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Research Article

Redesign of Cover Lower Dies on Compaction Tool in Sealface Manufacturing Based on Powder Metallurgy Process

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A B S T R A C T

The cover lower dies are a crucial component in the ejector compaction tool system used in powder metallurgy for sealface production. However, failures during the compaction process have led to component deformation after the production of more than eleven sealfaces. This study investigates the ejector compaction tool system, focusing specifically on the cover lower dies, with the aim of optimizing the tool's construction. Employing the Pahl & Beitz design methodology, this research includes discussions with previous researchers, observation of existing tools, disassembly of the current tool, and simulation analysis. The study emphasizes static analysis to assess stress, deflection, and safety factor values, with a target safety factor exceeding 2.00 for the redesigned lower dies cover. The optimal solution involves changing the material to AISI D2 with a hardness of 62 HRC, modifying the cover lower dies thickness to 13 mm, and increasing the number of springs and retaining pins from 2 to 4. The results indicate that the redesigned ejector compaction tool system is operationally safe, signifying a successful improvement in its construction to enhance reliability and performance.

1. INTRODUCTION

Metallurgy plays a crucial role in the manufacturing industry due to its extensive use in the production of machinery, industrial parts, and components made from metal. The growing demand for advanced, lightweight, and strong metal components has led to the increasing popularity of powder metallurgy (PM)-based manufacturing. The powder metallurgy market is estimated to experience a compound annual growth rate of 12.5%, reaching $2.63 billion in 2022 and projected to attain $7.59 billion by 2030, as confirmed by Strategic Market Research. The Asia Pacific region holds a dominant position in the PM market, with a revenue share of 48.11% and is expected to reach $3.65 billion by 2030 [1]. It is worth noting that powder metallurgy is adopted in all high-end metal applications, such as automotive engines and machine parts. The modern automobile industry seeks to reduce the weight of vehicle bodies, and to achieve this, various alloy combinations are employed. However, the most advanced technology for producing lightweight cars and commercial vehicles is powder metal-based manufacturing. With the shift towards electric vehicles, there will be a significant demand for

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technologies aimed at modernizing vehicle architecture and reducing the overall structure's weight [2], [3].

Powder metallurgy (PM) is one of the additive manufacturing technologies that continues to grow today. PM is a technology that covers most metals and alloy materials, and with a variety of forms. PM is a manufacturing process for making reliable metal products [4]. Generally, powder metallurgy consists of four processes as shown in Fig. 1, including powder preparation, mixing, compaction, and sintering.

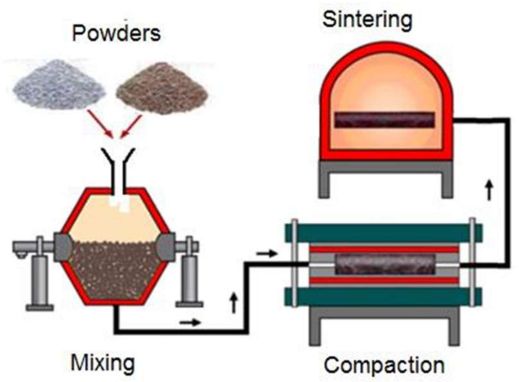

Figure 1. Powder Metallurgy Process [5]

The utilization of PM's high precision forming capabilities yields components possessing shapes that are nearly net, features that are intricate, and dimensions that are precise, all achieved without the need for additional machining. Through the production of components with a uniform structure, the PM process empowers manufacturers in creating products that exhibit enhanced consistency. Moreover, the PM process showcases a remarkable level of adaptability, allowing for customization of performance requirements [4]. As a result of the notable advantages associated with this PM process, numerous products reliant on metal powder materials, including a mechanical seal component, are successfully manufactured.

Mechanical seal is a mechanical device that functions to prevent fluid leakage from a space / container that has a rotating shaft. The sealing process occurs because the mechanical device has 2 end face components (end faces) at a position of 90° to the axis of the shaft which are always in contact with each other due to the axial force of the spring / spring [6]. Mechanical seals are commonly installed in various types of pumps, including centrifugal pumps, gear pumps, and screw pumps. These mechanical seals are comprised of multiple components, with one particularly critical component known as the sealface (see Figure 2). The primary function of the sealface is to prevent leaks by employing two flat surfaces that come into contact with one another. Typically, the sealface is referred to as the stationary seat, which denotes the immovable portion of the mechanical seal. In contrast, the rotating part is typically crafted from a softer material, while the stationary part must possess a higher level of hardness. Consequently, the two components can be composed of different materials, such as carbon versus silicon carbide, carbon versus ceramic, carbon versus tungsten carbide, silicon carbide versus silicon carbide, or silicon carbide versus tungsten carbide.

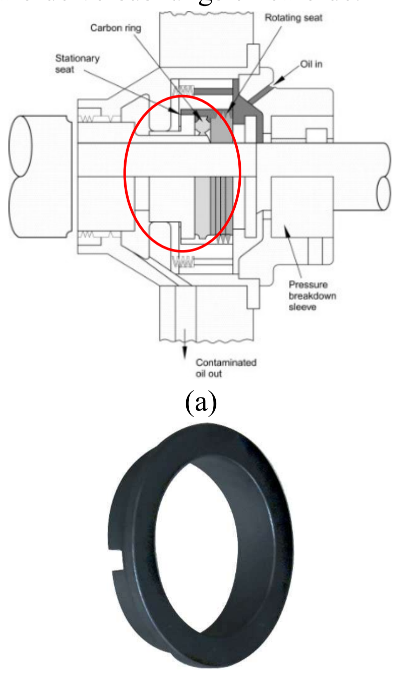

Figure 2. Stationary Seat (red circle) as Sealface (a), sealface product (b)

At present, there is an ongoing initiative taking place at Politeknik Manufaktur Bandung to produce a sealface in collaboration with a Private Corporation Industry. The selection of the PM method for the production process was based on its perceived efficiency in terms of time and material usage. In a manner like the powder metallurgy process in general, Politeknik Manufaktur Bandung

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follows four distinct processes, namely material preparation, mixing, compaction, and sintering, in order to produce the sealface. However, during the production process, there was a failure in the compaction stage. Specifically, the lower dies that cover the compaction tool's ejector system displayed a deformation during the production of more than 11 products (figure 3). This deformation, characterized by a bend, is corroborated by the presence of the retaining pen.

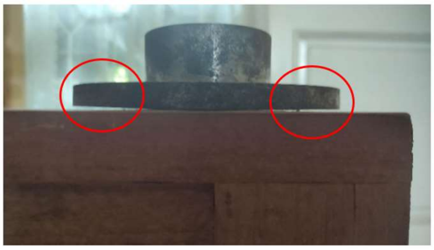

Figure 3. Cover existing lower dies on a flat surface by displaying different sides to show clarity (in red circle)

The deformation occurs due to the uneven distribution of the number of retaining pen on the cover lower dies and due to the tool disassembly process (the cover lower dies part is a component that is difficult to remove so it requires more effort in removing it).

Therefore, this study aims to investigate the failure and redesign an ejector system on the sealface manufacturing compaction tool, specifically at the cover lower dies component. The Pahl & Beitz method was used to help understand product requirements, facilitate the decision-making process in design and develop solutions that meet these needs. Finally, the design results were validated using CAE simulation analysis.

2. METHODOLOGY

Pahl and Beitz [5] proposed a way of designing products as described in their book; Engineering Design: A Systematic Approach (Fig. 4). The Pahl and Beitz way of designing consists of 4 activities or phases, each of which consists of several steps. The four phases are [6]:

1. Planning and task clarification
   It is a step to collect data related to problems or obstacles that arise from a study. After obtaining the root of the problem, a list of demands will be formed related to the design to be made.
2. Product concept design
   This stage is the step of determining the function and its structure. After that, the solution principle will be sought and the step of decomposing it into variants that can be realized.
3. Product shape design
   This stage starts from breaking down the design into modules followed by early design and final design.
4. Detail design
   This stage is the process of pouring the final design concept into working drawings, this is composed of detailed drawings which include a list of components, specifications, constituent materials, tolerances, and others.

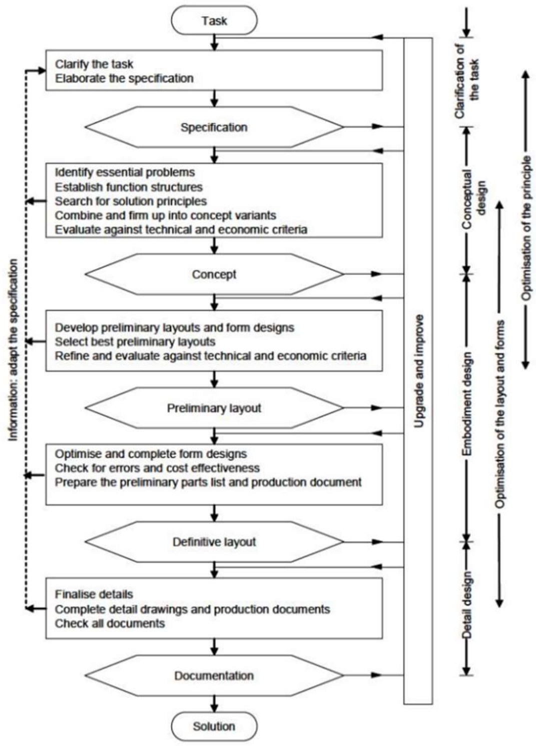

Figure 4. The design process according to Pahl & Beitz

3. RESULT AND DISCUSSION

3.1. Planning and Task Clarification

3.1.1. Data Collection

The existing machine will be the main reference in this investigation process in collecting data. From the investigation of the existing machine, it was concluded that:

1. Compaction tool is placed on the hydraulic press. This hydraulic press will provide a compressive force of 30 tons (294.199 kN) on the compaction tool when the compaction process takes place.
2. The material of the cover lower dies needs to be reviewed. This is because the cover lower dies component is a bouncy part after carrying out the production process of more than 11 products. Based on the results of the investigation, this component should be hardened first before the assembly process is carried out, which is not in accordance with the situation in the field that this component is not hardened.
3. In cover lower dies, the parameter to be reviewed is yield strength, because yield strength is the stress value where the material starts to undergo plastic deformation. Then, the cover lower dies component was also simulated analysis with the Solidworks application, and the von mises stress result of the component was obtained after receiving a 30-ton load of 2,059.990 MPa, which stress in this simulation exceeds the yield strength of AISI O1 material with a hardness level, which is 677 MPa. From this information, a safety factor of 0.328 was obtained.
4. There are only two dowels holding the cover lower dies part, which is one of the causes of the cracking of the cover lower dies component. From the results of the investigation, only two (2) retaining dowels were installed due to lack of space to increase the number of dowels. The number of dowels affects the load received by the cover lower dies so it needs to be optimized.

3.1.2. Problem Identification

This sealface product is produced through a powder metallurgy process, where one of the processes is compacting. During the compacting process, there was a problem where the cover part of the lower dies bounced after producing more than 11 products. This is certainly an obstacle to the production process of sealface products, which until now the production process has not continued. The bounciness of the lower cover dies component is caused by the inappropriate lower cover dies material and the retaining pen that holds the lower cover dies during the product forming process.

From the background of the problem, a list of demands for implementing the optimization tool emerged, which can be seen in Table 1.

Table I. Primary demands and secondary demands

Primary Demands		
No	**List of Demands**	**Description**
1	Design of cover lower dies	The design of the cover lower dies is more optimal than the existing design in resisting compressive loads with a safety factor value of > 2.00.
Secondary Demands		
No	**List of Demands**	**Description**
1	Assembly	Easy in assembly process
2	Maintenance	Easy in maintenance process

3.2. Product Concept Design

3.2.1. Blackbox and Glassbox

The following figure is a blackbox image of the compaction tool to be investigated. Black box is an explanation of the input, process and output produced by the compaction tool. In addition, the black box also provides an overview of the functions that work on the compaction tool so that

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it can produce products. Fig. 5 below is an image of the blackbox and glassbox of the compaction tool.

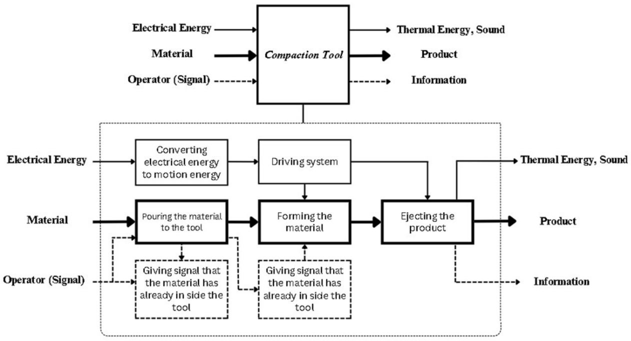


Figure 5 Blackbox and Glassbox

3.2.2. *Part Function Description*

After completing the black box, the functions contained in the compaction tool can be seen in Fig. 6

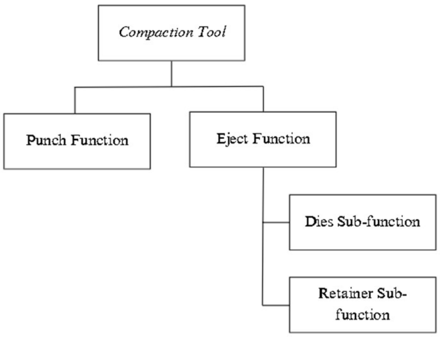


Figure 6. Part function description

The function parts of the Compaction tool include the punch function and the eject function.

1. Punch Function
   Punch has a function to provide compressive force to the dough material in the compaction tool. This punch must be strong in providing compressive force because there is a product formation process. In accordance with the problem limitation, the punch function will not be discussed more specifically in this study. Fig. 7 is an image of the punch function.

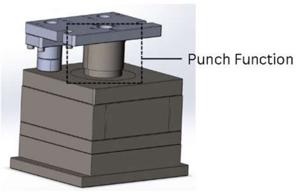


Figure 7. Punch function

2. Ejection Function
   Ejection on the compaction tool functions as a product mold and to remove the product from the compaction tool. In the ejection function, there are parameters that need to be considered, namely the cover lower dies material. The output of this function is a sealface product that is in accordance with the working drawings. In the ejection function, there are sub-functions of dies and sub-functions of holders, each of which functions as a product mold and as a system to push the product out of the compaction tool.
   a. Dies Sub-function
      Dies function as molds when the material is poured on the compaction tool. This component is also a component that helps the product ejection process when the product is finished forming. Fig. 8 is an image of the dies sub-function.

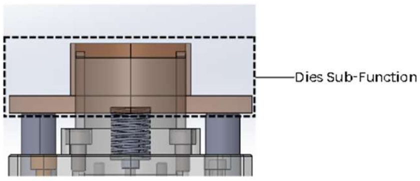


Figure 8. Dies Sub-function

   b. Spring and Retaining Pen Sub-function
      The spring here functions as a component that pushes the cover lower dies back to its original position, while the retaining pen functions as a limiter of the compaction process. This pen is in direct contact with the cover of the lower dies during the compacting process. An alternative to this sub-function is the number of retaining pin (Fig. 9).

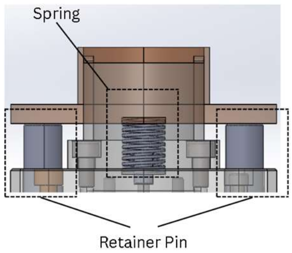


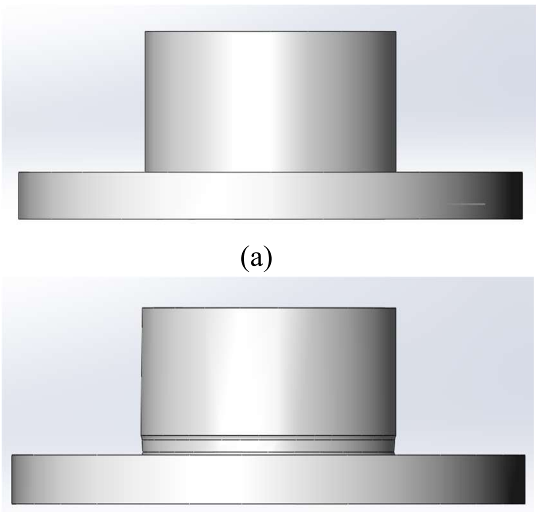
Figure 9. Spring and Retaining Pin Sub-function

3.2.3. *Optimalization Process*

In the optimization stage, the author uses software to simulate the analysis of the cover lower dies. Here, several stages of cover lower dies analysis simulation are carried out with different parameters.

1. Cover Lower Dies Using Hardened AISI O1 Material

According to the information that has been obtained, the cover lower dies uses AISI O1 material without going through the harden process, with an initial hardness level of 18.7 HRC and a yield strength of 677 MPa, which should be hardened first. Here the author wants to simulate the analysis of the cover lower dies by using the material properties of AISI O1 hardened to 62 HRC with a yield strength of 2200 MPa. But before that, the author wants to make geometry changes to the existing cover lower dies because the existing cover lower dies does not have an undercut (shown as Fig. 10 (a)). Therefore, here the author first makes an undercut on the existing cover lower dies (Fig. 9 (b)) before analysis.



(a)

(b)

Figure 10 Before and after undercut of cover lower dies

After that, the author conducted a simulation analysis on this existing cover lower dies by hardening the material to AISI O1 hardened to 62 HRC with a yield strength of 2200 MPa. Fig. 11 is the determination of Dynamics of Free Body Diagram in Solidworks software before the analysis is carried out.

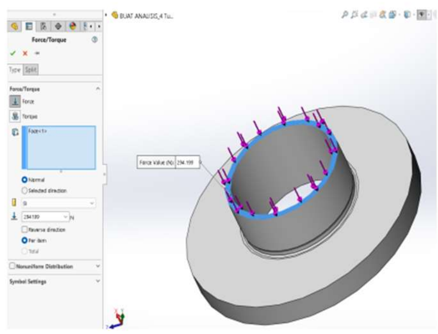
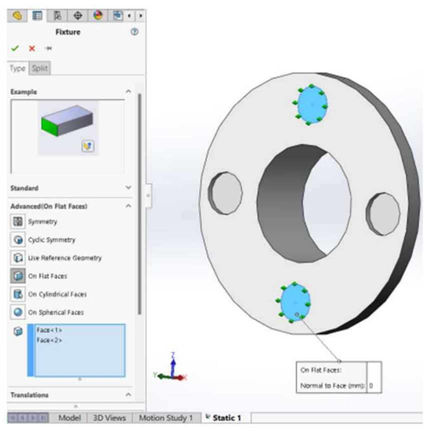
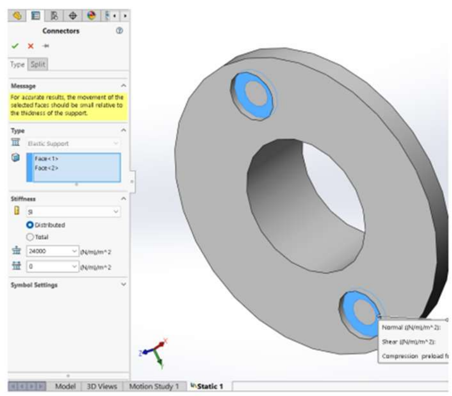
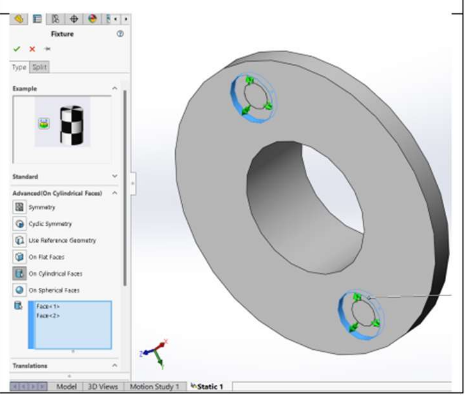
No	Descrioption	Visual
1	The pressing force exerted by the hydraulic press machine through the upper punch to the Lower Dies Cover	
2	2 pieces of Lower Dies Cover Retaining Pin (Fixture)	
3	2 Springs that become fixture elastic support	
4	2 Springs that become the fixture for locking the rotation of the lower dies cover	

Figure 11. Free Body Diagram Determination

After simulating the analysis, the results are shown in Table II.

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Table II. First Optimalization Simulation Result

The cover lower dies using AISI O1 material hardened to 62 HRC (Yield Strength = 2200 MPa)				
No	**Mesh (mm)**	**Element Total**	**Von Mises (MPa)**	***Safety Factor***
1	20	643	2142,346	1,027
2	15	1042	3034,692	0,725
3	10	2017	3481,944	0,632
4	6	6118	2542,004	0,865
5	5,5	7202	3336,257	0,659
6	5	10073	3924,829	0,561
7	4,5	13491	3721,256	0,591

From this table, a mesh convergence curve can be obtained by comparing the total elements with the stresses that occur. Figure 12 is an image of the comparison curve.

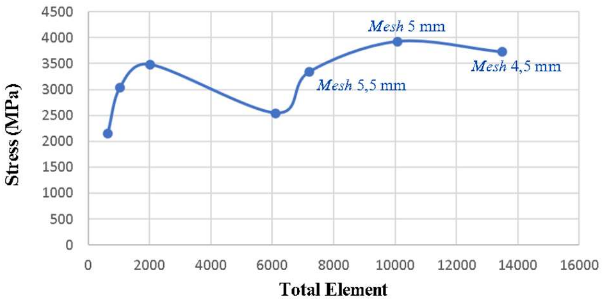
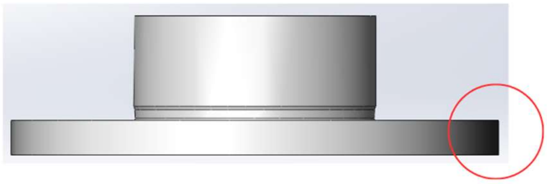


Figure 12. Mesh convergence of first optimalization

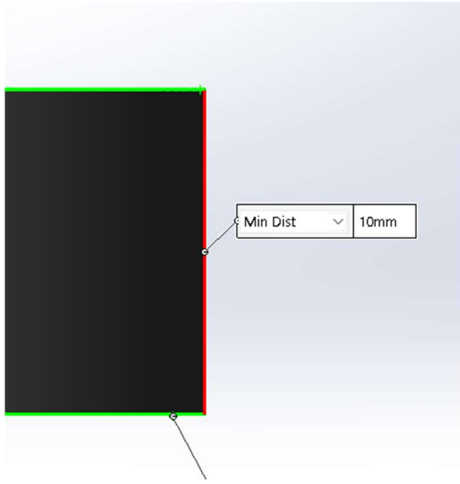
Based on the curve, the meshing convergence curve is sloping. This shows that as the curve slopes, the simulation results in the CAE software are acceptable. If there is a curve that slopes then increases or decreases drastically, the accepted result is the result of the curve that slopes because the results between one meshing size to another meshing size are close (convergent). In this simulation, the simulation results with a meshing size of 5.5 mm are chosen as a reference because they can already represent smaller meshing sizes, and this design is not optimal yet.

2. Changing the Thickness of Cover lower dies with Material AISI O1 62

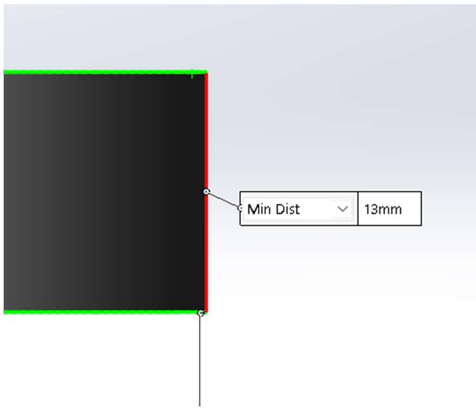
After obtaining a failure in the simulation results of the cover lower dies with AISI O1 material hardened to 62 HRC, the author wants to make changes to the geometry of the cover lower dies. The thing that will be changed on the cover lower dies is the thickness of the pen and spring holder, with an initial thickness of 10 mm, as shown in Fig. 13.



(a)



(b)



(c)

Figure 13. (a) Cover lower dies, (b) Existing thickness, (c) after optimalization thickness

Furthermore, the author simulates the analysis again with the same steps as in Fig.11, using the same material, AISI O1 with a hardness level of 62 HRC.

Table III. Second Optimalization Simulation Result

The cover lower dies using AISI O1 material hardened to 62 HRC (Yield Strength = 2200 MPa) with a thickness change to 13 mm

No	Mesh (mm)	Element Total	Von Mises (MPa)	*Safety Factor*
1	20	639	1474,293	1,492
2	15	1134	1889,215	1,165
3	10	2199	2377,744	0,925
4	6	7474	2408,773	0,913
5	5,5	8808	2444,931	0,900
6	5	12027	2041,365	1,078
7	4,5	15546	2747,722	0,801
8	4	21388	2754,491	0,799

From Table III., a mesh convergence curve can be obtained by comparing the total elements with the stresses that occur. Fig. 14 is an image of the comparison curve.

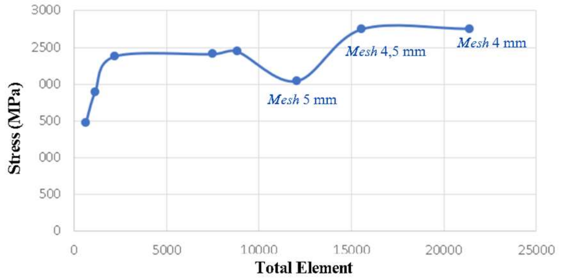


Figure 14. Mesh convergence of second optimalization

The simulation results according to the mesh convergence curve in Figure 14 show that thickening the cover lower dies still cannot withstand the stresses that occur, which is 2,747.722 MPa with a safety factor of 0.801, at a meshing size of 4.5 mm (convergent meshing size). It can be concluded that changing the thickness has not resulted in an optimal cover lower dies.

3. Changing the Cover lower dies Material to AISI D2 62 HRC

After obtaining failures in the simulation results of the cover lower dies by changing its thickness, the next step the author took was to make material changes to the cover lower dies. Here, the author has chosen a material with better yield strength parameters than AISI O1 with a hardness level of 62 HRC, namely AISI D2 with a hardness level of 62 HRC. AISI D2 with a hardness level of 62 HRC has a yield strength of 2970 MPa, which has a difference of 770 MPa with AISI O1 with a hardness level of 62 HRC.

Furthermore, the author conducted an analysis simulation on the cover of lower dies with AISI D2 material with a hardness level of 62 HRC with the same procedure according to Fig. 11, but using the existing thickness, which is 10 mm.

Table IV. Third Optimalization Simulation Result

The cover lower dies using AISI D2 material hardened to 62 HRC (Yield Strength = 2970 MPa)				
No	**Mesh (mm)**	**Element Total**	**Von Mises (MPa)**	***Safety Factor***
1	20	643	2142,346	1,386
2	15	1042	3034,692	0,979
3	10	2017	3481,944	0,853
4	6	6118	2542,004	1,168
5	5,5	7202	3336,257	0,890
6	5	10073	3924,829	0,757
7	4,5	13491	3721,256	0,798

Table IV. is the result of the analysis of cover lower dies with AISI D2 62 HRC material with various meshing sizes. From this table, a mesh convergence curve can be obtained by comparing the total elements with the stresses that occur. Fig. 15 is an image of the comparison curve.

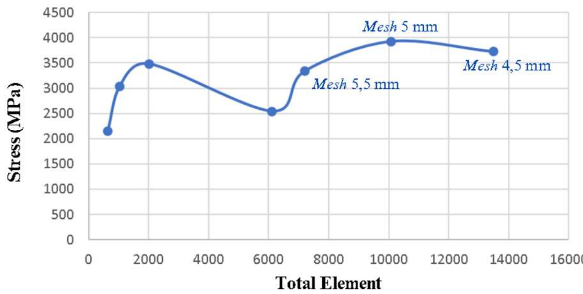


Figure 15. Mesh convergence of third optimalization

The simulation results show that the stress occurring in the cover lower dies is 3,336.257 MPa, with a safety factor of 0.890 with a meshing size of 5.5 mm. The safety factor that has been obtained still does not reach the minimum permissible value, so the author needs to carry out the next stage of optimization.

4. Changing the Thickness of Cover lower dies Using AISI D2 62 HRC Material

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After obtaining failures in the simulation results of the cover lower dies with AISI D2 material hardened to 62 HRC with a thickness of 10 mm, the author wants to increase the thickness of the cover lower dies to 13 mm.

Furthermore, the author simulates the analysis again with the same steps as in Fig. 11, the results can be seen in Table V.

Table V. Fourth Optimalization Simulation Result

The cover lower dies using AISI D2 material hardened to 62 HRC (Yield Strength = 2970 MPa) with a thickness change to 13 mm.				
No	**Mesh (mm)**	**Element Total**	**Von Mises (MPa)**	***Safety Factor***
1	20	639	1474,293	2,015
2	15	1134	1889,215	1,572
3	10	2199	2377,744	1,249
4	6	7474	2408,773	1,233
5	5,5	8808	2444,931	1,215
6	5	12027	2041,365	1,455
7	4,5	15546	2747,722	1,081
8	4	21388	2754,491	0,799

Table V. is the result of the analysis of cover lower dies with AISI D2 62 HRC material of various meshing sizes with component thickness being 13 mm. From this table, a mesh convergence curve can be obtained by comparing the total elements with the stresses that occur. Fig. 16 is an image of the comparison curve.

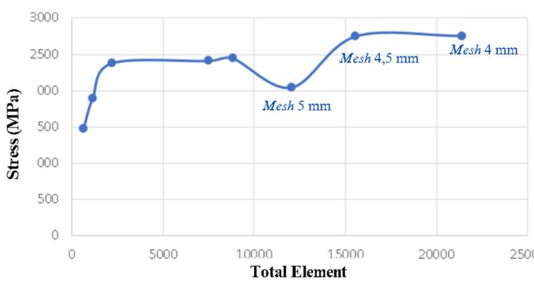


Figure 16. Mesh convergence of fourth optimalization

The simulation results according to the mesh convergence curve in Fig. 16 show that the thickening of the cover lower dies still cannot withstand the stress that occurs, which is 2,747.722 MPa with a safety factor of 1.801, at a meshing size of 4.5 mm (convergent meshing size). It can be concluded that changing the thickness with AISI D2 62 HRC material still does not produce an optimal cover lower dies design.

5. Making Changes to the Ejector Compaction Tool System Construction with AISI O1 62 HRC Material

All parameters that can be changed on the cover lower dies have been optimized and the achievement of the function of the cover lower dies is still not fulfilled. The next step that the author took was to optimize the support system of the cover lower dies. Based on the observation, the function of the cover lower dies is supported by springs and retaining dowels that surround the cover lower dies. Figure III.18 is an image of the components that support the cover lower dies.

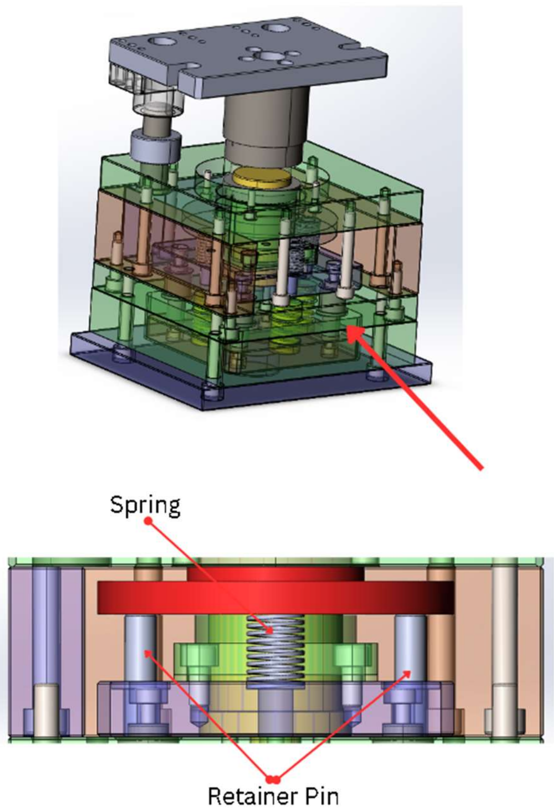


Figure 17. Support components of cover lower dies

From the observation, it is obtained that the layout of the spring and the retaining pen that supports the cover lower dies is as shown in Figure 18, with the note that the thick lined circle is the spring and the shaded circle is the retaining pen.

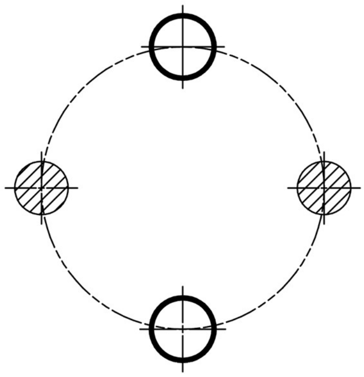


Figure 18. Layout of the existing springs and retaining pins

Seeing this phenomenon, here the author tries to rearrange the existing layout. The author tries to maximize the space available in the ejector compaction tool system in the layout rearrangement process. After that, a new layout is obtained according to Figure 19.

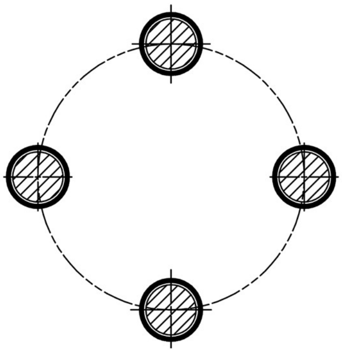


Figure 19. New layout of springs and retaining pins

In Figure 19, the position of the retaining pen is inside the spring to maximize the remaining space in the ejector compaction tool system. After making a new layout, the spring and retaining pen components need to be adjusted in number and dimensions. For the retaining dowels, the diameter will be adjusted from ⌀20 mm to ⌀12.5 mm (Figure 20) and the number from 2 pieces to 4 pieces. The spring will be adjusted from MISUMI SWC 20-30 spring to MISUMI SWY 20-30 spring and the number from 2 pieces to 4 pieces.

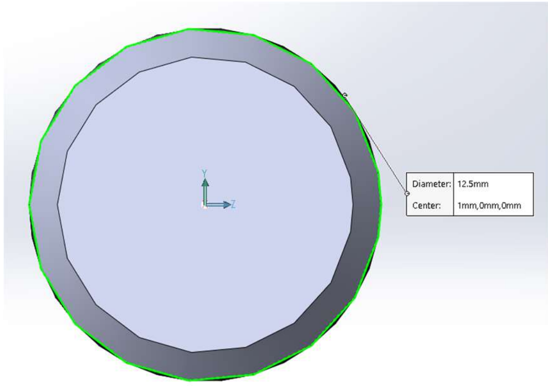
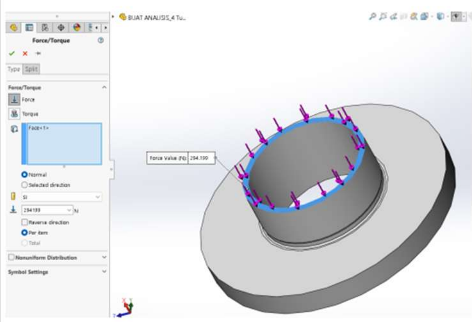
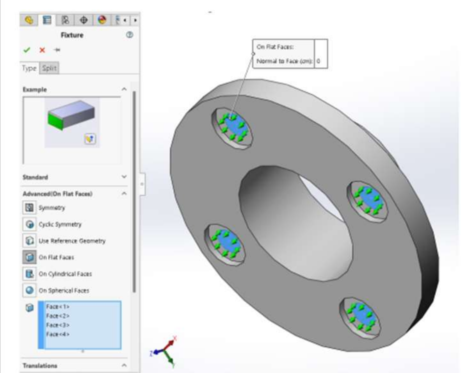


Figure 20. Retaining pin new diameter (12.5 mm)

After that, the author conducted a simulation analysis using software. The material to be used in this simulation is the starting material, AISI O1 which is hardened to 62 HRC. For the thickness of the cover lower dies, the thickness of the optimization result is 13 mm. Table III-8 is a table of Free Body Diagram determination before simulation is carried out.

No	Description	Visual
1	The pressing force exerted by the hydraulic press machine through the upper punch to the Lower Dies Cover	
2	4 pieces of Lower Dies Cover Retaining Pen (Fixture)	

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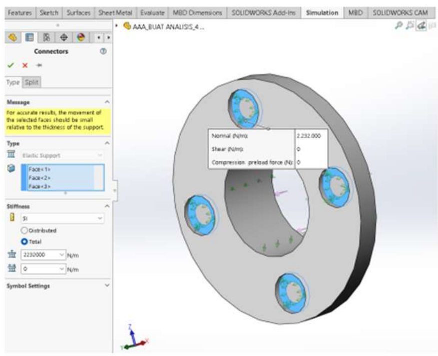
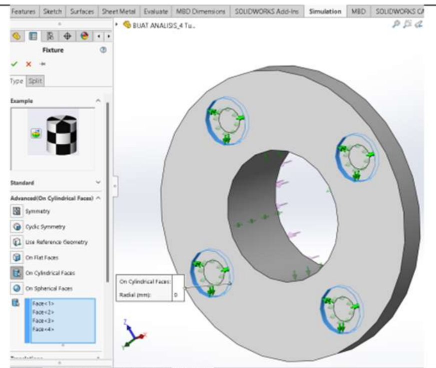
3	4 Springs that become fixture elastic support	
4	4 Springs that become the fixture for locking the rotation of the lower dies cover	

Figure 21. Free Body Diagram Determination of new Construction for simulation

Table VI. Fifth Optimalization Simulation Result

The cover lower dies using AISI O1 material hardened to 62 HRC (Yield Strength = 2200 MPa) with a change in thickness to 13 mm and changes in the layout of the spring and retaining pins				
No	**Mesh (mm)**	**Element Total**	**Von Mises (MPa)**	***Safety Factor***
1	20	894	1298,943	1,694
2	15	1366	1350,604	1,629
3	10	2440	1422,610	1,546
4	8	3730	1124,706	1,956
5	7,5	4439	1351,911	1,627
6	7	5229	1609,805	1,367
7	6,5	6236	1613,233	1,364
8	6	7515	1403,300	1,568
9	5,5	8899	1425,040	1,544
10	5	12151	1356,126	1,622
11	4	23233	1507,659	1,459

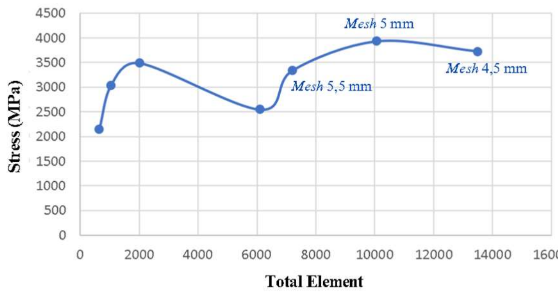


Figure 22. Mesh convergence of fifth simulation

The results shown at Table VI. And Figure 22. show better results than before. The stress that occurs in the cover lower dies is 1425.040 MPa with a safety factor obtained of 1.544 at a convergent meshing size, which is 5.5 mm in size. However, the resulting safety factor still cannot reach the minimum value. Therefore, it can be concluded that further optimization stages still need to be carried out.

6. Making Changes to the Construction of the Ejector Compaction Tool System with AISI D2 62 HRC Material

By applying the optimization results in the previous stage, here the author simulates the analysis again on the cover lower dies, but with another choice of material that was previously selected, namely AISI D2 with a hardness level of 62 HRC. Next, the author made material changes to the software before analysis, then the author determined the Free Body Diagram of the cover lower dies in accordance with Figure 21. Table VII. is a table of simulation results of analysis that has been carried out.

Table VII. Sixth Optimalization Simulation Result

The cover lower dies using AISI D2 material hardened to 62 HRC (Yield Strength = 2200 MPa) with a change in thickness to 13 mm and changes in the layout of the spring and retaining pins				
No	**Mesh (mm)**	**Element Total**	**Von Mises (MPa)**	***Safety Factor***
1	20	894	1298,943	1,694
2	15	1366	1350,604	1,629
3	10	2440	1422,610	1,546
4	8	3730	1124,706	1,956
5	7,5	4439	1351,911	1,627
6	7	5229	1609,805	1,367
7	6,5	6236	1613,233	1,364
8	6	7515	1403,300	1,568
9	5,5	8899	1425,040	1,544
10	5	12151	1356,126	1,622
11	4	23233	1507,659	1,459

From table above, we obtained mesh convergence curve corresponding to Figure 23.

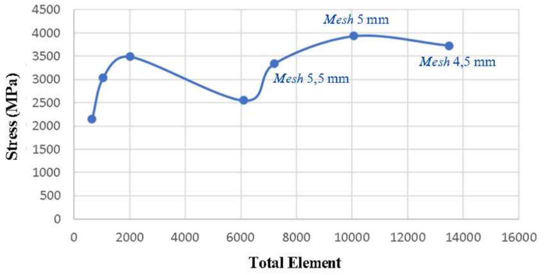
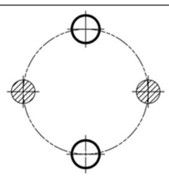
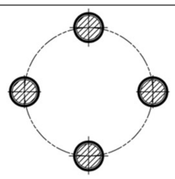


Figure 23. Mesh convergence of sixth simulation

From Figure 23., the von mises stresses on the lower dies cover is 1425.040 MPa with a safety factor of 2.084 at a convergent meshing size, which is 5.5 mm. These results show that the cover design of lower dies has reached the minimum safety factor value, and it can be said that the design of cover lower dies has been optimized.

Table VIII. is a comparison table between the existing lower dies cover design and the optimized lower dies cover.

Table VIII. Comparison between existing and optimized cover lower dies design

Redesign Cover Lower Dies		
Parameter	**Existing**	**Optimalization Result**
Cover lower dies material	AISI O1 hardened to 62 HRC with yield strength 677 MPa	AISI D2 hardened to 62 HRC with yield strength 2970 MPa
Cover lower dies thickness	10 mm	13 mm
Springs and retainer pins layout		
	The shaded area is a retaining pin, and the thickly lined area is a spring	
Spring type	MISUMI SWC 20-30	MISUMI SWY 20-30
Retainer pin diameter	⌀20 mm	⌀12,5 mm
Von mises stresses	2.059,990 MPa	1.425,040 MPa
Safety factor	0,328	2,084

3.2.4. *Final Result of Optimalization Process*

After the optimization process is carried out, the final optimization results show that the new lower dies cover design has been optimized. Figure 24 is a summary of the optimization results that have been carried out on the lower dies cover component and its variables.

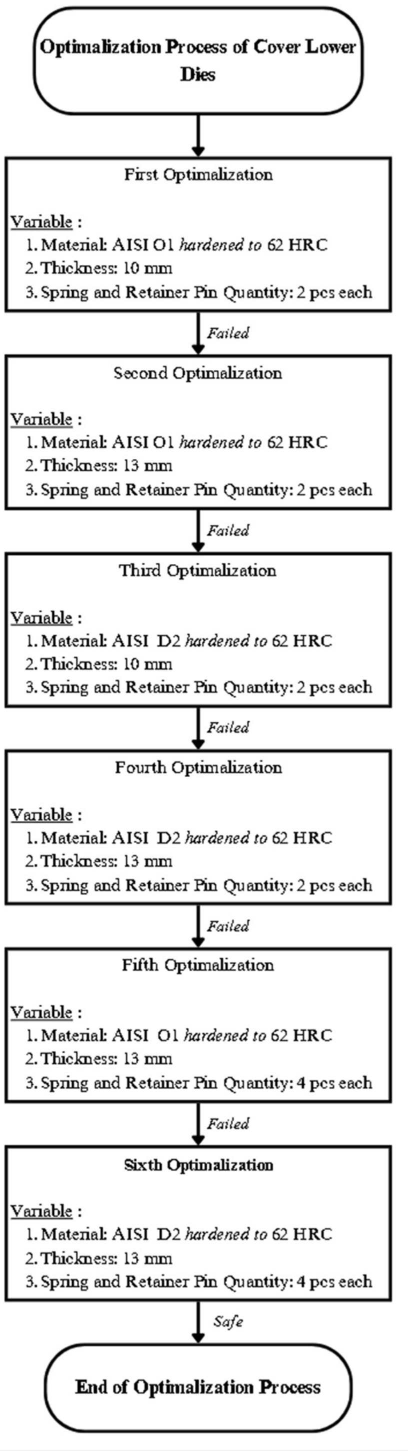


Figure 24. Flowchart of Optimalization Stages of Cover lower dies

3.3. ***Product Shape Design***

At this stage, alternative variations of the concept that have been selected are designed in detail. The output of this stage is a 3D model of the compaction tool with the new ejection system.

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3.3.1. Making Design Draft

The first step in designing the shape of the product is to make a draft design. The purpose of making this draft design is as a visualization of the design to be made and easier to do details. Figure 25 is an initial draft of the draft that has been made.

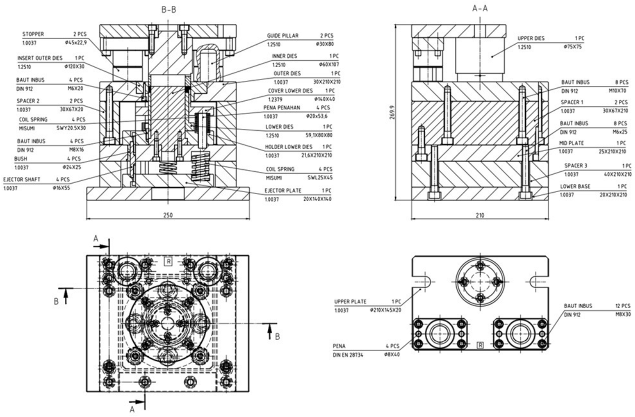

Figure 25. Early draft of the compaction tool design

3.3.2. Preliminary Evaluation of Design

Fulfillment of the list of demands that have been made previously can be evaluated, the results of the process of planning, drafting and designing. The results of the initial evaluation of the design can be seen in Table IX.

Table IX. Fullness of the list of demands after the optimization process

Primary Demands			
No	**List of Demands**	**Description**	**Result**
1	Design of cover lower dies	The design of the cover lower dies is more optimal than the existing design in resisting compressive loads with a safety factor value of > 2.00.	Fulfilled
Secondary Demands			
No	**List of Demands**	**Description**	
1	Assembly	Easy in assembly process	Fulfilled
2	Maintenance	Easy in maintenance process	Fulfilled

3.4. Detail Design

At the detailed design stage, the designer creates, compiles, shapes and pays attention to the process of making and validating working drawings as well. The output of this stage is the draft design and working drawings of the compaction tool.

3.4.1. Draft Design

The results of 3D designs that have been made using the help of CAD software will be presented in the form of draft designs. A draft design is an overall construction drawing of the product that has been made, in which there is information about the arrangement of components that support the product and the position of the components. A draft draft of the compaction tool has been completed.

3.4.2. Detail Design

After successfully designing a product concept in 3D, the next step is to create a working drawing in which there is material information, geometry, dimensions, tolerances and various kinds of product views so that they can be read, understood, and processed. Drawing detail of the compaction tool components has been completed.

3.5. Design Validation

The simulation results of the lower dies cover that have been done previously will be validated by manual calculations. From the manual calculations that have been done, Table X. is the result that have been obtained along with the results of the analysis simulation that has been carried out

Table X. Data comparison between simulation and manual calculation

Validation Control	**Simulation Analysis Result**	**Manual Calculation Result**	**Deviation**

Von Mises Stress	1425,040 MPa	1568,549 MPa	9.1%
Safety factor	2,083	1,893	9.1%

4. CONCLUSION AND SUGGESTION

4.1. Conclusion

Based on the investigation and optimization process that has been carried out on the ejector system of the compaction tool, it is concluded that:

1. This research has created an ejector system design from the compaction tool, especially the cover lower dies component with more stable dimensional parameters with the production of a safety factor more than the permissible value (2.00 – 3.00) so that it is more optimal than the previous design, the impact is the efficiency of the compaction tool.
2. In the ejector system of the compaction tool, there are changes including:
   a. The material of the lower dies cover was changed from AISI O1 to AISI D2 hardened to 62 HRC.
   b. The geometry of the cover lowers dies by changing the thickness to fulfill the function.
   c. Layout along with the number of springs and retaining pens that support the ejection function.
   d. Spring type in adjusting the new layout.
   e. The diameter and length of the holding pen in accordance with the new layout.
3. From the design of the new ejector system, a simulation analysis with the help of software was carried out so that a voltage of 1425.040 Mpa was obtained with a mesh size of 5.5 mm, a maximum displacement value of 0.158 mm, and a safety factor of 2.083.

4.2. Suggestion

From the investigation and research process that has been done, there are several suggestions that the author has made. Among them are the following:

1. Further investigation of the dimensions of the compaction tool component is necessary because there are components with disproportionate geometry.
2. The development of a material entry system into the compaction tool can be done because currently the process of entering material into the compaction tool is still done manually.

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