optimization in a collaborative environment concurrently with the product engineering. The third phase in this concept is focusing on operative production planning and control down to the factory floor. The fourth phase emphasizes on the generation of virtual manikin with Indian anthropometric dimensions. The fifth phase involves the integration of the virtual manikin in the virtual work cell. The final phase involves the ergonomic analysis using software. This approach requires an extremely high effort and future research is needed to developed methods and tools for this approach. The benefits of this approach,

- The approach is more cost effective.
- Improves economy
- Provides necessary comfort requirements for the workman.
- Induces automation
- Improves accuracy in operation
- Reduces timing cycle for the operation
- Increases productivity

As a conclusion of this work the following deliverables were obtained,

- Work cell area : 3.30 x 2.50 x 2.90 m
- No. of human labours : 1 per shift
- No. of work shifts : 3 per day
- Total working labor : 3 per day
- Component to deburr : Royal Enfield – 500CC – Flywheel.
- Weight of component : 3.7Kg
- Existing RULA score : 3
- Existing Job Hazard Score : 21
- Tool used : Automatic Robotic Deburring Tool
- Tool Life : 15 – 20 Days
- Timing cycle : 32 seconds per component
- Errors : Zero

The RULA score value and the Job Hazard Score value proves that the layout is highly safe and comfortable for the worker to handle the components.

REFERENCES


