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Sanding and Buffing in the Aviation Manufacturing Industry: A Case Study

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Abstract: The primary objective of this assessment was to assess and recommend engineering changes for the task of sanding and buffing a propeller hub and to establish a proper standard of practice and procedures that limit (or decrease) the potential for injuries. Management at this aviation manufacturing facility determined that there was a potential for injury while performing this task of sanding and buffing a propeller hub. These injuries could be sustained from improper workstation design and improper use of equipment required for performing the manufacturing tasks. Since no injuries had been reported at the time, we proactively evaluated the environment and the task to determine where the potential injuries were likely to occur. Using an ergonomic assessment tool, Rapid Entire Body Assessment (REBA) ergonomic assessment, and the 5S model, we were able to determine which aspects of the task presented the highest risks for potential musculoskeletal injuries. By implementing our recommendations from these assessments, the reduction in potential injury saved this aviation manufacturing facility $21,045-$179,896 in worker's compensation and increased the employee's quality of life.

Keywords: Musculoskeletal Disorders, Manufacturing, Ergonomics

1. Introduction

In the United States, there are thousands of manufacturing facilities. According to the Bureau of Labor Statistics (2016)**,** production workers at manufacturing facilities are one of the most common populations to incur injuries in the workplace. This could be due to multiple causes such as improper workstation design, poor work posture, and excessive energy demand. Proactively responding to ergonomic problems not only benefits the employee immediately, but it also benefits the employer by avoiding the financial burden of worker's compensation due to these injuries. According to the National Safety Council, in 2016-2017, the average cost for worker's compensation was $40,051 (2019). By proactively fixing an ergonomic problem, the employee benefits by avoiding injury, enjoying a better quality of life, and can provide better quality work.

This ergonomic evaluation assessed an aviation manufacturing facility in the southeastern United States. The objective of this assessment was to examine an aviation manufacturing employee performing their designated task of buffing and sanding a propeller hub to determine whether any ergonomic problems existed and what proactive solutions could be implemented. The aviation manufacturing facility consists of approximately 50 employees. Many of the employees at this location have been working at this facility and performing the same task for 5-20 years. The primary responsibility for this facility is to manufacture different mechanical parts for various aircrafts. Once these parts have been manufactured and inspected, they are shipped to other aviation manufacturing facilities for installation and use in constructing the aircraft. This case study presents frequent, repetitive motion and improper workspace ergonomics. It was determined that injury to the wrists, arms, or back is inevitable without proper modifications to the workstations. These potential injuries could include but are not limited to: carpal tunnel syndrome ($30,509 annual worker's compensation cost), lower and upper back strain ($33,140 annual worker's compensation cost), and inflammation ($36,076 annual worker's compensation cost). Implementing proactive solutions can benefit both the employer and the employee.

2. Method

The overall job task of the female employee that is the focus of this evaluation is to sand and buff the central hub of an airplane's propeller to diminish any microcracks that could later expand and break the propeller. The employee uses multiple tools at two different workstations in order to complete the sanding and buffing process of each hub. These two workstations are approximately 8-10 feet apart and include a cement floor with no anti-fatigue mats. These hubs are 5-12lbs depending on the size of the aircraft. Once the sanding and buffing of the hubs is completed, the employee takes them to another employee to be inspected. The employee takes a break after each hub is completed.

Workstation 1:

The first workstation consists of a table where the employee sands and buffs the hubs. The table was equipped with a vent that vacuumed in the particles generated by sanding the hub. At this table, the employee sat and used multiple 3M tools to sand and buff the entire area of the hub. These tools weighed approximately 5 pounds and were not counterbalanced. The majority of these tools required a pistol grip, however, one tool required an inline grip, and another required a pinch grip. The tools and the sanding/buffing head attachments varied depending on the precision of the task.

Workstation 2:

The second workstation was about 10 feet away from the first and consisted of a belt sander where the employee continued the process of removing microcracks. The employee stood at this station for approximately 3 to 4 minutes and rotated the hub at different angles across the belt sander.

Transport to Inspection:

Once a hub was completely sanded, the employee took the hub to inspection which was approximately 100-150 feet away from workstation 1 and workstation 2. However, the employee generally completed multiple hubs and placed them on a cart to take to inspection collectively.

2.1 Video Analysis

At the time of this assessment, the female employee had not reported any discomfort, pain, or injuries in relation to this task. However, the company had flagged this task for further analysis.

Workstation 1

Workstation 1 was a workbench-like table with a work surface that was estimated to be about 48 inches tall (or high). In the analysis of workstation 1, it appeared that the height was manageable because the task required precision buffing of the imperfections in the hub. Along the back edge of the workstation, there were several boxes that are storing the additional attachments for the pneumatic tools. The storage location of these attachments presented concern based on the frequent arm extension to access the tools from a seated position. When the tools were in use, they were not accompanied with a counterweight that is recommended for use with tools weighing greater than 3 lbs (Fernandez and Marley, 2013). When the pneumatic tools were not in use, they were set off to the side of the worksurface creating a hazard by adding excess clutter within the work area. In the video, the employee was sitting at this workstation on an average stool and the feet did not touch the floor. The stool was raised to imitate a sit/stand stool but did not provide the necessary support for the back.

Workstation 2

Workstation 2 consisted of a belt sander that was used to buff a larger surface area of the hub. The belt sander was a mechanized piece of equipment with an automated belt that was wrapped with sandpaper. This minimized the amount of movement required from the user. This task was performed while standing on a concrete floor with no anti-fatigue mat. Operating the machine included a high frequency of radial and ulnar deviation which are hazardous wrist movements. In addition to the deviation, the absence of a device to support the hub caused an alarming amount of extension and deviation in the wrist. The tasks that involve the belt sander are mostly static with the exception of wrist movements and the occasional movement of the arms. Even though the employee is at workstation 2 for only a few minutes at a time, at the rate of 25 hubs a day, the time spent at the belt sander is averaged at two hours a day. The anti-fatigue mat at the sanding belt station appears to be misplaced and far away from the workstation. The belt sander running at workstation 2 produces a lot of noise, 92+ dbA (Government of Western Australia Department of Mines, Industry Regulation and Safety, 2014), and the employee is not wearing ear protection.

Transport to Inspection:

The videos did not demonstrate this task, but the cart that is used for transport is visible in the background.

3. Assessments

Two assessments were used to evaluate these tasks: An Ergonomic Assessment Tool and the Rapid Entire Body Assessment (REBA).

Ergonomic Assessment Tool:
Using the Ergonomic Assessment, the employee's tasks at each workstation were evaluated. This assessment considered different postures of various sections of the body and how many times each minute these postures are observed throughout the duration of the task. The sections included in this evaluation were the neck, upper arms, lower arms, wrists, grip, back, lower extremities, and overall posture. Once the posture and frequencies of each section were input, the form automatically calculated and output a decision on whether that posture and frequency of that section were acceptable. It communicated these decisions by different colored shapes: a green circle indicated that the posture is acceptable, a yellow square indicated that the posture should be further evaluated, and changes considered, and a red hexagon indicated the posture was unacceptable and needs to be addressed immediately. This evaluation was useful because it conducted a load evaluation as well. This section evaluated if the load required to be handled by the worker was acceptable. The Ergonomic Assessment considered how heavy the load was in relation to the person holding it, the size of the object, and the coupling quality. This section also followed the same output display format as the posture and frequency sections.

Rapid Entire Body Assessment (REBA):
Using the Rapid Entire Body Assessment (REBA) (Hignett and McAtamney, 2000), the employee's tasks at each workstation were evaluated. The REBA is a tool made for quickly evaluating the risk of injury associated with the postures performed during a task (Fernandez and Marley, 2013). It considered posture information using two body sections that were categorized as Section A and Section B. Section A was the neck, trunk, and legs and Section B was the upper arms, lower arms, and wrists. The REBA calculated an overall posture score before finally adding couplings and activities such as static work and repetitive small motions. Finally, a score ranging from 1-13 was output that assigned a risk level to the employee's task.

4. Results

Workstation 1
Ergonomic Assessment Tool: The findings of the workstation 1 assessment indicated unacceptable (red) postures at the upper arms, wrists, and grip, and moderate posture issues (yellow) at the neck, lower arms, and back. Flexion at the employee's shoulders was observed due to frequently maneuvering the pneumatic tools about the hub on the workstation. This raised serious concerns about the possibility of an imminent shoulder injury such as a rotator cuff tear. Another cause for concern was the combination of repeated flexion, extension, and deviation of the wrists when the tools and hubs were manipulated. These types of motions and manipulations dramatically increased the risk for developing carpal tunnel syndrome. The pistol and inline tools were held with a bent wrist. A tool requiring a pinch grip was also used. These types of inappropriate grips also carried a risk for carpal tunnel syndrome. The moderate posture issues included flexion at the neck due to looking down at the hub, mild angle lower arm flexion and extension, and slightly bending forward over the workstation. These postures carried a risk for neck pain, elbow pain/injury, and lower back pain.

Rapid Entire Body Assessment (REBA): The result of the posture analysis at workstation 1 using the REBA was a score of 10. The REBA defined a score of 10 as "High Risk" and recommended to "Investigate and Implement Change". Section B had the highest score due repetitive small range actions. The high score of Section B in addition to the moderate neck and trunk scores of Section A indicated that changes needed to be implemented. This confirmed the findings of the JFA assessment that indicated a severe risk of shoulder and wrist injuries, and moderate risk for neck, elbow, and back pain or injuries.

Workstation 2
Ergonomic Assessment Tool: The findings of the workstation 2 assessment indicated unacceptable postures at the wrists and moderate posture issues with the neck, upper arms, and lower arms. In order to rotate the hub along the belt sander, the employee continuously deviated both wrists which increased the risk of injury due to repeated flexion at the shoulder and elbows. This inflated the risk for pain and injuries at these joints during the task as the hub is rotated and moved along the belt sander. While the belt sander is in use, the employee was seen flexing the neck downwards which can be a cause of discomfort in the neck. The load evaluation gave an acceptable (green) result.

Rapid Entire Body Assessment (REBA): The result of the posture analysis at workstation 2 using the REBA was a score of 4. REBA defined this score as "Medium Risk" and recommended to "Further Investigate, Change Soon". This lower score mirrored the JFA assessment for workstation 2 since that assessment only found one unacceptable posture.

5. Recommendations

The implementation of the recommendations made from the assessment helped mitigate the potential for injury at both workstations. The recommendations adhered to the 5S Method, a five-step method that help establish an efficient, effective, and safe workplace. The steps in the 5S Method include sort, set in order, shine, standardize, and sustain.

Workstation 1

An adjustable clamp to hold the hubs should be mounted to the back of the workstation. This clamp should be size adjustable to account for different sized hubs. The arm mounting the clamp to the wall should have an adjustable elbow joint allowing for the hub to be moved on all planes with respect to the person completing the task. The 3M pneumatic tools should be counterbalanced and include universal joints. To comply with the "shine" step, the clamp, the 3M tools, and the counterbalance system should be given regular maintenance to keep them in good working order. An adjustable sit/stand stool and an adjustable footrest should both be provided.

Implementation of the "sort" and "set in order" steps from the 5S Method include adjustments to the storage locations of the pneumatic tools and their attachments. A holder/organizer for the 3M sanding and buffing tools that are not in use should be placed on the right side of the workstation, as the employee is right-handed. This holder would include sections for unused tool heads, sections for securing the counterbalanced pneumatic tools. The holder allows for the tools to be within reach of the employee and prevents them from swinging and injuring the employee. The boxes holding new sanding and buffing attachments should be moved to the left side of the workstation to avoid the employee having to reach repetitively outside of the normal range of motion.

A removable grip should be provided for the precision 3M tool that currently must be held with a pinch grip. It should be removable so that in the case a hub has small openings, the employee could remove it to maneuver the tool within the hub. The employee should be provided with a well fitted padded Kevlar glove for the dominant hand that is used to hold the tools to avoid laceration and vibration from the pneumatic tools. Finally, the employee should be provided with and required to wear ear protection since the noise levels are above 85 dbA (United States Department of Labor).
Once implemented these recommendations should then be standardized as explained through the "standardize" level in the 5S Method. Steps should be taken by the worker at the workstations to maintain the consistency of tool placement, handling, posture, and movements. By having a standard of practice and procedure, it increases the probability that efficiency and safety precautions will continue to increase.

Before and After Recommendations Diagrams

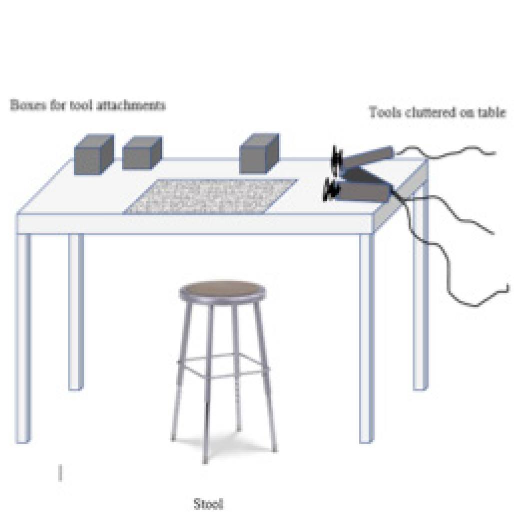

Figure 1. Workstation 1 Before

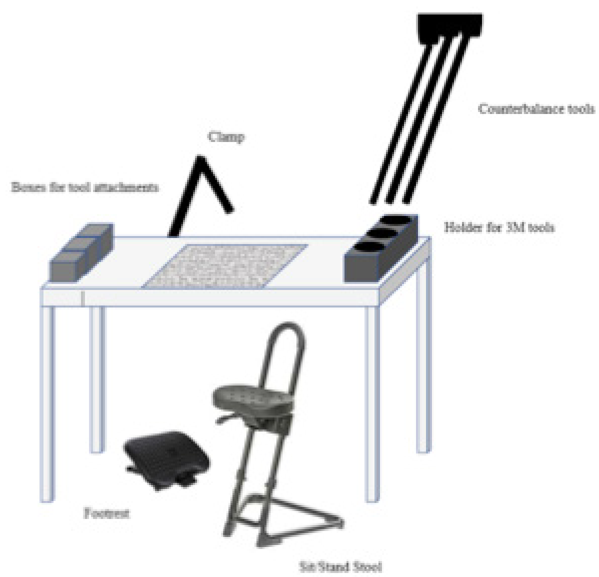

Figure 2. Workstation 1 After

Workstation 2

An adjustable clamp very similar to the one recommended for Workstation 1 should also be installed for this workstation. The difference between these would be that this one would likely need to be floor mounted due to the nature of the belt sander. The clamp would allow the employee to maneuver the hub along the belt sander without having to hold it for several minutes. An anti-fatigue mat should be placed in front of the belt sander where the employee stands.

Transport to Inspection

Although the dimensions of the cart were unknown, the standard dimensions for four-wheeled carts are 51.2" X 39.4" X 55.1" (Fernandez & Marley, 2013). It was important to ensure that vertical handles were also provided. The worker transporting the hubs should make sure to put the cart in a straight line using both hands to minimize the amount of physical stress on the wrists, arms, and shoulders. In accordance with the "shine" principle of the 5S Method, the cart should be routinely maintained quarterly (as a minimum) to ensure the casters are in good shape.

6. Discussion

Workstation 1

The implementation of the adjustable clamp raised the height of the hub and therefore minimized the flexion of the neck. As the clamp held the hub in one stationary position, it also lessened the excessive repetitive flexion of the upper and lower arms, increasing the task efficiency and safety. The addition of a counterbalance for each pneumatic tool decreased the amount of deviation, flexion, extension, and unnecessary repetitive movement in the wrist. The universal joint was also a fundamental addition to the pneumatic tools that helped alleviate unnecessary wrist and arm movements by allowing the tools to move freely.

Moving the attachment storage to the side helped remove the extended reach that was necessary to obtain the items that were in the storage boxes along the back of the workstation. The implementation of a tool holder/organizer to the side of the workstation helped keep the hoses from the pneumatic tools out of the work area. By adding a removable grip to the pinch tool, the use of a pinch grip was eliminated. The sit/stand stool with a footrest reduced any discomfort and potential for risk in the back due to back flexion.

According to the Ergonomic Assessment, these recommended changes resulted in a reduction of unacceptable postures (red) from three to zero, and a reduction of moderate posture issues (yellow) from three to two, and a total of six acceptable (green) postures.

Workstation 2:

The implementation of a clamp at this belt sander workstation minimized a large amount of deviation of the wrist. The employee will also no longer be responsible for holding the load while the task is being performed at the belt sander. The height adjustable clamp decreased the amount of flexion of the neck. When handling the hub, it is important that protective gloves were worn to reduce the potential of cuts on the hands and that an anti-fatigue mat was always present at the machine.

According to the Ergonomic Assessment, these recommended changes resulted in the elimination of the unacceptable wrist posture (red) and reduced it to a yellow. These recommendations also eliminated the three previous yellow postures for a total of seven green postures.

7. Costs and Savings

Using the suggested recommendations listed above, here are examples of potential items that could have been purchased.

- Sit/Stand Stool ($292): Lyon Sit/Stand Stool, adjustable seat height with 10" range, adjustable seat angle with 20 degree pivot angle, helps take up to 70% of the weight off of the legs and feet.
- Footrest ($42): 3M Adjustable height/tilt footrest, 18" wide non-skid plastic platform with soft bumps
- Clamp ($15): Toggle Clamp, 100lb capacity.
  - Custom Clamp: prices can vary based on material and design
- Tool Holder ($63): Holds 6 tools
- Padded Palm Kevlar Gloves ($19.18)

By purchasing these items (or similar items) and making the suggested recommendations, the company avoided high worker's compensation costs. If the employee had continued to perform the task without any of the recommendations implemented, there would have continued to be a high risk of multiple work-related musculoskeletal disorders (Table 1). One or more of these injuries could cost this aviation manufacturing facility a minimum of $21,045 while the previously stated recommendations cost only 5% of that at $1,087. If the employee were to experience all of the work-related musculoskeletal disorders, the overall direct cost to this aviation manufacturing facility could be $179,896 which is 166 times the amount for all of the recommendations. Using the total cost of our recommendations, $1,087 (Table 2), and dividing it by the possible injury "strain" which has a direct cost of $33,140 (Table 1), the payback period was approximately 0.03 years or 11 days.

Table 1. Costs of Possible MSDs from Current Tasks Table

Without Recommendations	
Possible Injuries	Cost to Industry
Carpal Tunnel	$30,509
Inflammation	$36,076
Sprain	$29,989
Strain	$33,140
Hearing Loss/Impairment	$21,045
Respiratory Disorder	$29,137
Direct Total Costs	$21,045-$179,896

SOURCE: National Council on Compensation Insurance, Inc (NCCI)

Table 2. Recommendation Costs Table

<table>
<tr><th colspan="4">With Recommendations</th></tr>
<tr><th></th><th>Workstation Adjustment</th><th>Cost to Industry</th><th>Total</th></tr>
<tr><td rowspan="7">Workstation 1</td><td>Sit/Stand Stool</td><td>$292</td><td rowspan="7">$1,036</td></tr>
<tr><td>Footrest</td><td>$42</td></tr>
<tr><td>Move Shelving Boxes</td><td>$0</td></tr>
<tr><td>Counterbalance Tools</td><td>$82 x 6 tools = $492</td></tr>
<tr><td>Shelving for Holding Tools</td><td>$63</td></tr>
<tr><td>Clamp</td><td>$15</td></tr>
<tr><td>Universal Joint</td><td>$22 x 6 tools = $132</td></tr>
<tr><td rowspan="2">Workstation 2</td><td>Reposition/Buy Anti-Fatigue Mat</td><td>$0-$18</td><td rowspan="2">$51</td></tr>
<tr><td>Padded Kevlar Gloves</td><td>$33</td></tr>
<tr><td colspan="3">Grand Total</td><td>$1069-$1087</td></tr>
</table>

8. References

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