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The Innovation Breakthrough in Digital and Disruptive Era

Design of Horizontal Shell Core Casting Machine for Small and Medium Enterprise in the Automotive Sector

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Abstract. The manufacturing industry plays an important role in a country's economy because it can produce high-value products and has the opportunity to create jobs for local communities. In this study, the authors designed a horizontal shell core casting machine for small and medium enterprises in the automotive sector with a productivity of 60 seconds per cycle of products is designed based on requirements needed. This shell core casting machine is a device to produce shell core molds used to manufacture automotive components and parts. The design of this device was focused on engineering design in the form of 2-dimensional drawings and computer aided design models in 3-dimensional form. This study was done in collaboration with a local machinery manufacturer in Karawang district in Indonesia. It is expected from these designs will become a reference to manufacture shell core casting machines to support national industrialization impacted on improving the local community's economy.

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1 Introduction

This Casting is one of the oldest manufacturing processes in the world since around 4000 years ago before technology had developed in the IX century in Europe [1]. This process is related to the manufacturing of workpieces made of metal by heating the metal up to a certain temperature and pouring it into a mold made of sand, ceramic, or metals that influences each other [2]. Theoretically, the type of molten metal and its composition affect significantly the mechanical behaviour and properties of the product of the related component, although the heat-treatment process can improve the mechanical properties of the casting components [3], [4].

Nowadays, technology has become a key driver of the economy of the nation. The industry is one of the stages of economic development that is considered important to accelerate the economic progress of a nation [5]. Industrialization is a process of changing the economic structure from an agricultural or agrarian economic structure to an industrial economic structure. It cannot be denied that industrialization has had a positive impact on the economy of Indonesia. In other words, the manufacturing sector has emerged as a dominant contributor of added value and grows rapidly to keep pace with the rate of growth in the agricultural sector.

Karawang district is one of the main regions in West Java province in Indonesia, which has great potential for the machinery industry due to its location close to the large enterprises of automotive industries in the region. This leads the small and medium enterprises in that region, especially in the industrial sectors, to have a good opportunity to grow, and good potential to increase local income, which in turn creates jobs for the local community. Based on the Gross Regional Domestic Product (GRDP) in Karawang district, West Java, Indonesia, the manufacturing sector contributes the largest contribution of around 5% in 2021 [6]. One of the small medium enterprises in manufacturing in this region is PT Dreig Pratama Indonesia, which works mainly in machinery based on customer requests and orders. This can help local manufacturers to fulfil their need for machinery equipment and parts without importing them, which are very expensive. This comes up from the issue that machinery equipment in Indonesia has a high potential demand for domestic needs. However, still need a lot of attention, especially the type and quantity of goods, the technology used, the market opportunity, and the price.

2 Theoretical Analysis

The development of casting machine from year to year develop continue and progress in accordance with industrial developments [7], sand molding has developed from only using BENTONITE binders to the use of chemical binders (FURAN and PEP SET), which are more practical and have better quality [8]. According to Campbell [9], hot metal liquid in a few

moments will decrease in heat and so on it will harden. The heat resistance of metal fluids depends on:

- a) Metal liquid,
- b) Metal freezing,
- c) Metal – the inner surface of the mold.

Basically, the shell cores can be made manually or on machines. As stated by Mádi [10], the phenol resin is used to bond the prepared sand mix with about 2 to 5 % thermosetting resin of phenolic type to produce a shell core. It is aimed to avoid resin segregation. Beforehand, the core box is prepared by preheating to a temperature of about 200 °C to 315 °C. Furthermore, this phenol resin-bonded sand is either dumped or blown into the preheated metal core box [11]. The mixture of phenol resin-bonded sand core is then baked in a core oven at 190 °C to 232 °C to harden the core [12]. The resin is allowed to melt to the specified thickness until gets cured, and the excess sand can be dumped. The hardened core is then extracted from the core box. The completed shell core contains a very smooth surface, for about 3125 micro mm root mean square, and close tolerance, for about 0.003 mm/mm. The shell core-making process can be autonomously mechanized and held shortly [13]. High permeability is achieved in shell core making. Shell cores can easily store for future use. Shell cores are costly as compared to cores produced by other methods.

The high-frequency coreless electric furnace was used for the first time in the U.S. in the 1930s [14]. Next, thermal sand was applied for molding and core sands in 1940. Furthermore, the "D- process" was developed in 1952 for making shell molds with fine, pre-coated sand. In 1953, the hotbox core sand process in which the cores are thermally cured was invented. Then in 1954, a new core binder—water glass (sodium silicate) hardened with CO₂ from the ambient air, came into use.

In this study, the horizontal shell core casting machine with a productivity of 60 seconds per cycle of products is designed based on the requirement needed in collaboration with PT Dreig Pratama Indonesia, a local small and medium enterprise of manufacturing in Karawang district, West Java, Indonesia

3 Methodology

The implementation of the method in this paper refers to the standard development design for prototypes sourced from the V-Model [15]. The V-Model is a unique linear development methodology that is widely used in any application aimed to create a system or a device [16]. The V-Model focuses on a waterfall- like method following strict step-by-step steps [17]. Although the initial phase is the broad design stage, progress continues through increasingly detailed stages, leading to implementation or prototype, and finally back through all the testing phases before the proposed system or device is complete [18]. The V-model triggers a series of linear steps that must occur throughout the work cycle, one at a time, until the system is complete.

In this study, the development of the horizontal shell core casting machine was the idea in the concept of the operation phase through the waterfall model. The first phase was the demand from customer need of the main automotive manufacturers in Indonesia that produce shell core casting of automotive parts. The second phase was a literature review and problem identification to have a deep understanding and the detailed problem of the common issue in shell core casting machines. The third phase was determining the requirement and specifications as a foundation to develop a new design for the proposed horizontal shell core casting machine. The requirement and specification phase are selected in such a way as to propose necessary requirements followed by its specification to determine the feature set of the shell core machine. After that, the fourth phase was parameter identification.

Based on the requirement, the proposed design of shell core casting machine is consisted of several parts below:

1. Sand Hopper.

A sand hopper is a stationary unit on a shell core casting machine used to store and deliver prepared sand mixtures, for making shell cores mold based on the required volume of sand mixture.

2. Pressure tank

A pressure tank is an essential part of a shell core casting machine to make high quality resin castings especially true with difficult recesses and complex mold. Under high pressure, air bubbles are created and mixed with the resin to be ready to deliver into the core box via a high-pressure connecting hose and core box shooter.

3. Core box shooter.

The core box shooter contains a sand shooting mechanism. The sand shooting mechanism is located at the upper part of the base. The base is equipped with two air cushion moving guide rails, a lifting worktable, and a moving worktable, where the moving worktable is located above the lifting worktable. The two-air cushion moving guide rails are respectively located at two sides of the lower surface of the moving worktable so that the core box shooter is small in an occupied area. Furthermore, a proportional valve is adopted in the hydraulic system to regulate speed, to produce high accuracy speed. The core box is designed to be used for wear resistance, stable, and reliable in operation.

4. Core box

The core box is designed to compact a mass of core sand once it is placed in the mold cavity at a required location with proper alignment. It allows the molten metal to occupy space for solidification and produce hollowness in the casting. The environment in which the core is placed is much different from that of the mold. The core has to withstand the severe action of hot metal which completely surrounds it. The cores are classified according to the shape and position in the mold required. Core boxes are generally made of metal.

The requirement and specification needed to construct the horizontal shell core machine as can be seen in Table 1.

Table 1. Requirement and specification of proposed horizontal shell core casting machine.

Core box size (mm)	520x510x395
Max. weight of sand shot (kg)	15
Template opening and closing dimensions (mm)	max: 800; min:450
Max. clamping force of the core box (kg)	1000
Productivity (s) per cycle	60
Use pressure (Mpa)	0.5
Shot sand pressure (Mpa)	0.48
Power (AC) volt	380
Heating Method	Gas heating
Heating Power	20
Sanding Method	Bucket elevator

The sixth phase is design development followed by generating CAD drawings. Utilizing the feedback and requirements and specification created during the requirements and specification phase, the next stage is used to produce a proposed design of the shell core machine that will outline all the technical components. CAD drawings are developed using SOLIDWORKS considering the stages needed for the final design as shown in Figure 1 below.

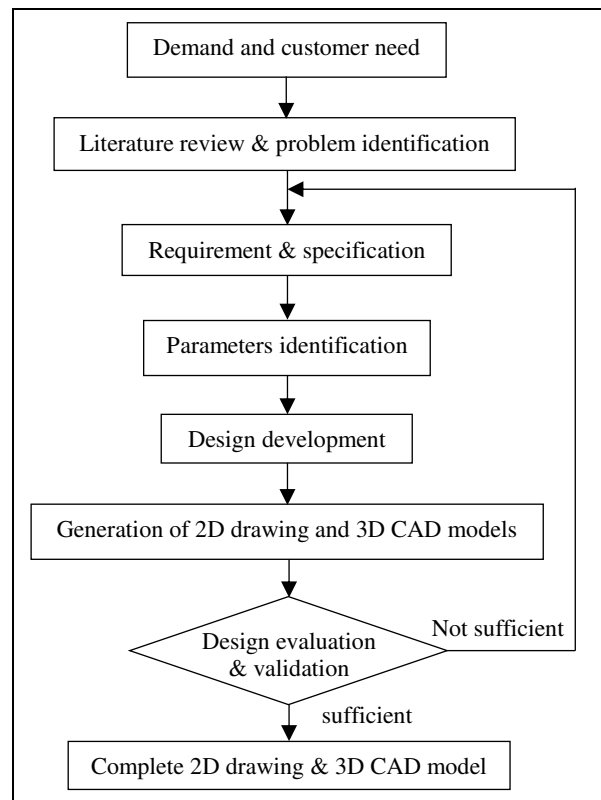


Fig. 1. Flow chart of activity in designing a horizontal shell core casting machine in this study Sand Hopper.

4 Result and Discussion

This section shows the complete design of the horizontal shell core casting machine in 2D drawing

and 3D CAD models based on specifications required as shown in Figures 2 and 3. In the 2D technical drawings (Figure 2 and 3), it can be seen that the design of the core box shooter is placed in the above position of the shell core casting box (core box). The core box shooter is designed to be able to accommodate and transport the sand taken from the sand hopper to the location of the nozzle shooter for resin mixture supply. The resin is then sprayed into the core box shooter for mixing with the sand and simultaneously herded the sand-resin mixture supply into the core box with high pressure without gravity resistance. On the other hand, the core box shooter is designed in such a way can be moved horizontally as a transporter of the sand-resin mixture supply into the shell-casting core box. The shell core casting box is placed in a row under the core box shooter aimed for the finished shell core products easier to be taken by the machine operators so that the production cycle can run more quickly and efficiently.

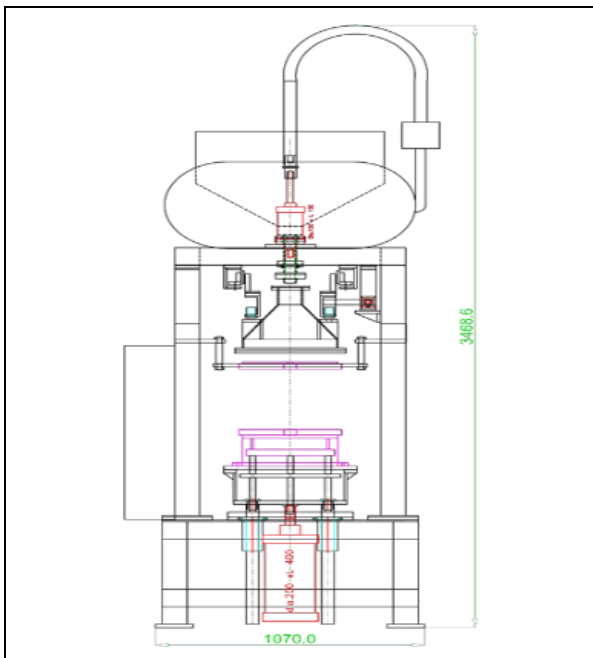


Fig. 2. Completed 2D technical design of the horizontal shell core casting machine from side view.

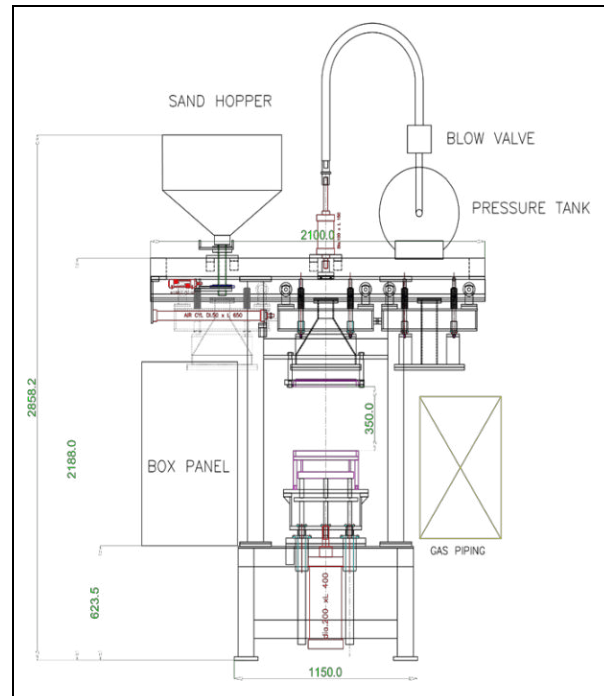


Fig. 3. Complete 2D technical design of the horizontal shell core casting machine from front view.

The complete 3D mechanical CAD model of sand hopper and pressure tank can be seen in Figure 4(a) and 4(b) respectively. The sand hopper is provided as a reservoir for the sand to be ready to transport into the core box at any time with the help of the core box shooter. In addition, the pressure tank is provided to accommodate the high-pressure air needed when the resin was shot via the nozzle shooter into the core box shooter for the mixing process with the sand. A blow valve is placed as planned on the firing hose so that the shot pressure can be controlled properly. With the help of this high-pressure air from the nozzle shooter, it is allowed the sand-resin mixture is dribbled and compressed into the core box for the next process called burning.

In Figure 4(c) the complete 3D mechanical CAD model of the core box and core box shooter was done in the integrated compact design. It can be seen that the nozzle shooter is placed in the middle of the core box shooter when the mixing and compression processes are ready to be done. Furthermore, Figure 4(d) shows the complete 3D mechanical CAD model of the sand hopper, pressure tank, core box, and core box shooter in the integrated compact design together with the supported frame for those components. The construction of the shell core casting machine is designed robustly so that it can withstand high loads from the core box shooter, pressure tank, firing hose, shell core casting box, electrical wiring, heating elements, etc., which are needed in this shell core casting machine.

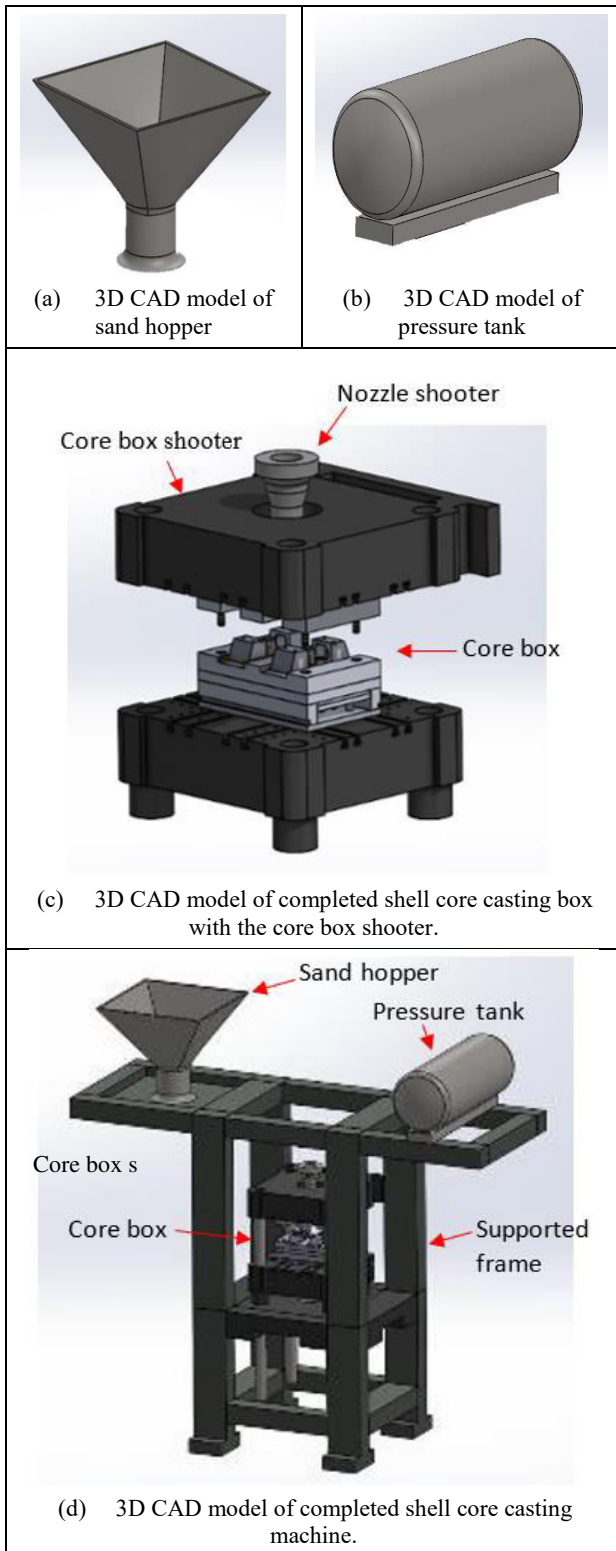


Fig. 4. 3D CAD model of the sand hopper and pressure tank, (a) 3D CAD sand hopper, (b) 3D CAD pressure tank, (c) 3D CAD shell core casting box complete model, dan (d) 3D CAD complete view.

5. Conclusion

From this study, a horizontal shell core casting machine was designed based on a requirement of production of 60 seconds per cycle of products. The design specification is determined in such a way through rigorous, intense, and long discussions

together with PT Dreig Pratama Indonesia, a small-medium enterprise in the Karawang region, West Java, Indonesia, which works in manufacturing. The proposed design planning was constructed based on the standard development design for prototypes sourced from the V-Model consisting of problem identification, requirement specification, parameter identification, and generating CAD drawings model. The last stage was the validation of the proposed design where to ensure the design suit the specification and requirements needed. From the complete 2D engineering drawing and 3D CAD model, it can be seen clearly the horizontal shell core casting machine with sizes and dimensions that suit the demand, even though the electrical wiring, control panel, and heating element are not included in the design asked. Eventually, it can be concluded that this horizontal shell core casting machine is designed successfully and complies with the requirements and specifications needed, and later on can be used as a reference for the physical manufacture of a shell core casting machine in the next agenda.

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