CAD modelling of fire safe valve body by reverse engineering

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Abstract. The government of Indonesia has a regulation called local content to push the manufacturing industries in order to increase their competitiveness. In order to reach that goal, technology transfer has been done, but it is a long way to go and impractical. So, one way to go is by the understanding of the product that has to be made. Reverse engineering is a specific technique to use because of its practicality. As the name implied, reverse engineering is the inverse of engineering design because the starting point is the product itself instead of the idea. In this paper, the product used as a case is the body of the fire-safe valve. The final goal of the reverse of the body part of the valve is the idea behind it or called the design intent. However, it is going to be a long process, and as the first step that will be presented in this paper, the goal is to get its CAD model of the fire-safe valve body.

1. Introduction

Indonesia economy has been supported by energy industries which is oil and gas. The key aspect of that industry is distributing which is done mostly using pipes and valves. However, those components, specifically the valves, have to be manufactured outside the country. The government, using the regulation of local contents, has pushed the local manufacturers to increase their capabilities. Some have been made locally as shown in Figure 1.
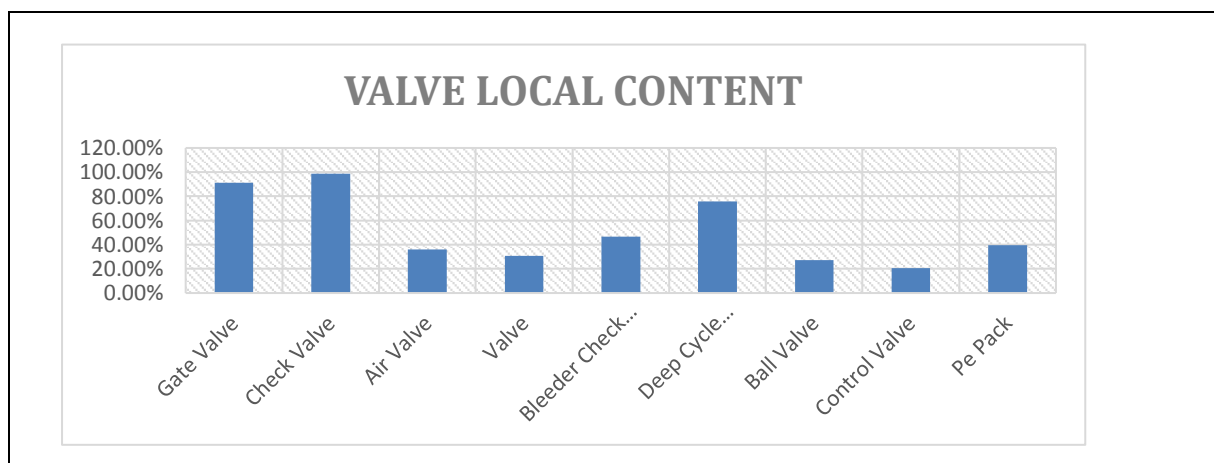

Figure 1. Valves local content.

Hence, there are some valves have low local content such as ball valve and control valve that only has 20% or below in value. In this paper, fire-safe valve which is trunnion mounted ball valve is used as the study case and the method utilized is by using reverse engineering.

Reverse engineering is defined by Wang [1] as a process of measuring, analysing and testing to reconstruct the mirror image of an object or retrieve a past event. It is a technology of reinvention, a road map leading to reconstruction and reproduction. It is also the art of applied science for the preservation of the design intent of the original part. So, to be concluded, the final step is to get the design intent.

The practices of reverse engineering are studied by some researchers like Bey using a priori model [2] for CAD model reconstruction and Afeez by producing CAD model of assembly [3]. Paulic [4] and Valerga [5] has done his reverse engineering for a part by scanning it using a 3D scanner, producing the CAD Model and Rapid Prototyping by Additive Manufacturing. Barai [6] made the differences by measuring with CMM instead of 3D Scanner. The modelling by reverse engineering algorithm is developed in a paper by Fayolle [7]. The fitting of the point cloud to CAD is studied by Benko [8]. Au attempted to use feature base to its reverse engineering process [9]. Further, Pescaru attempt to automated the process [10]. Finally, Buonamici [11] created the process of reverse engineering using a template (the premade model of the scanned product). However, the concept comes from Durupt [12]. S.K Curtis also explaining the method of reverse engineering if there are multiple samples to be reversed [13]. The evolution concept of reverse engineering to shape engineering was explained by Anwer [14]. The next step in reverse engineering is by determining the geometrical tolerance, as explained by Kaisarlis [15] and Saenz-Nuno [16]. Another use of reverse engineering also discovered by Rysinski to diagnose machine condition [17].

This paper has the difference from those papers by combining the classical engineering drawing (the planning of measuring by the view of products) and the process of getting the data using 3D scanner and CMM. The object of the fire safe valve is as the following Figure.
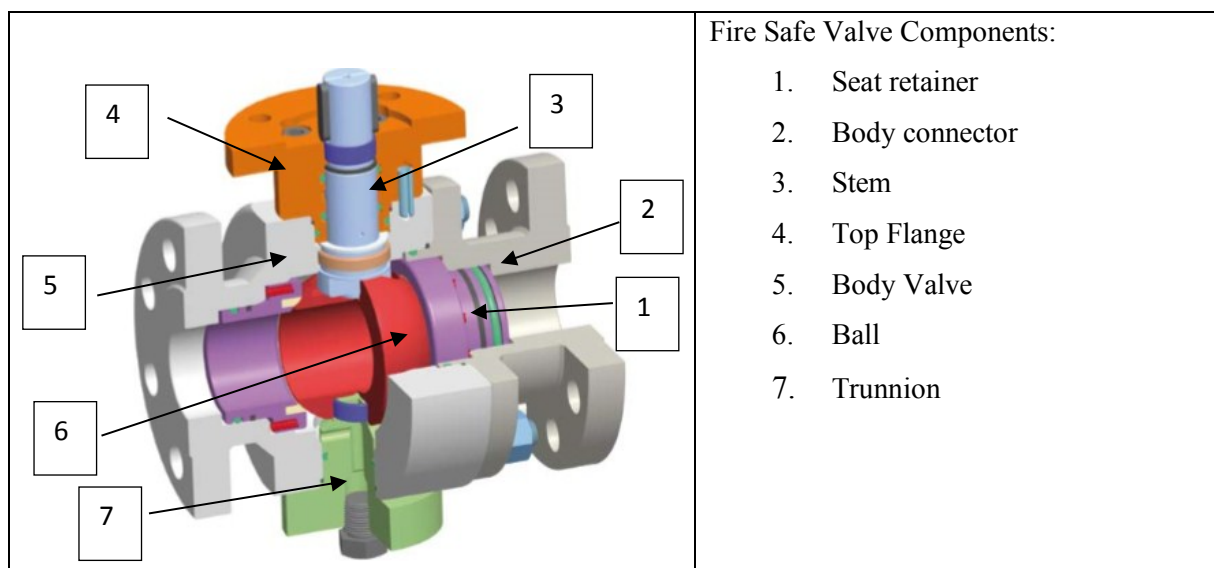

Fire Safe Valve Components:
1.   Seat retainer
2.   Body connector
3.   Stem
4.   Top Flange
5.   Body Valve
6.   Ball
7.   Trunnion

Figure 2. Fire safe valve assembly.

2. Methodology

The methodology in this paper is started by features (geometrical elements) identification by capturing the 6 section views. This view called front view, back view, side view, top view, bottom view and inside view. Those views could be seen in Figure 3. From those views, then some features such as holes, threaded holes and pins. So there are 3 main features which are base feature (in this case the main body of the valve body as the place for other features attached), the feature to ensure the function of valve

itself (regulating the flow of fluid) and mated features (connected to other feature in different part of valve body).

After the process has been done, the next step is measuring the features (size, form, orientation and location) using the 3D Scanner. The purpose of the feature identification is to minimize the process of measuring using 3D Scanner (started from the base feature and so on).
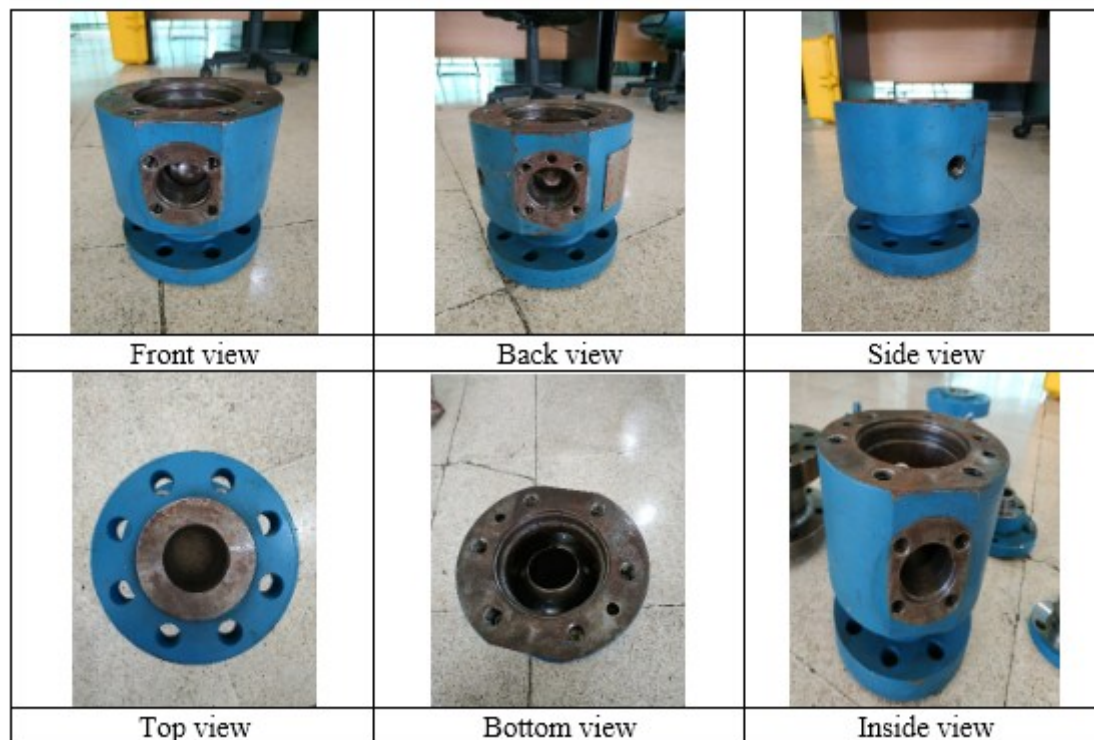

Figure 3. Fire safe valve body features identification.

The order of scanning is started from the front view and ended to bottom view. The weakness of the 3D Scanner is its limitation to capturing the features in surface. Hence in order to overcome that limitation, the next step is to cut the product into two halves. Then the scanner is used to capture the features inside from inside view. Fire safe valve body scanning is shown in Figure 4.

The features inside are the most functional because it is the place where fluid flows and regulated. Point cloud from every view is then generated. Those point clouds then stitched into a single entity of fire-safe valve body.
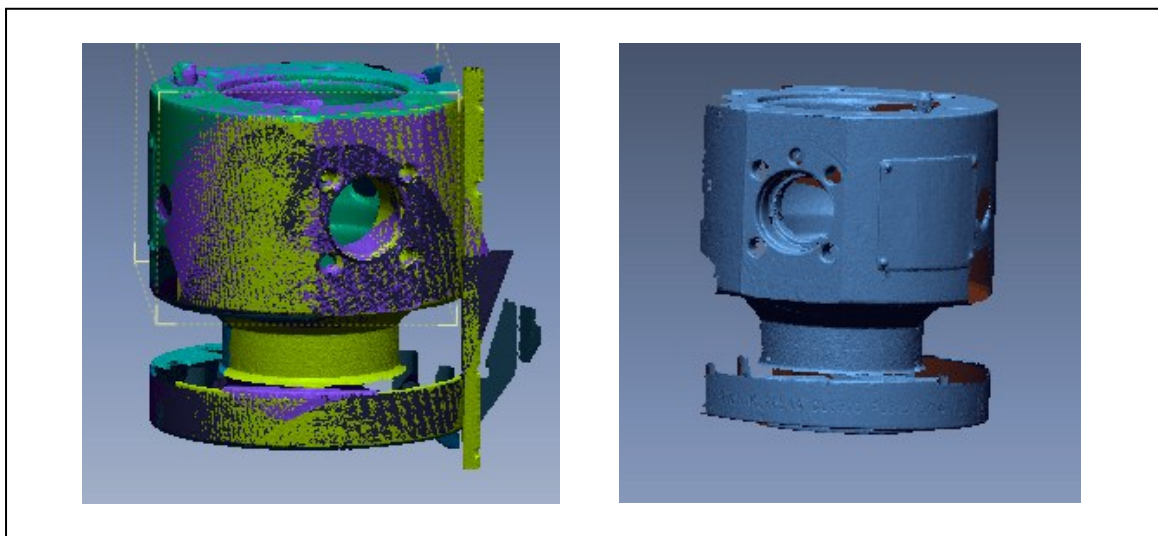
Figure 4. Fire safe valve body scanning.

Figure 5. Stitched (left) and meshed (right) point clouds of fire safe valve body.

The residue point cloud needs to be also cleaned (as can be seen in Figure 5 left). Then, those points linked to make the triangles (tetrahedral mesh). The meshing process is vital to get the surface of the model. The surface has to be closed in order to fill that to become a solid 3D model (Figure 5 right).
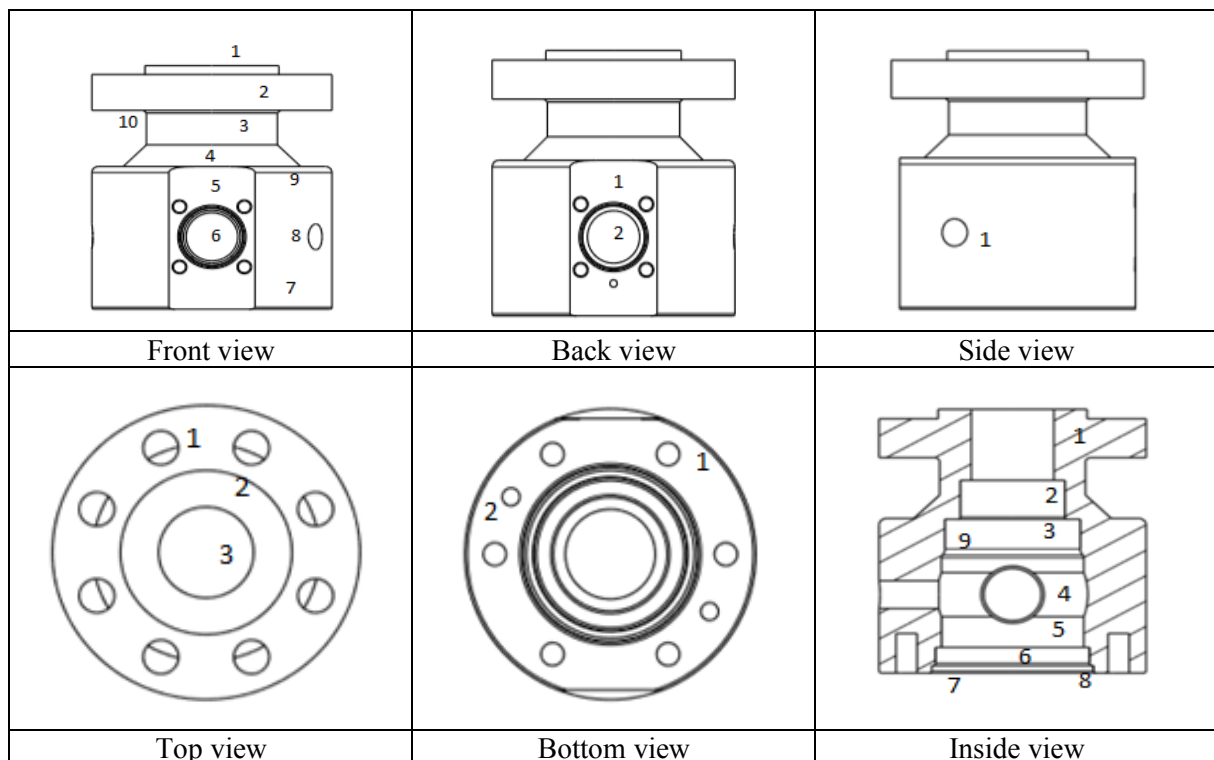
Figure 6. Features identified that is needed to be measured.

However, the accuracy of measuring by 3D Scanner is not sufficient. It is the resolution of the device itself and the noise in the process (the room condition, for example). The further processes are needed to accurately measure features that are numbered for each view in Figure 6. The device that has the better resolution is Coordinate Measuring Machine (CMM). It is used to get the accurate dimension for each feature in part to be reversed.

3. Results

Features, as identified in Figure 6 has an unideal geometrical specification (for example, the orientation of the hole is not exactly 900). The main reason behind this error (no matter how high the resolution of the measuring device) is the error in the manufacturing process of the part. Reverse engineering is mostly understood as creating the mirror image as Wang defines in his first part of sentence [1]. However, it is needed to be understood further from the definition that reverse engineering main goal is to get design intent (the ideas of the product designer). The correction has to be done to get the accurate 3D CAD Model.
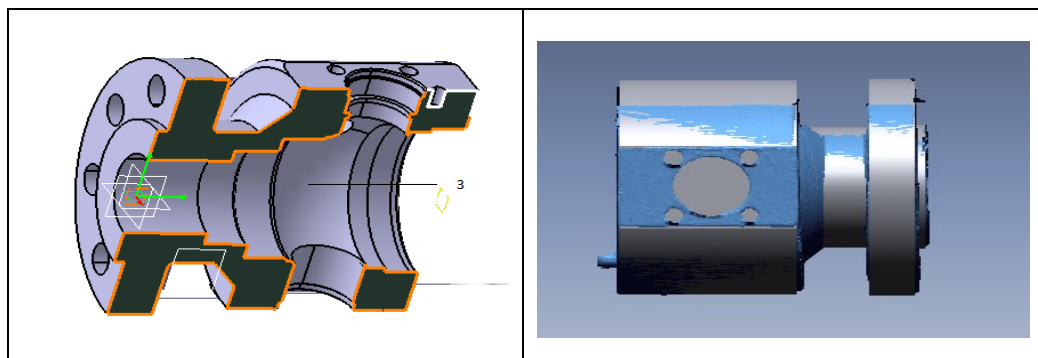

Figure 7. CAD model of fire safe valve body.

The most crucial step to build 3D CAD Model is by determining the reference for the locations of features as presented in Figure 7 (left). Terminology for that reference as defined by ASME 14.5 and explained in the book by Cogorno is datum reference frame [11]. The coordinate system used in this model is cartesian (x, y and z). Every feature needed to be defined as its location from that datum reference frame. After that, the form of features is defined (cylinder holes or cylinder pin, for example). Then, its orientation has to be determined (its angle from the axis in the datum reference frame). Finally, the size of the feature is measured. Location, form, orientation and size of feature has to be corrected because the nominal dimension will be used in the 3D CAD Model. The correction could be done by corrected by changing its dimension to the part that is mated, like in Figure 6 Front View number 5 is the same with the dimension of the standard bolt. The feature that has the function of regulating like Figure 6 Inside View number 3 could be approximated to the nearest dimension before the comma. Further study needs to be done to get the right dimension.

4. Conclusions

Reverse Engineering is one technique to get the product information in order to recreate that or for other purposes such as maintenance. The process is done by getting the initial information of the product, understanding the part functions in assembly of products, measuring the part, modelling, engineering analysis, prototyping, and producing the final product. In this paper, the model is generated by measuring it using a 3D Scanner, and CMM then corrected it in CAD software. The final product in this study is the 3D CAD Model with the features defined with four characteristics: size, form, orientation and location. Characteristics could be seen in the feature tree in CAD software. This model could be analysed further by (Computer-Aided Engineering) CAE and Computational Fluid Dynamics (CFD). The model could also be used as the information of the product in manufacturing and analysed its manufacturability by using Computer-Aided Manufacturing (CAM). Hence, it could be concluded that 3D CAD Model is the excellent start in order to give the manufacturers the ability to recreate the product (in this case fire-safe valve) and documented it.

5. References

[1]   Wang W 2011 *Reverse Engineering the Technology of Reinvention* (USA: CRC Press) p 1
[2]   Bey A *et al.* 2011 *Journal of Photogrammetry and Remote Sensing* **XXXVIII**
[3]   Afeez A *et al.* 2012 *Journal of Engineering, Design and Technology* **11** 375-390
[4]   Paulic M *et al.* 2014 *Pro. Engineering* **69** 795 – 803
[5]   Valerga AP *et al.* 2015 *Proc Eng* **132** 1144 – 1151
[6]   Barai G D *et al.* 2015 *International Journal of Engrineering Research and Technology* **4** 539-546
[7]   Fayolle P and Pasko A 2015 *IEEE Congress on Evolutionary Computation* 2176-2183
[8]   Benko P *et al.* 2002 *Computer Aided Geometric Design* **19** 173-205
[9]   Au C K *et al.* 1999 *Computer-Aided Design* **31** 751-759
[10]   Pescaru R *et al.* 2016 *Conf. Series: MSE* **161**
[11]   Buonamici F *et al.* 2018 *Journal of Computational Design and Engineering* **5** 145–159
[12]   Durupt A *et al.* 2010 *Journal of Computing and Information Science in Engineering* **10** 1-4
[13]   Curtis S K *et al.* 2013 *The Journal of Molecular Diagnostics* **135** 1-8
[14]   Answer N *et al.* 2016 *The Canadian Journal of Music Therapy* **65** 165-168
[15]   Kaisarlis G J *et al.* 2006 *International Journal of the Computer, The Internet and Management* **21** 89-96
[16]   Saenz-Nuno M A *et al.* 2017 *Project management* **13** 472-479
[17]   Rysinski J *et al.* 2015 *Advances in Mechanical Engineering* **7** 1-9
[18]   Cogorno G R 2011 *Geometrical Dimensioning and Tolerancing for Mechanical Design* (United States: McGraw-Hill)