The Evaluation of Manual FOUP Handling in 300mm Wafer Fab

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Abstract-Semiconductor manufacturing industry is moving into the production of 300-mm wafers. To solve the increased workload problem in manual wafer handling, some personal guided vehicles (PGVs) have been developed to help in the transfer of Front Opening Unified Pods (FOUP). This study compares two kinds of PGVs with a traditional cart and evaluates the feasibility of using them for manual FOUP handling tasks. Manual FOUP handling capability was assessed. The results indicate that there is no obvious advantage in using any of the two evaluated PGVs over the manual cart. There is potential risk of causing musculoskeletal disorders for female operators to handle the 300 mm FOUP manually. Since the development of a fully automated intra-bay FOUP handling system is a project of high technical difficulty, a combination of manual and automated handling is the current approach. To enhance the operator’s health, safety and productivity, selection and training of operators, adequate design of handling tools and machine interface, assessment and balancing of workload are necessary.

I. INTRODUCTION

With the fast advancement in materials and processing technologies, semiconductor manufacturing has entered the era of the 300-mm diameter wafer. The increase in diameter from 200 mm to 300 mm causes a 2.25 time increase in surface area. The FOUP (Front Opening Unified Pod) is the container for 300mm-wafers. One lot (25 pieces) of 300mm wafers in a FOUP weighs about 9.0 kg, which is about 1.55 times the weight of one lot of 200 mm wafers in a pod (5.8 kg). The increased FOUP size and weight could cause
musculoskeletal disorders (MSDs) in manual wafer handlers. To prevent workers from developing MSDs problems, automating the material-handling system is the logical approach. Material-handling automation is now expanding from interbay automation to intrabay automation. Interbay transportation was successfully achieved using an overhead monorail system, i.e. AGV (automated guide vehicles) [1]. Intrabay automated FOUP handling systems such as OHT (overhead hoist transportation) are still under development. Because of the complexity of the wafer manufacturing process and the diversity of product types, it is difficult to fully automate intrabay FOUP transportation. Thus, some personal guided vehicles (PGVs) are available to aid in manual FOUP handling. To replace the conventional manual push cart with PGV is costly. It is necessary to conduct in depth evaluations to help the manager make tooling selection decisions. If manual operations are still needed to handle the FOUP, it is important to consider ergonomic issues such as the lifting capability of human operators, and the risk of producing lower back injuries. Two field studies were conducted with the following objectives:

1. Compare the effectiveness of using any of the two types of PGVs as compared with the traditional manual pushcart.
2. Evaluate the ability of female operators to manually handle FOUPs to minimize the risk of producing musculoskeletal injury problems.

II. METHOD

A. FOUP handling tasks

The FOUP handling task involves picking a FOUP from a stocker, moving the FOUP manually or with a FOUP handling tool, loading the FOUP into the process equipment load port or a rack, and unload a FOUP from a load port or a rack. One FOUP with 25 pieces of 300 mm wafers weighs about 9 kg. The height of the load port is about 90 cm. Three intra-bay FOUP handling tools were evaluated (Figure 1). They are briefly introduced in the following:

1) Mechanical PGV

This type of PGV has three major assemblies, i.e. cart, transfer mechanism and docking mechanism. The transfer mechanism uses a gripper and lever to reduce the effort in lifting and lowering a FOUP. The PGV must be docked at a specific position.
and mounted correctly before loading/unloading a FOUP onto/from the loading port.

2) Semi-automated PGV

This type of PGV requires electric power to function. It automates the FOUP loading/unloading operation from the PGV onto the load port, and vice versa. The operator only needs to push buttons.

3) Cart

The cart is used widely in 200 mm wafer fabrication. It is also currently used in 300 mm wafer fabrication in Taiwan. It is used to carry FOUPs from one place to another. All the loading/unloading FOUP operations on/from a process tool load port or rack are performed manually.

***Insert Figure 1 Here***

B. Experimental task of study 1

The experimental task involved simulating the typical FOUP handling task. The experimental task procedure involved pushing a FOUP handling tool from a starting position to the specific load port, loading/unloading a FOUP onto/from the load port and then pushing the FOUP handling tool back to the starting position. The total distance was 37.2 m. The three FOUP handling tools (2 PGVs and 1 cart) were used to perform the experimental task in random order. The experimental task was repeated three times using each FOUP handling tool. A total of 27 separate tests (3 operators × 3 FOUP handling tools × 3 repeats) were conducted.

Three female operators from a semiconductor manufacturing company volunteered to participate in this study. Their mean age was 23 years. Their mean body height and weight was 163 cm, and 59.1 kg respectively. The study purpose and procedure was explained to all subjects prior to the experiment. FOUP handling was part of volunteer operator’s routine job functions. The time spent for each test was recorded to indicate the efficiency of the FOUP handling tool. The completion time was defined as the time spent completing the experimental task. The push force was measured as the peak pushing force while pushing a FOUP handling tool from a starting point to the specified load port. The other measured push force was the peak pushing force while docking the FOUP handling tool at the load port. Analyses of variance were performed to evaluate the effect of each
FOUP handling tool on the dependent variables. The significant level was set as $\alpha=0.05$.

C. Experimental task of study 2

This study focused on evaluating the operator lifting capabilities under 300 mm wafer handling conditions. A psychophysical study was conducted to determine the maximal acceptable lifting weight (MAWL) for these operators. Twenty-four female operators from the study company participated the experiment. Their mean age was 22.6 years. Their mean body height and weight was 161.9 cm, and 53.5 kg respectively. The reason for using female operators to perform the experiment task was that the wafer handling tasks in the study company were performed primarily by female operators. The experimental procedure for obtaining the MAWL was similar to the method reported in [2], [3]. The experimental task involves pushing the cart, and loading and unloading a FOUP from the cart into the load port at two handling frequencies. The height of the load port and the cart was 90 cm. The two-frequency level was to simulate the workload under low and high workload conditions.

III. RESULTS AND DISCUSSIONS

A. Compare three FOUP handling tools

The ANOVA results indicate that the FOUP handling tool had a significant effect ($p < 0.05$) on all of the dependent variables. The means and standard deviations of the dependent variables and other observations for the three FOUP handling tools are presented in Table 1. The results can be divided into two parts, i.e. the efficiency from using the FOUP handling tool, and the force requirement when manipulating the FOUP handling tool.

***Insert Table 1 Here***

1) The manipulation efficiency of the FOUP handling tool

Figure 2 shows that the completion time using the cart was the least, followed by using the mechanical PGV and the semi-automated PGV. This is because the cart has the lightest weight and can be pushed quickly. Both the mechanical PGV and the semi-automated PGV required docking operations, and thus took a longer time than
the cart. Moreover, the semi-automated PGV required some time to execute the loading/unloading operations, and therefore required the longest time to complete the experimental task.

2) The force requirement when using the FOUP handling tool

Figure 3 indicates that pushing the cart required the least amount of push force, followed by the semi-automated PGV and mechanical PGV. This is again due to the weight of the cart was about 50% of that of the semi-automated PGV or mechanical PGV. Greater effort was required to turn and manipulate the semi-automated PGV or mechanical PGV.

When docking the FOUP handling tool at the process equipment, operating mechanical PGV required a little less pushing force than operating the semi-automated PGV, as shown in Figure 3. Since there is no docking operation for the cart, no push force for docking was required. Although the PGV can reduce or eliminate the lifting force, comparing with the cart, the additional pushing force for docking the PGV at the process equipment is a transfer of force exertion from lifting to pushing. Both the mechanical PGV and semi-automated PGV were designed only to interact with the load port of the process equipment, but not with the WIP rack. When using this PGV to transfer a FOUP onto a rack, the operator still needed to lift the FOUP and place it on the rack manually. The semi-automated PGV was also not compatible with the rack for FOUP transfer. The WIP rack is especially important for the foundry type of semiconductor production.

B. Manual FOUP handling capability evaluation

For the result of study 2, the ANOVA results indicate that the handling frequency effect on the maximal acceptable weight for lifting (MAWL) was significant (p<0.05). It is logical that the MAWL at a 1/min handling frequency (11.15 kg) was significantly lower than that at 1/5min handling frequency (12.03 kg). The average MAWL of the 24 female workers was greater than a one-lot 300 mm wafer load in a FOUP (9.0 Kg). From the SEMI’s safety guideline for ergonomics SEMI S8-0701, it is necessary to assure that 99%
of the male workers and 75% of the female workers are capable of performing the FOUP loading task [4]. The MAWL of the 25th percentile of operators was 8.63 kg for 1/min, and 8.88 kg for 1/5 min. Both were lower than the weight of a FOUP with 25 pieces of 300 mm wafers (9.0 kg). The result revealed that FOUP handling with the three tools indicated the potential risk of producing musculoskeletal injury while performing FOUP transfer task. It is thus important to make sure that the designs of FOUP, the handling tools, load port, and operation procedure are ergonomically sound. The training operators in the appropriate methods for manually lifting and pushing the cart and the selection of physically fit operators are necessary. The organization’s management approach, e.g. an exercise program to warm up and strengthen muscles, with frequent breaks are also helpful.

IV. CONCLUSION

Based on the results of study 1, it is obvious that the mechanical PGV and semi-automated PGV still have some drawbacks. The main disadvantage when using the two PGVs is that they are not compatible with the racks that are an important tool for WIP in foundry type fab facilities. In addition, these two PGVs are too heavy (over 120 kg with a fully loaded FOUP), require longer manipulation time and greater pushing force to perform the FOUP handling tasks as compared with the cart.

The study 2 results suggest that not all the female operators are capable of performing the FOUP handling tasks using the cart. There is potential risk for musculoskeletal problems in FOUP handling tasks. It is important to emphasize the training and supervision of adequate manual FOUP handling procedures and selecting physically fit female operators that are capable of performing the FOUP handling tasks in a safe and efficient manner. It is also recommended that management assign male operators to perform the rather frequent FOUP handling tasks in the receiving and storage areas. Of course, the eventual goal is to fully automate the intra-bay FOUP handling by the overhead hoist transfer (OHT) system. This is an on-going project with high degree of technical difficulty especially for foundry type of operations.
REFERENCES


Table List

TABLE 1 THE MEANS AND STANDARD DEVIATIONS FOR THE PERFORMANCE OF THE THREE SUBJECTS AMONG THREE FOUP HANDLING TOOLS

Figure List

Fig. 1. The three FOUP handling tools evaluated in this study
Fig. 2. The completion time of three subjects when operating the three FOUP handling tools
Fig. 3. The pushing force of three subjects when operating the three FOUP handling tools while walking or docking
<table>
<thead>
<tr>
<th></th>
<th>Mechanical PGV</th>
<th>Semi-automated PGV</th>
<th>Cart</th>
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<tr>
<td>Total Mass Loaded, kg</td>
<td>About 120</td>
<td>About 140</td>
<td>About 60</td>
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<tr>
<td>Complete Time, sec</td>
<td>102.8 (17.9)*</td>
<td>140.6 (17.1)</td>
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<td>Docking Time, sec</td>
<td>7 (1.7)</td>
<td>12.2 (3.4)</td>
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<td>Loading Time (on loadport), sec</td>
<td>14.9 (3.8)</td>
<td>33.6 (5.6)</td>
<td>4.7 sec (0.6)</td>
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<tr>
<td>Loading Time (on rack), sec</td>
<td>5.8 (1.1)</td>
<td>Impossible</td>
<td>4.9 (0.8)</td>
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<tr>
<td>Pushing force while walking (left hand), kg</td>
<td>9.4 (1.3)</td>
<td>7.8 (2.9)</td>
<td>4.6 (1.6)</td>
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<td>Pushing force while walking (right hand), kg</td>
<td>9.4 (3.5)</td>
<td>8.2 (4.7)</td>
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<tr>
<td>Pushing force while docking (left hand), kg</td>
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<tr>
<td>Pushing force while docking (right hand), kg</td>
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<td>8.6 (3.6)</td>
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</tbody>
</table>

*: The value in parentheses is standard deviation.
Handling Tool

- Pushing Force (kg)
  - Walking (left hand)
  - Walking (right hand)
  - Docking (left hand)
  - Docking (right hand)

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<th>Handling Tool</th>
<th>Walking (left hand)</th>
<th>Walking (right hand)</th>
<th>Docking (left hand)</th>
<th>Docking (right hand)</th>
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<td>Semi-auto PGV</td>
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<tr>
<td>Cart</td>
<td>8.6</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

NA: Not available.