# THE INTAKE PORT OF DI-ENGINE TYPE VIKYNO RV165 DESINGED USING 3D-CAE SOFTWARE

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## ABSTRACT

*The intake manifold profile in a marine diesel engine profoundly influences engine intake performance, which, in turn, significantly impacts the engine's power characteristics and exhaust emissions which leading to marine polution and challenging the marine sustainable development. Improving the performance of the appropriate geometric design of the intake manifold in order to optimize the study time is a key basis. This research aims to build a parametric model for the 3D profile of the VIKYNO RV165-2 engine intake line. By changing the value of parameter variables in the model through SolidWorks software, it is able to design and change the 3D profile design of the intake manifold. The 3D model of the intake line will be parameterized based on the 2D design drawings of this part provided by VIKYNO. The parameter variables used are upper inclination, lower inclination, curvature, intake valve diameter, input cross-section. Many different 3D models of intakes will be created with respect to the values of parameter variables changed by using SolidWorks software. The results of the study provided a parametric model for the 3D profile of the intake tract, linking the parametric variables of the model with Solidwork software as a basis for speeding up this detailed 3D design process. The 3D design of the intake by the parametric model compared to the 3D design of the intake manifold by direct rendering from the 2D drawing has a difference of no more than 2% in volume. This adaptability and precision are crucial for ensuring air intake efficiency for marine engines operating in diverse and challenging marine conditions.From the platform model, the change of input variables is displayed quickly on new designs, in accordance with the standard, and thereby the model is selected for the stage of researching the efficiency of air intake on the engine.*

***Keywords:** CAE, Diesel engine, intake port geometry, numerical design.*

## I. INTRODUCTION

Numerical modeling is a tool formed to make predictions and evaluate the performance of a physical system in practice in which implementing theoretical or experimental analysis methods is difficult. Along with computer science and information technology development, digital simulation tools are increasingly enhanced to support industrial product research and development. To ensure reducing the amount of time required for the development process and avoid limitations of experimental measuring equipment, numerical simulation has proved its necessary and increasingly vital role in the early stages of the design process. Numerical tools are increasingly recognized as pivotal and versatile resources in enhancing design efficiency, significantly reducing materials and energy consumption. Applying these tools to the design of diesel engine intake ports holds the promise of improving marine pollution caused by engine emissions.

The research and development of diesel engines also jumped on the bandwagon by applying advanced simulation tools: AVL – Fire, CFD, Ansys ICE, ... [1,2,3,4] to showcase the mixture formation and combustion of diesel engines fully, intuitively, and realistically, thereby the engine design is improved. The digitization of the physical model is a fundamental step in the simulation process.

A key factor in renovating the quality of diesel engines is improving the intake cycle quality. Enhanced intake efficiency and increased tangled movement of the intake airflow into the engine cylinder improve the quality of mixture formation. The nature of the airflow in the cylinder at the time of fuel injection directly affects the combustion process and is a dominant factor in the power and pollution emissions of direct injection diesel engines [5,6].

Nowadays, professional graphics tools such as SolidWorks, CATIA, Inventor, etc., can eliminate most hurdles in digitizing a part or a cluster of machine parts. With the available details of design drawings and actual products as the study's object (spiral intake inside the cylinder cover of the VIKYNO engine – RV165-2), the 3D digitization is based on two basic ways:

One is to use 3D scanning technology to model details from the actual product. This takes time and a certain cost. 3D scanning is only possible when there is an actual product and serves the reverse engineering process, with little effect in improving and optimizing the product. [8]

Another is directly building 3D models from 2D design drawings (Fig. 1) using specialized design software such as SolidWorks, CATIA, and Inventor. However, building an accurate 3D loading throat according to the design drawings and ensuring smoothness in areas where there is a transition from square to round profile is not simple and time-consuming.

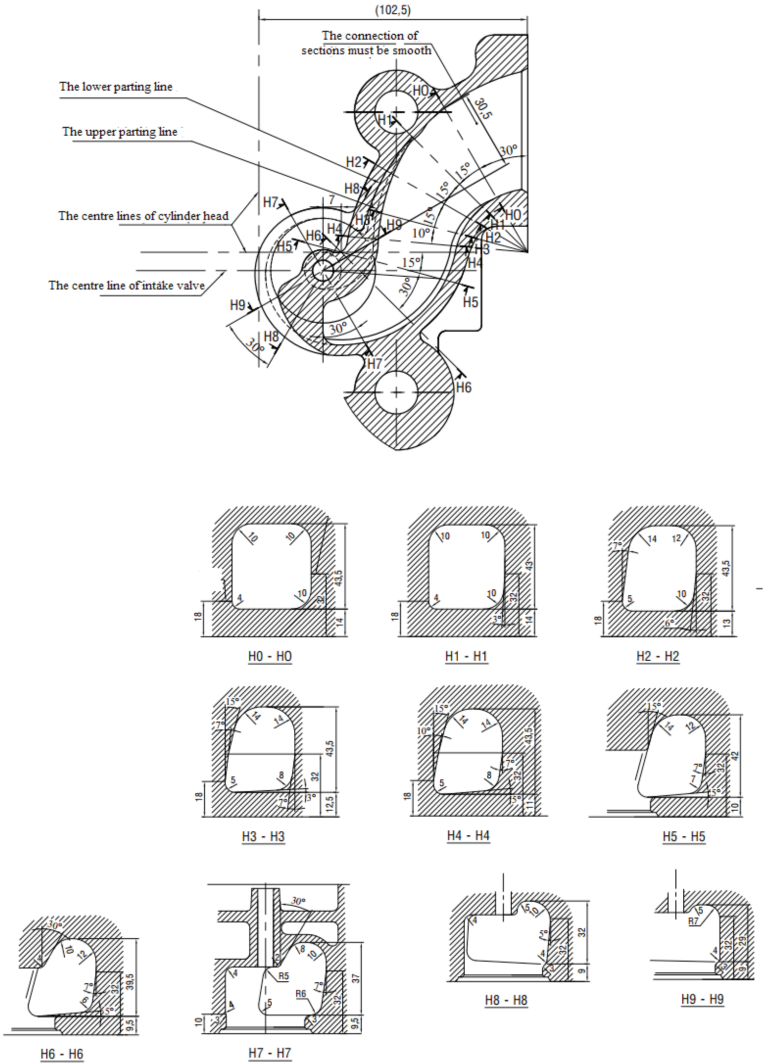


**Fig. 1. Design of 2D intake manifold of Vikyno RV165-2 Diesel engine [7].**

In SVEAM's product lines, the RV165-2 engine is designed and manufactured by the R&D department engineers, developed based on Kubota's RV125-2 engine (12.5 hp) more than 25 years ago, producing about 3,000 engines per year. The engine entered mass production in 2005; however, limited technological advancement has been applied to improve and enhance the working performance of engines.

This study presents the method of building the geometric profile of the RV165-2 diesel intake throat by setting parameters and digitizing this model using SolidWorks software. This method ensures smoothness in the transition zones in the 3D model of the loading throat. In addition, the synchronization of design parameters with the "Design Table" command in SolidWorks software makes it possible to create a new model corresponding to the value of each different set of parameters continuously and almost immediately (only takes about 3 seconds) without having to reconstruct the 3D model in SolidWorks. It is necessary to build the digital model for the process of simulating the engine's operation, which acts as the basis for constructing an algorithm that optimizes the future spiral intake throat profile of this engine.

## II. RESEARCH METHOD

**1. Effect of inlet manifold's shape on the air entraining into the combustion chamber**

*1.1. Flow rate [9]*

Flow rate is a ratio between the actual flow measured in standard conditions and theoretical flow:

$$\alpha_a = \frac{\dot{m}_a}{\dot{m}_t}$$

Actual flow measured in standard conditions

$$\dot{m}_a = V\frac{P_a}{RT_a}\ (\mathrm{kg}/s)$$

Theoretical flow:

$$\dot{m}_t = A\rho_s C_s\ (\mathrm{kg}/s)$$

Piston area:

$$\mathrm{A} = \pi \mathrm{D}^2/4\ (\mathrm{m}^2)$$

Density:

$$\rho_s = \frac{P_a}{RT_t}\left[\frac{P_2}{P_1}\right]^{\frac{1}{k}}\ (\mathrm{kg}/m^3)$$

Airflow velocity measured by entropy:

$$C_s = \sqrt{\frac{2k}{k-1}RT_t\left[1-\left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}\right]}\ (m/s)$$

$\mathrm{P_1} = 101325\ \mathrm{N/m^2}$, $\mathrm{P_2} = \mathrm{P_1} - \Delta\mathrm{P}$

*1.2. Swirl [5,6]*

An induction swirl is the intentional spinning of the intake air that promotes an even mixing of fuel and air when fuel is introduced to the intake or cylinder. Swirl is generally created by shapes in piston and cylinder head, as these shapes converge, they propel the air into motion. Some engines have flaps in the intake manifold that can be used to promote swirl.

Swirl intensity increases the velocity of the air entraining into the fuel jet, which means an acceleration of the mixing process. Also, excess swirl might cause the overlap of the sprays and an increase in unburned hydrocarbon emission. Swirl increases the ratio of the ignitable mixture at the ignition point and reduces the soot generation.

*1.3. The loss of the intake manifold [5,6]*

There are two types of losses:

- Loss along the pipe: the greater the energy loss when the pipe is long.
- Local losses: occur in locations where the section is variable. For short intake manifold, local energy losses significantly affect the overall energy loss on the pipeline.

**2. Operation process**

The intake manifold of the VIKYNO RV165-2 engine is parameterized based on the important dimensions from the 2D design of this part (Fig.1). On that basis, the 3D model of the intake manifold has two construction methods:

- Build a 3D design by rendering method directly from 2D design drawings
- Building a 3D design by parametric rendering method

The two versions of the intake manifold created from the two methods above are compared based on the model's intake manifold style and volume. The process is shown in Figure 2.

**3. Build a 3D design by rendering method directly from 2D design drawings (method 01)**

The existing intake throat design of the VIKYNO RV165-2 engine is described by multiple sections at different locations, and these sections are connected by curves located on the upper and lower mold faces, as presented in Fig.1.

To create 3D modeling using Solidworks software: From a 2D design like Fig.1, the only 3D rendering method is to use the LOFT command to connect the sections along the paths together (Fig.2). The drawback of this rendering is that it depends a lot on how it is interpolated by the software, which takes a long time.

The result after completion is shown in Figure 3

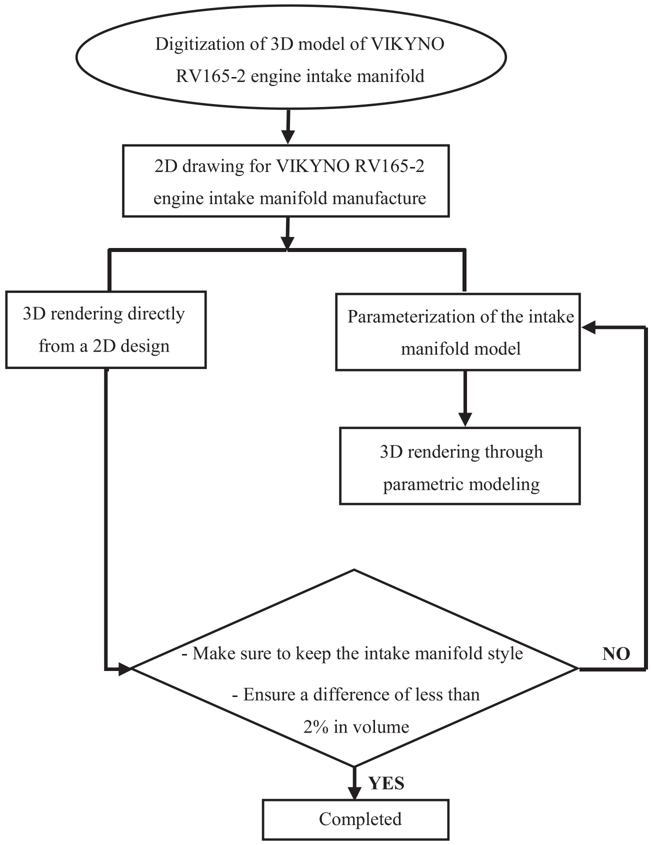


**Fig2.The process of performing 3D modeling of VIKYNO RV165-2 engine intake manifold by the parametric method.**

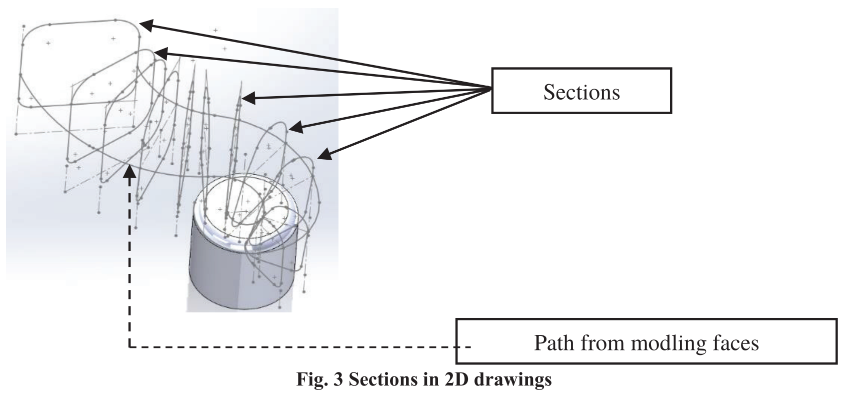


**Fig. 3 Sections in 2D drawings**

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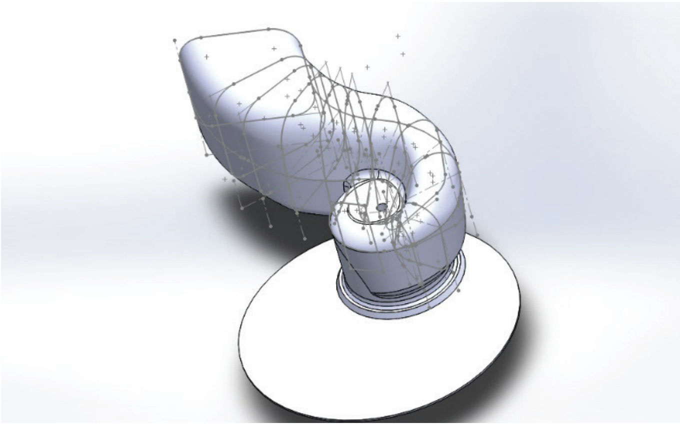

**Fig. 4 Intake manifold rendered by 2D rendering method.**

**4. Building a 3D design by parametric rendering method (method 2)**

*4.1. Set parameters for the intake throat model.*

To ensure that the operation features of the VIKYNO RV165-2 engine remain unchanged, the 3D intake throat model, after setting parameters, must meet the following requirements:

Make sure to maintain the spiral-loaded throat

Ensure the similarity in the shape of the 3D model when conducting digitalization using two methods, 01 and method 02.

The volume difference of the intake manifold in the two rendering methods is less than 2%.

Based on the important dimensions in the spiral intake throat design of the engine under study and the set goals, the plan to parameterize the spiral intake throat model is proposed as follows: (Fig.4 and Fig.5)

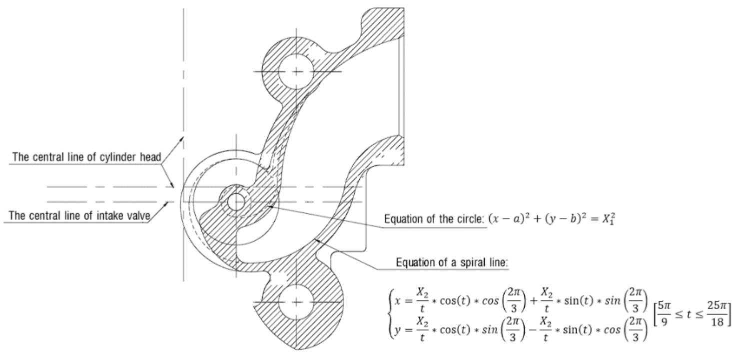


**Fig. 5 The functions representing generatrixes of the intake manifold.**

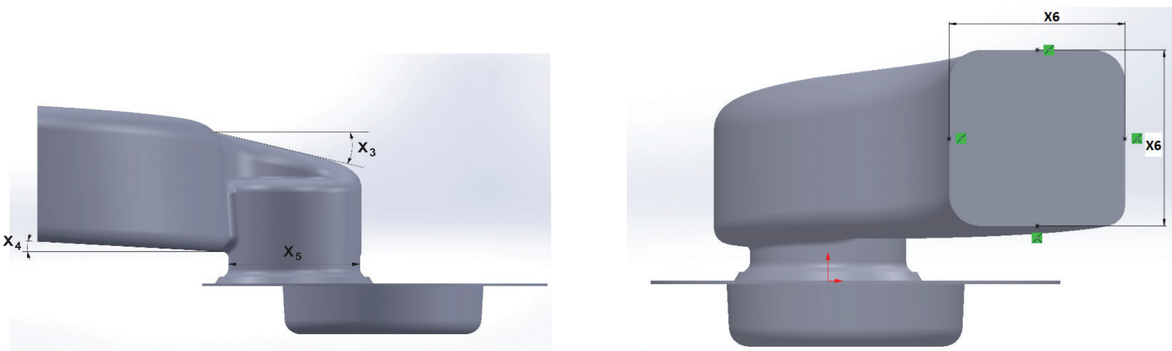


**Fig. 5 The important geometric dimensions are chosen for parameterization.**

**Table 1. Proposed intake manifold parameters**

| No. | Design parameters | Boundary conditions | To annotate |
|---|---|---|---|
| 1 | $X_1$(mm) | $15 \le X_1 \le 18$ | The radius of circle equation 01: The lower and upper bound values ensure that when the geometric shape of the intake throat changes according to the parameter, the original structure of the Cylinder Cap remains unchanged. (the coefficients a, and b in the circle equation 1 are the center coordinates of this circle and can change once X1 changes but must ensure tangential conditions at the intersection of arcs). The value for approaching the existing 2D loading throat design is $X_1$=17 |
| 2 | X2 (mm) | $102 \le X_2 \le 105$ | Spiral Equation Coefficient 2: The lower and upper bound values ensure that when the geometric shape of the intake throat changes according to the parameter, the original structure of the Cylinder Cap remains unchanged. The value for approaching the existing 2D throat design is $X_2$=103 |
| 3 | $X_3$ (deg) | $11 \le X_3 \le 13$ | The upper angle of inclination: the upper and lower bound values ensure that when the geometric shape of the intake throat changes according to the parameters, the original structure of the cylinder cap remains unchanged. The value for approaching the existing 2D loading throat design is $X_3$=12.5 |
| 4 | $X_4$ (deg) | $2 \le X_4 \le 4$ | The lower angle of inclination: The angle of inclination exits the mold during the molding process, and the effect is not great on the loading process. The value for approaching the existing 2D loading throat design is $X_4$=3.5 |
| 5 | $X_5$ (mm) | $40 \le X_5 \le 42$ | The lower bound value meets the conditions to ensure that the required air flow meets the maximum power of the engine is 16.5 Hp;<br>The upper bound value ensures that it does not break the structure of the existing cylinder cover and is consistent with the lifting amount of the intake valve. The value for approaching the existing 2D loading throat design is $X_5$=40 |
| 6 | $X_6$ (mm) | $45 \le X_6 \le 47$ | The lower bound value meets the conditions that ensure the required air flow meets the maximum power of the engine of 16.5 Hp.<br>The upper bound value ensures that the structure of the existing cylinder cover is not broken. The value for approaching the existing 2D loading throat design is $X_6$=45. |

*4.2.Rendering by a parametric method*

At the 2D-design stage: Maintain the cover dimensions and the dimensions are not parameterized. Replace the profile of the sections with parameterized variables. 3D design stage: The profile of the intake manifold is completely controlled by designing variables by combining the following commands: Extruded [10], Extruded – Cut [10], and VarFillet [10] in SolidWorks. The LOFT command use is limited, which significantly reduces interpolation from software. The results obtained from the software are illustrated in Fig.6

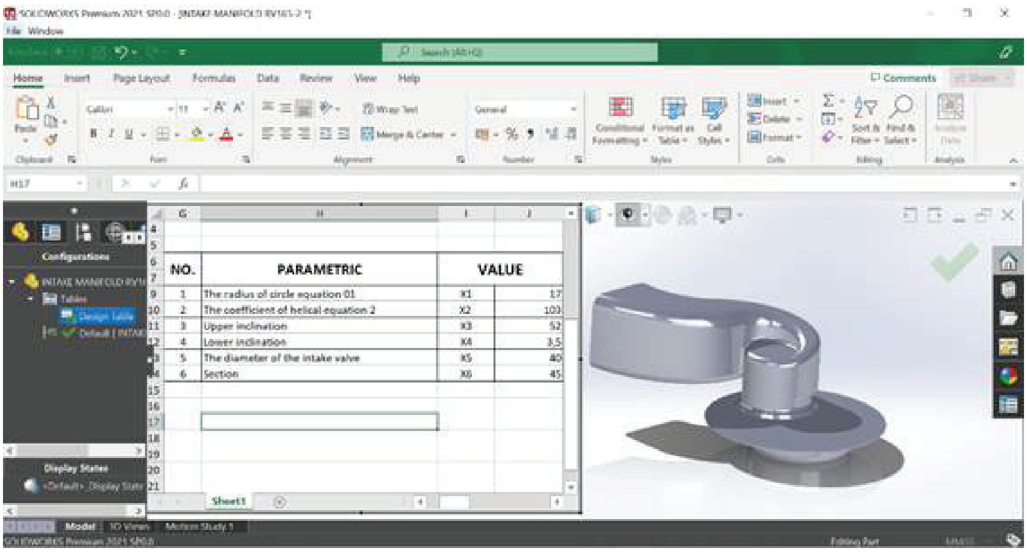


**Fig. 7 Intake manifold rendered by the parametric method**

## III. RESULTS AND CONCLUSIONS

### 1. Results

*1.1.Qualitative assessment*

Compared with the original intake manifold (Fig.3), the disparity in the volume of the intake manifold rendered by the parametric method is not more than 1.7%.

■ Method 01: volume value is195.64 $cm^3$

■ Method 02: volume value is 192.35$cm^3$with design parameter set: $X_1 = 17$; $X_2 = 103$; $X_3 = 12.5$; $X_4 = 3.5$; $X_5 = 40$; $X_6 = 45$

*1.2.Applying the parametric model to build new intake throat cases*

Along with altering the parameter values ($X_1$, $X_2$, $X_3$, $X_4$, $X_5$, $X_6$), the geometric profile of the spiral intake throat also changes. For a certain set of parameter values, a specific case is determined. The time to build a new 3D model is very fast. On average, it takes about 3 seconds to complete a new model.

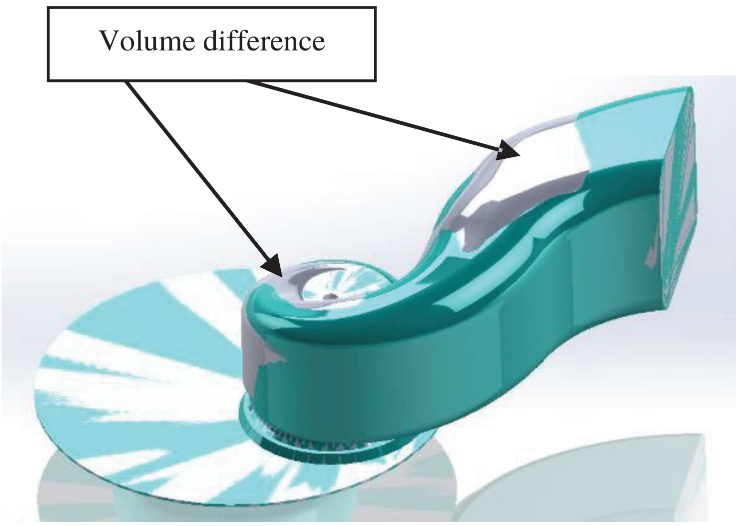


**Fig. 8 3D model comparison of two methods.**

**Table 2. New cases when changing parameter variables**

| Cases | Value of parameters | | | | | | Loading throat volume ($cm^3$) |
|---|---|---|---|---|---|---|---|
| | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | |
| Case 1 | 17 | 103 | 12.5 | 3.5 | 40 | 45 | 192.34 |
| Case 2 | 17 | 103 | 12.5 | 3.5 | 40 | 45 | 193.62 |
| Case 3 | 17.25 | 104.25 | 12.5 | 3.5 | 40 | 45 | 195.27 |
| Case 4 | 15.75 | 102.75 | 11.5 | 2.5 | 40 | 45 | 189.86 |
| Case 5 | 18 | 104.70 | 12.27 | 4 | 40 | 45 | 195.31 |

**2.Conclusions**

Successfully set parameters and a digitized3D model of a spiral loader for the VIKYNO RV165-2 Diesel engine on SolidWorks software were conducted. The study's results greatly reduce the detailed design time and can be completely applied in the design of charging systems for diesel engines with greater capacity.

The built digitized modeling this study is indispensable for the process of simulating engine operation to ensure high reliability while minimizing the time and cost of designing engine improvements.

The construction of this spiral-loaded throat model using parametric variables is an important basis for optimizing the design of this part. The findings of this research could be extended to other marine equipment to enhance efficiency and contribute to sustainable development.

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