

## 6. CONCLUSIONS

This research has demonstrated that Fitts' index of difficulty is applicable to two-handed assembly tasks. However, it cannot be directly used to estimate the time required to assemble a heavy plate, due to the missing z-axis degree of freedom. The participants tended to perform the assembly tasks in two steps. First, they tried to transfer the plate to the target line and then, if necessary, rotate the unmatched end onto the target line. Therefore, a new index of difficulty for heavy plate assembly tasks was developed by combining the index of difficulty equations of each step.

Since overhead cranes may become a bottleneck in a production system, humans or higher-performance cranes are the obvious options. This research studied humans' performance in performing 4 assembly methods: One person without an overhead crane, Two-person team without an overhead crane, One person with a regular overhead crane, and One person with a spring-equipped overhead crane. The results showed that, for all methods mentioned above, there are linear relationships between the movement times and the tasks' difficulties in each level of heaviness. It means that the movement times can be accurately predicted once the tasks' difficulty, assembly method, and weight are known.

The results also demonstrated the assembly time comparison of the four methods at different level of heaviness. It is clear that one person with a regular overhead crane requires more time to assemble a plate, comparing to the others. In addition, from the experiments, the assembly times were minimized when two people help each other assembling the plate. However, once the weight goes beyond 70 Lbs., the One person with a spring-equipped overhead crane method becomes dominant.

For heavy plate assembly tasks, weight becomes a main factor in increasing the assembly time. The results showed that, for one person, the assembly speed remains stable until the weight is greater than 20Lbs. Once the weight goes beyond 20Lbs., the speed starts dropping in proportion to the increasing weight. This critical point also occurs in the Two-person team method. Once the weight goes beyond 40Lbs., the assembly speed of the Two-person team method starts decreasing linearly along with the weight. These indicate that at the lower than critical point, the assembler can comfortably perform the assembly tasks without effects from the weight.

By adding a spring between the hook and the gripper of an overhead crane, the assemblers do not have to press the UP/Down buttons on the crane controller to lift or lower the plate. It returns the control back to the hand-eye loop of the assembler, increasing the efficiency in assembling the plate. The assembly times, then, are greatly reduced. However, using an inappropriate spring for a particular weight might lead to a longer assembly time. A too stiff spring might not provide enough flexibility to the assembler to manipulate the heavy plate easily. A too soft spring could create a parasitic oscillation. To deal with variety parts' weights, a variable-stiffness spring should be investigated.