Optimizing the Assembly Process in the Hang on Part Station by Adding Supporting Tools at Automotive Company PT. XYZ Indonesia

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I. INTRODUCTION

Transportation is one of the most important needs for people in Indonesia. As the number of population is ranked fourth in the world, the demand for vehicles is also constantly rising. Many international brands of automotive companies start their sales and marketing in Indonesia. As some of the companies prove their success transactions in Indonesia, the other firms come also to the country to follow their steps.

The firms have to do whatever they can to continue their existence in Indonesia. Having a company here gives many advantages for them. Beside the minimum salary of the workers, the factor of developing country also affects the number of sales. These factors lead many automotive manufacturers to make an investment in the country. Due to the high demand from the market, they start to increase the productivity and produce the best quality vehicles as many as they can.

PT. XYZ Indonesia assembles the worldwide famous car brand in Desa Wanaherang, Kabupaten Bogor, Jawa Barat, Indonesia. The brand can be said as one of the best car manufacturers from Germany. The headquarters are located in Stuttgart, Baden-Württemberg, Germany. This firm started to produce cars in 1926.

One of the main problems in the assembly line comes from the Hang On Part (HOP) station which the workers should set up the engine hood and trunklid of the cars. This station appears on two production lines: line one, which produces Sedan, and also line two, which assembles SUV. This can be
Since almost all of the processes in the station are using a manual system, some problems appear when the production department plans to increase the daily target. Inside the station, the workers have to set up the hood and trunklid manually. This condition makes the worker have to do it together, start from carrying the hood until adjust and connect it with the body of the car. A laborer cannot do that activity alone, therefore they have to wait for another one. Sometimes a laborer does not work only in one station, he also has to work in another place. The bigger problem also appears when it comes to the adjustment process. This is the process which the hood and trunklid have to be connected with the body of the car. This process takes quite long time because they have to check if the position is correct and it is still in tolerance. It can be a serious problem when the production department increases the number of production.

There is a potential for another problem to appear in the station as the production department plans to change the process at the assembly line. At the beginning of 2018, the company has discussed about the possibility of changing the policy to import the body of the car from Germany. Refer to the government rules, the company planned to choose Incomplete Knocked Down (IKD) option to import the cars from Germany. It means the cars that are received by the factory will still be having doors. It means that all cars will come to the HOP station with doors attached on their body. The workers in the station will have another extra task since they also have to remove the doors first. To remove one door, they have to work together at the same time. One of them have to hold the door while the other release the connecting part. Otherwise, the door will fall down or touch the body of the car and make a scratch.

These problems have to be fixed because they can cause waste of waiting, motion, and also talent. They should find a solution due to this condition. When these cases can be fixed, they do not have to be afraid to increase the production capacity when the demand becomes higher because the workers can work optimally doing all processes in the station.

II. METHODOLOGY

A root cause is a factor that caused a non-conformance and should be permanently eliminated through process improvement. From a root cause, there can be many mistakes then. Therefore, to prevent many problems that might happen, finding the main cause should be done. Root cause analysis (RCA) is a collective term that describes a wide range of approaches, tools, and techniques used to uncover causes of problems. This method can be divided into eight steps:

1. Clarify the problem
2. Breakdown the problem
3. Set the target
4. Analyze the root cause
5. Develop countermeasures
6. Implement countermeasures
7. Monitor results and processes
8. Standardize and share success

These steps also include the Plan, Do, Check, and Act (PDCA) cycle. Steps one through five are the planning process. The implementation can be found in step six. The step seven is checking process. Last step involves acting out the result of the new standards.

This practical problem solving can be a powerful tool to face the obstacle in the organization. It allows people to have a common understanding of what defines a problem and what steps are going to be done in order to overcome the problem efficiently.

A. Clarify the Problem

To know if there is any problem, there can be three ways to find. First, anything which is a deviation from the standard. Second, the gap between the expectation and the real condition. The last one, the unfilled customer need.

From those theory, the problem at the station can be found. The process to carry and connect the engine hood and trunklid can be optimized and be done by only a labor. The process of releasing the doors from the body of the car actually also could be done by one worker. However, there are some risks which could happen if the process is done by only one worker. Since the doors do not have anything to hold them, it could fall down. Based on that reason, this process has to be handled by two laborers at least. This condition makes some added time is needed at this station. This unnecessary long time and waste of worker’s talent at the station can be categorized as the main problem.

B. Breakdown the Problem

After finding the problem from the first step, it can be broken down into more detailed case. It can be seen smaller and more individual with eyes. The manual process which use human power will increase the possibility of mistakes. When
we see the process in the station step by step, there will be unnecessary time as the first worker has to work together at the same time with the second one to set up the hood and trunklid, also release the door. The reason behind this is because the workers do not have any tool to help them carrying the engine hood, trunklid, and holding the door.

Because of those reasons, waste of talent that occurs in this process can be seen clearly. One of the worker can just work for another task rather than help the first one carrying the engine hood and trunklid and holding the doors which can be optimized and be done by only a person. When the process is being handled by the workers, they also find some motions which are not ergonomic for them. They find that some movements are not so comfortable for them.

These problems can be shown by diagram below:

![Diagram showing process time and motions](image)

**Figure 2. First Problem (a) and Second Problem (b) Breakdown Diagram**

C. **Set the Target**

This step is all about focus on what is needed to complete the project. This should be challenging, but still within the limits and must be an improvement for any of the process. For this step, the general target would be reducing cycle time of the station. Since the main problems are the material handling time for engine hood and trunklid, and also releasing time for doors, this also would be the main objective of the conducted research. The details of the processes at the station can be seen below:

- Line 1 first worker activities:
  1. Preparation (together)
  2. Set up the front hinge
  3. Set up the stroot
  4. Engraving process (together)

- Line 1 second worker activities:
  1. Preparation (together)
  2. Prepare the previous car
  3. Engraving process (together)
  4. Carry hood from pallet (together)
  5. Set up with nuts (together)
  6. Tighten up the nuts and cabin inspection (together)
  7. Touch up the hinges
  8. Take edge guard from the pallet
  9. Set up the edge guard
  10. Tighten up with tool
  11. Set up spring and cover for trunklid
  12. Preparing the trunklid at its pallet
  13. Carry the trunklid from the pallet (together)
  14. Set up with nuts (together)

- Line 2 first worker activities:
  1. Preparation (together)
  2. Prepare the previous car
  3. Engraving process (together)
  4. Carry hood from pallet (together)
  5. Set up with nuts (together)
  6. Tighten up the nuts and cabin inspection (together)
  7. Set up with nuts (together)
  8. Carry the trunklid from the pallet (together)
  9. Set up with nuts (together)
The duration of every process is expressed by Table 3.1:

<table>
<thead>
<tr>
<th>No</th>
<th>Activity</th>
<th>Worker</th>
<th>Duration (second)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Preparation</td>
<td>V</td>
<td>V 15</td>
</tr>
<tr>
<td>2</td>
<td>Set up the front hinge</td>
<td>V</td>
<td>V 20</td>
</tr>
<tr>
<td>3</td>
<td>Set up the street</td>
<td>V</td>
<td>V 23</td>
</tr>
<tr>
<td>4</td>
<td>Engraving process</td>
<td>V</td>
<td>V 150</td>
</tr>
<tr>
<td>5</td>
<td>Carry hood from pallet</td>
<td>V  V</td>
<td>40</td>
</tr>
<tr>
<td>6</td>
<td>Set up with nuts</td>
<td>V</td>
<td>V 40</td>
</tr>
<tr>
<td>7</td>
<td>Tighten up with nuts and cabin inspection</td>
<td>V  V</td>
<td>90</td>
</tr>
<tr>
<td>8</td>
<td>Touch up the hinge</td>
<td>V</td>
<td>V 110</td>
</tr>
<tr>
<td>9</td>
<td>Take the edgeguard from pallet</td>
<td>V  V</td>
<td>12</td>
</tr>
<tr>
<td>10</td>
<td>Set up the spring and cover for trunklid</td>
<td>V</td>
<td>V 180</td>
</tr>
<tr>
<td>11</td>
<td>Tighten up with tool</td>
<td>V</td>
<td>V 44</td>
</tr>
<tr>
<td>12</td>
<td>Set up spring and cover</td>
<td>V</td>
<td>V 22</td>
</tr>
<tr>
<td>13</td>
<td>Preparing trunklid at pallet</td>
<td>V  V</td>
<td>40</td>
</tr>
<tr>
<td>14</td>
<td>Carry the trunklid</td>
<td>V  V</td>
<td>40</td>
</tr>
<tr>
<td>15</td>
<td>Set up with nuts</td>
<td>V  V</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Total time</td>
<td>1</td>
<td>1856</td>
</tr>
</tbody>
</table>

- Line 2 first worker:
  1. Preparation (together)
  2. Set up the gas pressure stool for engine hood
  3. Set up the stopper for engine hood
  4. Carry engine hood from the pallet (together)
  5. Set up with nuts (together)
  6. Front cabin inspection
  7. Adjustment (together)
  8. Carry trunklid from the pallet (together)
  9. Tighten up with nuts (together)
 10. Back cabin inspection (together)
 11. Adjustment (together)
 12. Set up dowel and for chrome
 13. Preparation for set up chrome
 14. Set up chrome
 15. Set up logo
 16. Set up bracket liftgate
 17. Assemble lockstrike
 18. Set up lockstrike
 19. Check lamp at the pallet
 20. Set up lamp (together)
 21. Set up cover depillar (together)

- Line 2 second worker:
  1. Preparation (together)
  2. Set up the stopper for trunklid
  3. Set up the edge guard for trunklid
  4. Carry engine hood from the pallet (together)
  5. Set up with nuts (together)
  6. Check the trunklid
  7. Adjustment (together)
  8. Carry trunklid from the pallet (together)
  9. Tighten up with nuts (together)
 10. Back cabin inspection (together)
 11. Adjustment (together)
 12. Go to another station
 13. Set up stopper liftgate

The duration of every process could be seen in the table below:

<table>
<thead>
<tr>
<th>No</th>
<th>Activity</th>
<th>Worker</th>
<th>Duration (second)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Preparation</td>
<td>V</td>
<td>V 15</td>
</tr>
<tr>
<td>2</td>
<td>Set up the gas pressure stool for engine hood</td>
<td>V</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>Set up the stopper for engine hood</td>
<td>V</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>Set up the edgeguard for trunklid</td>
<td>V</td>
<td>14</td>
</tr>
<tr>
<td>5</td>
<td>Carry the engine hood from the pallet</td>
<td>V</td>
<td>43</td>
</tr>
<tr>
<td>6</td>
<td>Carry with nuts</td>
<td>V  V</td>
<td>24</td>
</tr>
<tr>
<td>7</td>
<td>Front cabin inspection</td>
<td>V</td>
<td>45</td>
</tr>
<tr>
<td>8</td>
<td>Adjustment</td>
<td>V</td>
<td>V 212</td>
</tr>
<tr>
<td>9</td>
<td>Check the trunklid</td>
<td>V</td>
<td>V 30</td>
</tr>
<tr>
<td>10</td>
<td>Carry trunklid from the pallet</td>
<td>V</td>
<td>45</td>
</tr>
<tr>
<td>11</td>
<td>Tighten up with nuts</td>
<td>V  V</td>
<td>22</td>
</tr>
<tr>
<td>12</td>
<td>Back cabin inspection</td>
<td>V</td>
<td>V 52</td>
</tr>
<tr>
<td>13</td>
<td>Preparation for set up chrome</td>
<td>V</td>
<td>V 225</td>
</tr>
<tr>
<td>14</td>
<td>Set up trunklid</td>
<td>V  V</td>
<td>43</td>
</tr>
<tr>
<td>15</td>
<td>Set up with nuts</td>
<td>V  V</td>
<td>45</td>
</tr>
<tr>
<td>16</td>
<td>Set up logo</td>
<td>V</td>
<td>45</td>
</tr>
<tr>
<td>17</td>
<td>Set up bracket liftgate</td>
<td>V</td>
<td>V 110</td>
</tr>
<tr>
<td>18</td>
<td>Set up stopper liftgate</td>
<td>V</td>
<td>V 110</td>
</tr>
<tr>
<td>19</td>
<td>Assemble Lockstrike</td>
<td>V</td>
<td>V 65</td>
</tr>
<tr>
<td>20</td>
<td>Set up lockstrike</td>
<td>V</td>
<td>V 120</td>
</tr>
<tr>
<td>21</td>
<td>Set up gas spring and drive spindle</td>
<td>V</td>
<td>V 42</td>
</tr>
<tr>
<td>22</td>
<td>Set up ventilation flap</td>
<td>V</td>
<td>V 36</td>
</tr>
<tr>
<td>23</td>
<td>Set up cross member</td>
<td>V</td>
<td>V 90</td>
</tr>
<tr>
<td>24</td>
<td>Check the lamp at the pallet</td>
<td>V</td>
<td>V 87</td>
</tr>
<tr>
<td>25</td>
<td>Set up lamp</td>
<td>V</td>
<td>V 322</td>
</tr>
<tr>
<td>26</td>
<td>Set up cover depillar</td>
<td>V</td>
<td>V 45</td>
</tr>
<tr>
<td></td>
<td>Total time</td>
<td>1</td>
<td>1834</td>
</tr>
</tbody>
</table>

From those activities happen in Line 1 and Line 2, the target that has been set is reducing the cycle time by optimizing some processes. The target also could be reducing the number of worker in some processes so they can be optimized by working in other area if it is necessary. The expected result depends on what kind of improvement could be done in the activities.

After observing all the processes in the station, there are activities can be categorized as the main target to be improved.

The main activities we are focusing on can be found in the table below:
The main target of activities in Line 1 and 2 would be related to the engine hood and pallet. These activities are categorized as “not-optimized” processes because of some reasons. The first reason is time. Time to carry the hood and trunklid from the pallet can be minimized more. The actual distance between pallet and the car being proceeded is not too long. The next reason is the number of worker. The target which is being set from the beginning is not only about the time, it is also the worker. The number of worker to proceed the activities can be reduced as well. If it can be reduced, the other worker can work on another task.

### Tabel III

**Main Target to be Improved in Line 1**

<table>
<thead>
<tr>
<th>No</th>
<th>Activity</th>
<th>Worker</th>
<th>Duration (second)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Preparation</td>
<td>V V</td>
<td>15</td>
</tr>
<tr>
<td>2</td>
<td>Set up the front hinge</td>
<td>V V</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>Set up the stroot</td>
<td>V</td>
<td>23</td>
</tr>
<tr>
<td>4</td>
<td>Engraving process</td>
<td>V V</td>
<td>150</td>
</tr>
<tr>
<td>5</td>
<td>Carry hood from pallet</td>
<td>V V</td>
<td>40</td>
</tr>
<tr>
<td>6</td>
<td>Set up with nuts</td>
<td>V V</td>
<td>40</td>
</tr>
<tr>
<td>7</td>
<td>Tighten up with nuts and cabin inspection</td>
<td>V V</td>
<td>90</td>
</tr>
<tr>
<td>8</td>
<td>Tack up the hinge</td>
<td>V</td>
<td>110</td>
</tr>
<tr>
<td>9</td>
<td>Take the edgeguard from pallet</td>
<td>V</td>
<td>12</td>
</tr>
<tr>
<td>10</td>
<td>Set up the spring and cover for trunklid</td>
<td>V V</td>
<td>180</td>
</tr>
<tr>
<td>11</td>
<td>Tighten up with tool</td>
<td>V</td>
<td>30</td>
</tr>
<tr>
<td>12</td>
<td>Set up spring and cover</td>
<td>V</td>
<td>44</td>
</tr>
<tr>
<td>13</td>
<td>Preparing trunklid at pallet</td>
<td>V</td>
<td>22</td>
</tr>
<tr>
<td>14</td>
<td>Carry the trunklid</td>
<td>V V</td>
<td>40</td>
</tr>
<tr>
<td>15</td>
<td>Set up with nuts</td>
<td>V V</td>
<td>40</td>
</tr>
</tbody>
</table>

D. Analyze the Root Cause

This is a vital step to solve the problem. This will help to identify the factors that caused the issue on the first place. All potential root cause must be considered properly.

To bring up the root cause, a tool called Ishikawa Diagram will be very useful. From this diagram, many causes can be seen which lead to the main problem. The causes are also categorized into some aspects which are easier to be analyzed. The Ishikawa Diagram will be shown below:

![Ishikawa Diagram](image)

Table 1. First Problem Ishikawa Diagram

![Ishikawa Diagram](image)

Table 2. Second Problem Ishikawa Diagram

### III. Results

A. Manual Process of Carrying Engine Hood and Trunklid

After several times observing, the activities in the station basically can be divided into two major parts, which are set up the engine hood and set up the trunklid.

- **Line 1 First Worker Engine Hood Process:**
  1. Preparation (together)
  2. Set up the front hinge
  3. Set up the stroot
  4. Engraving process (together)
  5. Carry hood from pallet (together)
  6. Set up with nuts (together)
  7. Tighten up the nuts and cabin inspection (together)
8. Touch up the hinges

- Line 1 Second Worker Engine Hood Process:
  1. Preparation (together)
  2. Prepare the previous car
  3. Engraving process (together)
  4. Carry hood from pallet (together)
  5. Set up with nuts (together)
  6. Tighten up the nuts and cabin inspection (together)
  7. Touch up the hinges

Since I know the main target which is going to be improved, I take some of the most important activities and put them into a Gantt chart. The activities I labelled as the most important ones if they require at least two workers to be done. The details of those activities can be expressed by Gantt Chart as Figure 4.3:

- Line 1 First Worker Trunklid Process:
  1. Take edge guard from the pallet
  2. Set up the edge guard
  3. Tighten up with tool
  4. Set up spring and cover for trunklid
  5. Preparing the trunklid at its pallet
  6. Carry the trunklid from the pallet (together)
  7. Set up with nuts (together)

The same thing happens also in line two of assembly line. In this station, the activities appeared seem more than the activities happen in the same station in line 1. However, I still put the activities which require at least two workers into the most important activities. Below will be mentioned all the processes which are already grouped into two categories, for setting up engine hood and trunklid.

- Line 2 First Worker Engine Hood Process:
  1. Preparation (together)
  2. Set up the gas pressure stroot for engine hood
  3. Set up the stopper for engine hood
  4. Carry engine hood from the pallet (together)
  5. Set up with nuts (together)
  6. Front cabin inspection
  7. Adjustment (together)

- Line 2 Second Worker Engine Hood Process:
  1. Preparation (together)
  2. Set up the stopper for trunklid
  3. Set up the edge guard for trunklid
  4. Carry engine hood from the pallet (together)
  5. Set up with nuts (together)
  6. Check the trunklid
  7. Adjustment (together)

From those processes, we could classify all the “together” activities into a table and categorized them as the most important activities. Below can be found the details of the activities:

The details of those activities can be expressed by Gantt Chart below:

- Line 1 Second Worker Trunklid Process:
  1. Write the document of the car
  2. Carry the trunklid from the pallet (together)
  3. Set up with nuts (together)

- Line 2 First Worker Trunklid Process:
  1. Carry trunklid from the pallet (together)
  2. Tighten up with nuts (together)
  3. Back cabin inspection (together)
  4. Adjustment (together)
  5. Set up dowel and for chrome
  6. Preparation for set up chrome
  7. Set up chrome
  8. Set up logo
  9. Set up bracket lifigate
  10. Assemble lockstrike
  11. Set up lockstrike
  12. Check lamp at the pallet
  13. Set up lamp (together)
  14. Set up cover depillar (together)

- Line 2 Second Worker Trunklid Process:
  1. Carry trunklid from the pallet (together)
  2. Tighten up with nuts (together)
  3. Back cabin inspection (together)
  4. Adjustment (together)
  5. Go to another station
  6. Set up stopper lifigate
  7. Set up gas spring and drive spindle
8. Set up ventilation flap
9. Set up cross member
10. Set up lamp (together)
11. Set up cover depillar (together)

The details of those activities can be expressed by Gantt Chart as shown by Figure 8:

From the tables above, we can see how long it takes to do the activities together. Since the duration for the main target is not too significant, the objective of the research in this problem is to reduce the worker for the processes. It means that the solution for this problem should be able to make some of the activities above can be done by only one worker. Besides, the solution hopefully also can reduce the duration of the activities.

B. Manual Process of Releasing the Doors

Based on the new regulation the company has planned and probably will start from 2018, the cars which come from Germany will already have doors attached on them. If this proposal will be implemented, the company will receive the cars with almost complete parts.

If we look to the delivery cost, it will be an improvement as we know the delivery cost of doors themselves will not be needed anymore. The company can reduce their expenses in this side.

On the other hand, the production line in the factory will get a new task, which is releasing the doors from the body of the car. Although at the end they still have to attach the doors again, they still have to release the doors at first. The stations in assembly line still have to set the interior parts of the car, and they cannot do the process if the doors are still there. There will be two probability, the doors will have scratch or the worker will work with more efforts to keep the doors in a good condition.

If this plan will be realized, they already plan to make it in the HOP station. This station now takes care of setting up the engine hood and trunklid. This condition creates a new challenge by which it needs two workers at least to release the doors. One worker has to deal with releasing the nuts, while the other will be holding the door. This will be considered also as a waste of talent because the worker actually can work on another task. Sometimes it also takes a long duration as the first worker will have to wait for another worker to do the task.

If we breakdown the process of releasing the doors, we will know the steps of what the workers will do. The activities will be as shown in the diagram below:

From the flowchart above, we can see the activities that the workers do to release the doors. Basically, the procedure of releasing the door has quite similar steps with attaching the doors. It is only the reversal version of one another. These activities, if we take a deeper look, we can find deficiencies inside the processes. The main problem which appears is too many workers are required in these processes. They are mandatory required to do the activities. The details of those processes will be shown in the Table 5 below:

<table>
<thead>
<tr>
<th>No</th>
<th>Activity</th>
<th>Required Worker</th>
<th>Time (second)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Preparation</td>
<td>2</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>Take a Jig</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>Open the Nuts</td>
<td>2</td>
<td>60</td>
</tr>
<tr>
<td>4</td>
<td>Move the Door to the Jig</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>Attach the Door with Nuts</td>
<td>2</td>
<td>15</td>
</tr>
<tr>
<td>6</td>
<td>Move the Jig</td>
<td>1</td>
<td>15</td>
</tr>
</tbody>
</table>

We can see from the table above that half of all the processes need 2 workers at least to be done. The most reasonable activity to be improved is number three. The “open the nuts” process requires two workers while still needs 60 seconds to be completed. It shows that the activity actually can be said as the waste of waiting and talent. It actually can be done by a worker and the duration can be faster than before. The activity can be done faster than 60 seconds because that duration includes the time for the worker to wait for another worker.
IV. Discussion

A. Develop Countermeasures

In this part, the effective solution to solve the problems in the station are going to be conducted. The alternative solution can be created by optimizing the current facilities or designing the new one. The principal of the solution to the all two problems are the same, by designing the new supporting tools to help the worker in the station.

A.1. Choosing the Type of Gripper

As we know the main objective of the project is to design the supporting tool to optimize the setting up for engine hood, trunklid, and also keep holding the door, some factors which are important have been collected. The comparison will be represented by the table below:

<table>
<thead>
<tr>
<th>No</th>
<th>Type of Gripper</th>
<th>Advantage</th>
<th>Disadvantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Vacuum</td>
<td>Capable of gripping parts in high-speed motion applications</td>
<td>Dirty surface can clog the air lines circuit</td>
</tr>
<tr>
<td>2</td>
<td>Magnet</td>
<td>Can grip parts with holes which is not possible with vacuum grippers</td>
<td>When moved quickly, the part can slip out of the end effector</td>
</tr>
<tr>
<td>3</td>
<td>Mechanical</td>
<td>Greater versatility than vacuum cup</td>
<td>Cannot be done by semi-automated process, Can easily make a scratch on the surface of the object</td>
</tr>
</tbody>
</table>

If we see from the comparison above and relate it to the project, I would choose vacuum as the type of gripper that I am going to use. The decision of selecting vacuum is based on some reasons that have been mentioned in the table. The details will be explained in some points.

First, the vacuum will be safe to move the parts of the car. The supporting tool will still be moved by the operator in the station. It will not be an automatic process, so we cannot select the exact speed to move the parts. In case the worker is in a hurry to do the task, the part will still be safe sticking to the tool. The weakness of vacuum that has to be highlighted is the surface of the object must be clean. The simplest solution of this deficiency is to make a work procedure in which the worker must clean the surface of the object before sticking the vacuum. It is quite simple if we compare to the other weakness of magnet and mechanical.

The next reason is about magnet. Using magnet as an end-effector can be a good idea since it can grip any type of surface since it is made of metal. Magnet also can tolerate a surface with holes on it. This is a strength that vacuum does not have. However, using magnet can increase the possibility of failure. When it comes with the high-speed motion, the possibility of an object to fall is higher. As I have mentioned before, the supporting tool will not be automatic at all, so the speed cannot be standardized and depends on every operator.

Now, even mechanical gripper has greater versatility than vacuum cup, we actually do not need too much versatility since the objects are clear enough. We are not going to use the gripper to do another task. Besides, mechanical gripper needs an automatic manipulator and program to run this gripper. If it is done by human, the clamping force of mechanical will remain unstable. It can make a damage on the surface of the object. Moreover, this type of gripper also can easily make any scratch on the surface of the object.

Based on those reasons, I choose vacuum as the gripper for this project. This gripper theoretically is the most suitable type for this task. Many automotive factories also use this gripper to do this task.

A.2. Designing the Gripper for Engine Hood

The first design that will be conducted is the gripper to carry the engine hood. The design process considers many factors. The first factor is the dimension of the gripper. As vacuum has been chosen before, now the calculation of vacuum cups is going to be done. First, the number of vacuum cups which are going to be used has to be selected. Since the shape of the object is symmetric, three cups are enough to hold the hood so it will not fall to the opposite side of the vacuum cups. The work principal of the vacuum is that if the vacuum sucks in the horizontal way, it does not guarantee that it can maintain the vertical position also. The illustration can be seen in the picture below:

Figure 10. Vacuum Work Principal Illustration

From the figure above, we can see the work principal of vacuum. If the vacuum sucks the engine hood to the left in horizontal way which is illustrated by a yellow arrow, it prevents the object to fall to the right side. On the other hand, if the vacuum sucks the object vertical to the upside, it prevents the object to fall down.

Based on those explanation, it is better to suck the object in horizontal way because the surface area of the object is larger so it can be flexible for the gripper to be put on the
surface. To prevent the object falling down, a base can be designed as a foot for the object to stand on.

To calculate the vacuum area, we use the formula that has been mentioned before. We use the Pascal’s Law to calculate the area of the suction. The formula will be as given below:

\[
P = \frac{F}{A}
\]

The symbol \( P \) represents pressure (Pa) which can be calculated by divided the force (N) by the area of the surface (m\(^2\)).

The maximum amount of pressure in the normal air will be put as 1 bar or \( 10^5 \) Pa. The force can be put as the weight of engine hood. As the weight of engine hood is different each type, we put the heaviest weight possible so it can be used for all types of cars. The force will be 250 N. Now we calculate the area of the suction and will be expressed below:

\[
10^5 \text{ Pa} = \frac{250 \text{ N}}{A} \\
A = \frac{250 \text{ N}}{10^5 \text{ Pa}} \\
A = 0.0025 \text{ m}^2 \\
A = 25 \text{ cm}^2
\]

The number of cups we are going to use is three as mentioned before. Therefore, the area of suction has to be divided by three.

\[
A_{\text{for 3 cups}} = \frac{25 \text{ cm}^2}{3} \\
A_{\text{for 3 cups}} = 8.34 \text{ cm}^2/\text{each}
\]

Since we already know the area will be used for each vacuum cup, we can calculate the diameter of the cup. The shape of the cup’s surface is a circle so we can use the formula of circle’s area.

\[
A = \pi r^2 \\
8.34 \text{ cm}^2 = \pi r^2 \\
r = 1.63 \text{ cm} \\
d = 3.26 \text{ cm}
\]

The diameter we have got is 3.26 cm. It is the minimum diameter of vacuum cup we have to use to hold an object with a weight of 250 N. As the available cups in the market start with 2 cm and then 4 cm, we choose to use 4 cm diameter.

After choosing the diameter, then we start to design the gripper. The frames use the 80 x 80 mm iron. The result of design that has been made is as pictures in Figure 11:

\[
\begin{array}{|c|c|}
\hline
\text{Name} & \text{Iron, Cast} \\
\hline
\text{General} & \text{Mass Density} \\
& 7.15 \text{ g/cm}^3 \\
& \text{Yield Strength} \\
& 758 \text{ MPa} \\
& \text{Ultimate Tensile Strength} \\
& 884 \text{ MPa} \\
\hline
\text{Stress} & \text{Young’s Modulus} \\
& 120.5 \text{ GPa} \\
& \text{Poisson’s Ratio} \\
& 0.3 \text{ ul} \\
& \text{Shear Modulus} \\
& 46.3462 \text{ GPa} \\
\hline
\text{Part Name(s)} & \text{ISO 20x 20 00000005.ipt} \\
& \text{ISO 20x 20 00000006.ipt} \\
& \text{ISO 20x 20 00000007.ipt} \\
& \text{ISO 20x 20 00000008.ipt} \\
& \text{ISO 20x 20 00000009.ipt} \\
& \text{ISO 20x 20 00000010.ipt} \\
& \text{ISO 20x 20 00000011.ipt} \\
& \text{ISO 20 000000016.ipt} \\
& \text{ISO 20 000000017.ipt} \\
& \text{ISO 20 000000018.ipt} \\
& \text{ISO 20 000000019.ipt} \\
& \text{ISO 20x 20 00000020.ipt} \\
& \text{ISO 20x 20 00000021.ipt} \\
& \text{ISO 20x 20 00000022.ipt} \\
& \text{ISO 20x 20 00000023.ipt} \\
& \text{adapter} \\
\hline
\end{array}
\]

From the modelling that has been designed before, we can also count on the stress analysis. Stress analysis has a function to find if the material and structure of our model are strong enough. This time, Autodesk Inventor Professional 2019 will be used to calculate the stress analysis of this frame.

As mentioned before, iron will be selected as raw material to conduct the gripper. The size of iron has been mentioned before. Since we are going to use that material, we also can see the details of iron within the report produced by the software. The details of the properties of iron will be shown below:

Then the force should be put on the frame. For the first simulation, the force that is going to be added is only the vertical force of the engine hood’s weight. The amount of the force will be 250 N and laid on the base frame. The horizontal force will not be added in the first simulation, so we could know the strength of the gripper if it was only loaded by the engine hood and does not have any force loaded on it.

The constraint is also added in which the fixed constraint will be selected. The fixed constraint is going to be placed...
inside the cylinder on the top of the gripper. That cylinder later will be the connector to attach the gripper to the arm. The details can be seen in the Figure 4.25:

![Figure 13. Force Loaded and Constraint of the Hood’s Gripper](image)

For the second condition, we assume that the vacuum cups already hold the engine hood. The gripper which already hold the 250 N weight, can be imbalance since the load is quite heavy. The worst condition that might happen is the vacuum cups which actually face front side, can face downside. It means the load can be positioned under the gripper. The following figures will show the details of the load and constraint for this case:

![Figure 14. Force Loaded and Constraint of the Hood’s Gripper](image)

Then after doing the second simulation, we go to the last test. This simulation will analyze the real condition in which the gripper will have two parts of them getting load. One on the feet of the gripper, and one when the vacuum cups suck the object. This is the simulation that looks like the actual condition. When the engine hood is put on the feet, the vacuum cups will suck the engine hood at the same time. The gripper will receive the force of the load in vertical way and at the same time it also will receive the horizontal force from the suction side. The figures below will show the mentioned condition:

![Figure 15. Force Loaded and Constraint of the Hood’s Gripper](image)

From those three conditions, we can decide that this model can be realized to the real product. The simulations show that with all those three conditions, the model will still be the same gripper without any deformation. This shows that the model will be able to receive those forces on it. The results of the simulations can be summed up and shown by the table below:

<table>
<thead>
<tr>
<th>No</th>
<th>Condition</th>
<th>Material Used: Iron</th>
<th>Yield Strength (MPa)</th>
<th>Max Von Mises Stress (MPa)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Load on Feet</td>
<td>758</td>
<td>292.554</td>
<td>Valid</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Load on Vacuum Cups</td>
<td>758</td>
<td>73.9066</td>
<td>Valid</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Load on both</td>
<td>758</td>
<td>146.594</td>
<td>Valid</td>
<td></td>
</tr>
</tbody>
</table>

A. III. Designing the Gripper for Door and Trunklid

For the next gripper, we are going to conduct the same model for door and trunklid. The design is thought can be used for door and also the trunklid without changing anything since those two parts have almost the same looks. The gripper will still use the vacuum system to grip the object, in this case door and trunklid.

First, we have to calculate the area of vacuum we are going to use. This calculation relates to the size of vacuum we are going to use for this gripper. The work principal of vacuum is using the Pascal’s Law. The formula will be shown below:

\[ P = \frac{F}{A} \]

The symbol \( P \) represents pressure (Pa) which can be calculated by dividing the force (N) by the area of the surface (m²).

The maximum amount of pressure in the normal air will be put as 1 bar or 10⁵ Pa. The force can be put as the maximum weight of doors and trunklid. As the weight is different each type, we put the heaviest weight possible so it can be used for all types of cars. The force will be 250 N. Now we calculate the area of the suction and will be expressed below:

\[ 10^5 \text{Pa} = \frac{250 \text{N}}{A} \]

\[ A = \frac{250 \text{N}}{10^5 \text{Pa}} \]

\[ A = 0.0025 \text{m}^2 \]

\[ A = 25 \text{cm}^2 \]

The number of cups we are going to use is four. Therefore, the area of suction has to be divided by four.

\[ A_{\text{for 3 cups}} = \frac{25 \text{cm}^2}{4} \]

\[ A_{\text{for 3 cups}} = 6.25 \text{cm}^2/each \]

Since we already know the area will be used for each vacuum cup, we can calculate the diameter of the cup. The shape of the
cup’s surface is a circle so we can use the formula of circle’s area.

\[ A = \pi r^2 \]

\[ 6.25 \text{ cm}^2 = \pi r^2 \]

\[ r = 1.42 \text{ cm} \]

\[ d = 2.84 \text{ cm} \]

The diameter we have got is 2.84 cm. It is the minimum diameter of vacuum cup we have to use to hold an object with a weight of 250 N. As the available cups in the market start with 2 cm and then 4 cm, we choose to use 4 cm diameter.

Since we have got the size of the cup, which is 4 cm diameter, now we start to draw the gripper we are going to use. The concept will not have so many differences with the design before, it still has feet for the gripper to hold the vertical force of the object. The only different is this time there will be a kind of hook to hold the object not to fall to another side in case the vacuum got a problem. The hook will be connected to the object from the window’s blank area. Since the window is not set up yet, we can see that as our advantage. The picture of the design can be seen by the figure below:

The Yield Strength of the Iron will be 758 MPa. This is once again will be the main point to look at. The stress that is received by the model has to be less than the Yield Strength of the material. Otherwise, it will deform. Figures below will show the detailed picture of where the load and constraint take place:

Since we have go
t the size of the cup, which is 4 cm diameter, now we start to draw the gripper we are going to use. The concept will not have so many differences with the design before, it still has feet for the gripper to hold the vertical force of the object. The only different is this time there will be a kind of hook to hold the object not to fall to another side in case the vacuum got a problem. The hook will be connected to the object from the window’s blank area. Since the window is not set up yet, we can see that as our advantage. The picture of the design can be seen by the figure below:

Below will be shown the details of the material we use:

<table>
<thead>
<tr>
<th>Name</th>
<th>Iron, Cast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass Density</td>
<td>7.15 g/cm³</td>
</tr>
<tr>
<td>Yield Strength</td>
<td>758 MPa</td>
</tr>
<tr>
<td>Ultimate Tensile Strength</td>
<td>884 MPa</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stress</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Young’s Modulus</td>
<td>120.5 GPa</td>
</tr>
<tr>
<td>Poisson’s Ratio</td>
<td>0.3 ul</td>
</tr>
<tr>
<td>Shear Modulus</td>
<td>46.3462 GPa</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Part Name(s)</th>
<th>main</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISO 80 x 80 0000001.ipt</td>
<td></td>
</tr>
<tr>
<td>ISO 20 0000002.ipt</td>
<td></td>
</tr>
<tr>
<td>ISO 20 0000003.ipt</td>
<td></td>
</tr>
<tr>
<td>ISO 40 x 40 00000012.ipt</td>
<td></td>
</tr>
<tr>
<td>ISO 80 x 80 00000017.ipt</td>
<td></td>
</tr>
<tr>
<td>ISO 40 x 40 00000014.ipt</td>
<td></td>
</tr>
<tr>
<td>ISO 80 x 80 00000019.ipt</td>
<td></td>
</tr>
<tr>
<td>ISO 80 x 80 00000018.ipt</td>
<td></td>
</tr>
<tr>
<td>adaptor</td>
<td></td>
</tr>
</tbody>
</table>

Figure 16. Gripper Design for Engine Hood

Figure 17. Material Properties of the Door’s Gripper

Figure 18. Force Loaded and Constraint of the Door’s Gripper

In second test, we are going to put the load into for parts which are the holes of which the vacuum cups take place. The amount of force will the same as before which is the weight of the door. The constraint is also using fixed constraint and will be placed on the top of the frame. The details will be shown by the figure below:

The last test will check if the gripper can survive in the actual condition. The gripper will be used to hold the door, so it will be in standing position. The feet of the gripper will receive the force in vertical way from the weight of the object. On the other hand, the vacuum cups will also receive force in horizontal ways. The vacuum cups will have to suck the part in horizontal way. The figure below will show the part of the gripper in which the two forces take place:

Figure 19. Force Loaded and Constraint of the Door’s Gripper

Figure 20. Force Loaded and Constraint of the Door’s Gripper
From that result, we can see the Von Mises Stress that occurs to the model. The amount of stress once again is lower than the amount of Yield Strength. This means the gripper is valid to be conducted. The details of all results will be shown by the Table 4.5:

<table>
<thead>
<tr>
<th>No</th>
<th>Condition</th>
<th>Material Tool: Iron</th>
<th>Yield Strength (MPa)</th>
<th>Max Von Mises Stress (MPa)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Load on Foot</td>
<td>758</td>
<td>96.0788</td>
<td>Valid</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Load on Vacuum Cups</td>
<td>758</td>
<td>55.093</td>
<td>Valid</td>
<td></td>
</tr>
</tbody>
</table>

V. CONCLUSION

To solve the problems that occur in the Hang On Part station, conducting the new supporting tool is one of the solutions. The new supporting tool can help the worker to do the activities without using another human power. Many processes in the station are categorized as non-optimized process. The processes can be said as non-optimized because they contain waste every time the worker does the activities.

The wastes that happen in the process can be as waste of waiting and talent. The waste of waiting happens when the worker has to wait another to do the material handling that cannot be done only by one person. The waste of talent occurs in the same time. Another worker has to help when he can work on another task. The handling process can be optimized by adding supporting tool to move the object. The object can be such as engine hood, trunklid, and door.

As the planned model of the supporting tool has already been designed, the result can be seen as an improvement. Since it cannot be implemented in the near future, the improvement in cycle time in the station cannot be seen yet. When the new tool has been installed and used by the worker while doing the process, the improvement in time can be measured as number.

However, the improvement that has been achieved can be directly seen in the number of worker in some processes. The waste of talent can be reduced by using the new supporting tool in some processes. Some activities, that has to be done by two workers before, can be done only by one worker.

ACKNOWLEDGMENT

I would like to give huge glory to God, who has led me going through all the obstacles from the beginning. For only by His grace, I can start the project and finish it well.

I also would like to give an honor to my beloved parents who keep motivating me whenever I was hopeless in doing this thesis project. Respect is also given to my lovely sister who always be there for me.

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REFERENCES