ISSN: 2454-9940

INTERNATIONAL JOURNAL OF APPLIED SCIENCE ENGINEERING AND MANAGEMENT

E-Mail :
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INTERNATIONAL JOURNAL OF APPLIED SCIENCE ENGINEERING AND MANAGEMENT

ISSN2454-9940

www.ijasem.org

Vol 13, Issue.3 Sep 2019

MODELING THREE-DIMENSIONAL PUMP CASINGS USING REVERSE ENGINEERING

[1]K.Mounika,[2]R.Narmada
[12]Assistant Professor
Department Of Mechanical Engineering
Sree Chaitanya College of Engineering, Karimnagar

ABSTRACT

Reverse engineering is a crucial part of product design, particularly in cases when original documentation is missing. In order to create better or more accurate virtual or physical representations, it focuses on replicating important features from an existing item. This sometimes necessitates the replication of a Computer-Aided Design (CAD) model using a range of digitization techniques, enabling more study and breakthroughs in product design. Creating accurate CAD models, characterising geometric models, and segmenting structures are just a few of the jobs involved in the process. Reverse engineering plays a major role in the shift from physical to digital product designs and has many applications in the manufacturing, product design, and archaeology sectors. This study article delves into the basic concepts and techniques that underpin this process, emphasising the acquisition of 3D data via the use of instruments such as coordinate measuring machines (CMMs) and laser scanning.

KEYWORDS: Pump casing, scanning, 3D modelling, and reverse engineering

1. INTRODUCTION

Reverse engineering is the process of analyzing actual artifacts to create complete 2D or 3D documentation with enhanced precision thanks to contemporary technological breakthroughs like coordinate measuring and 3D scanning. It is crucial for scientific research and product geometry digitization, especially when 3D-CAD data is not available[1]. Engineering encompasses a wide range of tasks, including organizing, designing, producing, and measuring. Forward engineering and reverse engineering are its two main subcategories. While reverse engineering employs technology to examine existing product models and enable modifications or the production of similar ideas, forward engineering concentrates on turning abstract designs into working goods[2].

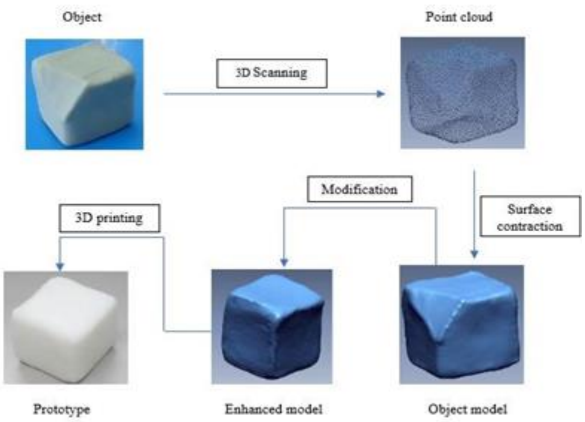

FIG.1. Conventional reverse engineering[3]

INTERNATIONAL JOURNAL OF APPLIED SCIENCE ENGINEERING AND MANAGEMENT
ISSN2454-9940
www.ijasem.org
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Reverse engineering is difficult because physical components come in a variety of shapes and sizes, and as technology advances, these components become smaller and more intricate. The complexity and potential errors involved with a variety of complicated surfaces make traditional measurement and manual inspection methods ineffective[4]. In an ideal world, reverse engineering wouldn't be necessary because to excellent design documentation. Adjustments are essential since in reality, many traditionally constructed systems have defects and require continual performance improvements. They usually have poor design, little documentation, and inaccurate or lacking design information, which makes this challenging[5]. The study of irregular particles is important in many disciplines since it has an effect on behavior and economics. These characteristics, such as size and shape, are used to analyze building materials, optimize space, and direct the design of concrete and asphalt. Engineers base their evaluations on factors including weight, volume, surface area, size, and shape[6].

Reverse engineering is incredibly helpful in redesigning, testing, and improving the structural integrity of watercraft components when combined with laser scanning technology and post-processing. Due to these components' complex and freeform forms, conventional measurement techniques have difficulty working with them. Seagoing watercraft designers can create precise 3D CAD models from scanned point cloud data, facilitating applications like CAE-based redesign, engineering, and simulation testing as well as quality evaluation in production[7].

2. METHODOLOGY

2.1 POINT DATA ACQUISTION TECHNIQUES

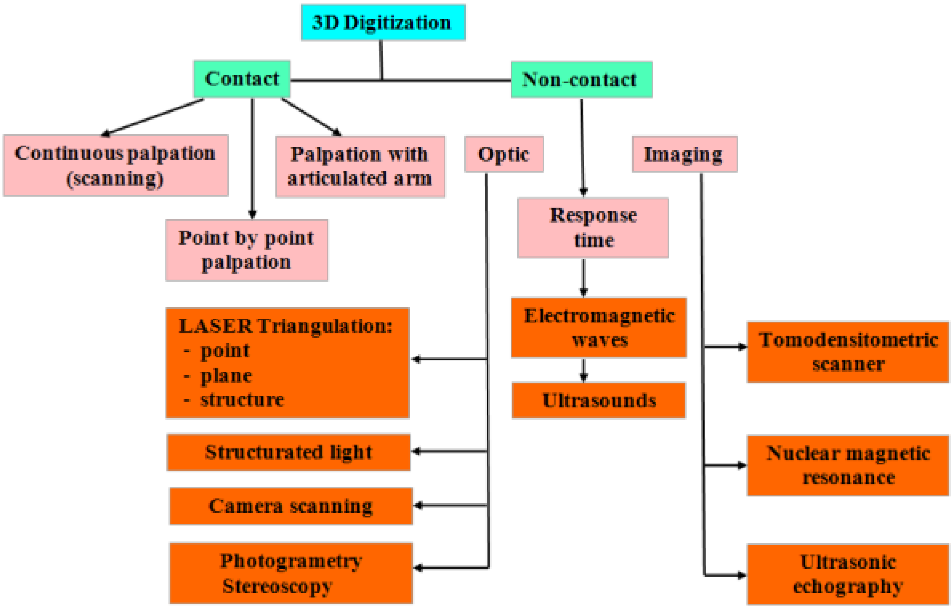

FIG.2. 3D digitizing technology[8]

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ISSN2454-9940
www.ijasem.org
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In order to capture information for a 3D model, scanners in the late 20th and early 80s used contact probes that repeatedly physically touched the object. However, more efficient methods were later developed as a result of the inefficiency and time-consuming nature of the earlier ones. When compared to other reverse engineering techniques, 3D scanning has proven to be the best and most accurate way for data collection and 3D model building[9]. Virtual design, simulation, and reverse engineering have all undergone revolutionary changes in the last 20 years because to 3D scanning, or digitalization. It entails transforming the actual physical structure of an object into a digital "point cloud" containing XYZ coordinates, frequently processed into surfaces, and saved in CAD formats like STL. With applications in reverse engineering, quick prototyping, and product inspection, the method blends material-based acquisition employing probes and sensors with soft interface modeling using algorithms and is supported by 3D laser scanning for exact point collection[8].

Contact scanning- Contact-based 3D scanning uses probes attached to articulated arms or other instruments to collect data through direct physical contact and from a variety of angles. CMMs are frequently used for quality assurance following product fabrication and maintenance[10]. Traditional contact-based methods, which have been around for a while, involve making mechanical contact between surfaces and a measurement tool, usually a probe or stylus. These methods are more accurate and produce better surface finishes. But they are frequently time-consuming[11]. In particular for objects with relief characteristics and well-defined geometrical elements, contact-based 3D scanning offers outstanding precision. It works well for scanning big objects like machinery and airplanes, but it is inappropriate for soft materials and slow and incorrect on unidentified surfaces[12]. Contact scanning systems, functioning as independent units, excel at low probing forces for accuracy, particularly on delicate materials, and use extremely thin styli (0.3mm) to capture precise information. They have a magnetic stylus breakaway mechanism that ensures workpiece and stylus protection in the event of user setup mistakes, as well as silent, clean operation[13]. In order to collect surface data, contact 3D scanning uses physical probe contact with an item to distort the probe. For quality control, systems like Coordinate Measuring Machines (CMMs) are frequently utilized, and this laser category excels in scanning reflective and transparent surfaces[9].

Non – contact scanning- Lidar or time-of-flight scanners use the known speed of light to calculate distances precisely by measuring the length of the laser's journey path. They use spinning mirror systems to scan larger regions, which enables them to scan huge objects, albeit at a slower processing rate[9]. There is no physical contact throughout this process[14]. Non-contact technologies, which can be active or passive, collect surface data using various active or passive mediums such as light, lasers, sound, magnetic fields, or X-rays. These methods are typically faster but have issues with transparent materials and small features[11]. Non-contact techniques are superior for quick and accurate Z-axis scanning (0.001mm or better), but they cannot scan reflective materials and are expensive to set up. They are appropriate for scanning soft materials but struggle with notches and steep surfaces because to reflections and susceptibility to airborne particles. Their X and Y-axis accuracy ranges from 0.035 to 0.060mm[12].

The following are a few common issues with useful data acquisition: (1) Reflective surface; (2) Occlusion; (3) Noise; (4) Missing or insufficient data; (5) Screening; and (6) Shading. When scanning an object with a highly **reflecting surface**, reflective surfaces provide the biggest problems. Having optical material is another cause of this problem. The constant coating of white spray is provided by a developer, which also reduces the shine[15]. **Occlusion** is the term used to describe the blockage of the scanning medium by an impediment or shadowing. The main scanners impacted by this problem include optical, acoustic, and magnetic scanners. One solution to this problem is to use numerous scanning equipment. Self-occlusion is a different kind of occlusion that arises from fixturing in which the geometry of the fixtures is included in the scan data. Fixture data elimination is complex and frequently necessitates many perspectives. During scanning, noise is captured. **Noise** is unwanted information, such as fittings, part-holding apparatuses, etc. We are having trouble with non-contact scanning because of this. Noise is decreased using various data fitting software[2]. Yet another significant issue when scanning dense material is **missing or inadequate data**. Sometimes scanning cannot identify threads, sharp edges, or hole depth due to the material's high density. This issue is fixed when the point cloud data has been processed. **Screening** occurs when a feature of the workpiece prevents the reflected light from reaching the receiver after a point has been illuminated by the transmitter. **Shading** occurs when a workpiece is located where the transmitted light cannot reach it but may be "seen" by the receiver. Spraying a diffuse reflecting substance on the work surface can solve the additional issues that light-based approaches confront when an item is fully or partially transparent[16].

Scanner Description- Scantech makes a portable, lightweight 3D scanner called the SIMSCAN. China-based Scantech is a maker of 3D scanners. With an outstanding acquisition speed of up to 2,800,000 points per second, this small handheld 3D scanner is quite fast. The SIMSCAN, which has been designated as metrology-grade, provides resolution and precision up to 0.020 mm, as well as volumetric accuracy up to 0.015 mm + 0.035 mm/m (or 0.015 mm + 0.015 mm/m when used in conjunction with the MSCAN-L15). It is among the lightest handheld laser 3D scanners in the world (203 x 80 x 44 mm), weighing only 570 grams as opposed to the typical 1 kilogram weight of this kind of item. The Scantech SIMSCAN, which promises to be able to scan a variety of items in a variety of real-world scenarios, takes 2,020,000 measurements per second utilizing blue laser lines or crosses over a 410 × 400 mm area. Depending on the project at hand, operators can utilize the device to capture small or huge objects by selecting hyperfine, ultrafast, or deep-hole scanning modes[16]. The non-contact gadget is a practical method for gathering 3D data[17].

ISSN2454-9940

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FIG.3. Simscan and FARO Platinum Arm with Laser scan Arm[16], [18]

A multinational manufacturer based in the United States named FARO produces the Faro Arm product line, which includes the FARO Edge, a metrology industrial 3D scanner. Laser triangulation is the foundation of the Faro arm. With this scanner, we can achieve precision of up to 0.025mm. 560,000 points are acquired each second at the point level. The calibration process for the scan system entails calibrating both the camera and the projector in the correct order so that the calibrated camera can be used to calibrate the projector[19]. This scanner's operational range is 0.115 to 0.230 meters[16]. With regard to data acquisition time, the Faro scanner is quicker[20]. The scanner weighs roughly 11 kg. Different programs, like Geomagic and Polyworks Inspector, handle point data[16].

2.2 MERGING PROCEDURE OF SCANED DATA:-

The process of merging involves combining all of the settings utilized for scanning. All of the data are call-in software such as Poly Works, Geomagic Control, etc. during the merging process. We need to integrate all the data because different configurations are associated with different product characteristics. To do this, we utilize this program, in which all the setups are called and combined. After merging all the data, we have one complete product from which to start building a 3D CAD model.

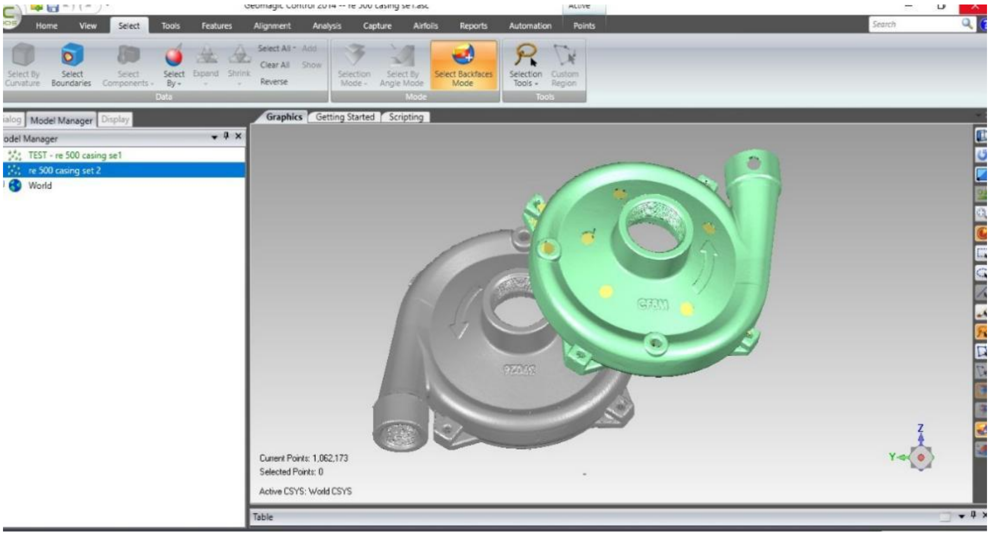

FIG.4. Two different setups for merging

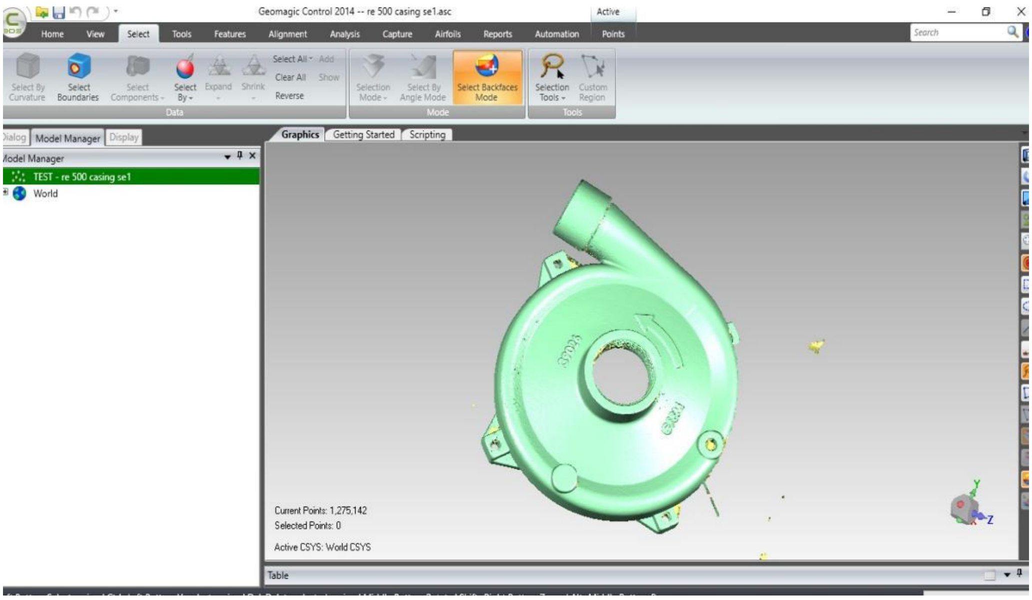

FIG.5. After merging all the setups

After the rotary measuring location has been set, the first sequence of measurements will start. After the second measurement in the initial measurement sequence, both scanned images will then appear for data alignment. In order for the subsequent measurements to be automatically aligned by the software, one must here choose a shared reference point that spans both scanned images. Once all the measurement sequence data have been recorded, these surfaces must be integrated by choosing a common reference point and aligning the measurement sequence[15].

Fig. 5 displays the object's whole scanned surface. Triangle mesh (mesh building, mesh editing, edit holes), global optimization, and selection can all be used to alter the data that comes from measurements. Depending on the application area, the four optimization methods for creating the triangle mesh are quality control, design, and reverse engineering. It's crucial to manage noise appropriately in various 3D operations to prevent distorted representation. However, the chosen scanner has an impact on noise characterization[21]. Alignment indicators are still discernible in an unoptimized triangle mesh. By filling in the gaps left by removing a section of the triangle mesh at the marker points, the stamp out/fill markers operation produces a smooth surface in those areas. Use the Smoothing and Sharpening Meshes option to sharpen the edges and smooth the mesh.

FIG.6. STL file format

STL file format is used for additional modelling. As illustrated in Fig. 6, the STL file is loaded into Siemens NX (CAD modelling software) to convert the point clouds' data into a 3D surface model. NX can also be used to dimension the model, as seen in Fig. 7.

An automated method of turning a physical thing into a three-dimensional (3D) surface representation or solid model is desired for use in industrial and commercial enterprises. Specific features are offered by a variety of commercial CAD-related programs to assist traditional RE. The active CAD file types include DXF, STEP, IGES, STL, and others[22].To ensure that the CAD model is under prescribed data, it is crucial to create 3D models from STL files. In order to determine the dimensions of the cad model and make any necessary modifications, we must compare the 3D model we just built to STL once more. The model is also provided certain clearly specified dimensions, allowing for adjustments to be made while creating the cad model. In this stage, several threads are provided, and the size of the holes is changed correspondingly.

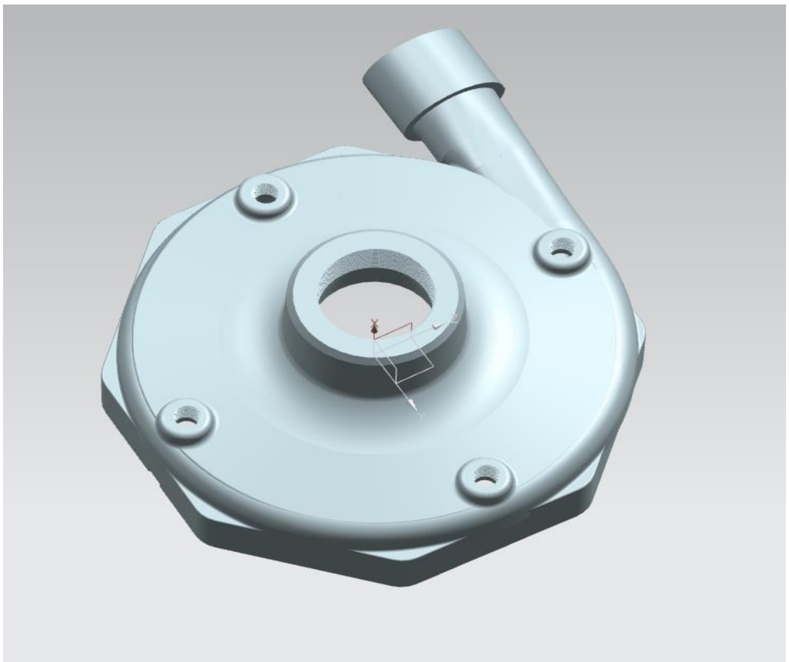

FIG.7. CAD model from STL

3. CONCLUSION

3D scanners are used in many different applications in modern production and quality control. The examination of an industrial PUMP CASING was used as an example to illustrate scanning in this post. Because of the intricate internal and external geometry of an industrial PUMP CASING, scanning with a SIMSCAN and FARO ARM scanner equipped with a rotary table requires specialised bolts in order to secure the body at an angle. Bright or polished surfaces must be cleaned or sprayed with surface developer in order to be measured accurately during scanning. The 3D scanner should always be maintained at normal temperature because of its sensitivity to temperature fluctuations. The measurement will stop when the sensor's temperature increases. Overall, the rapid measurement, excellent accuracy, lucid data, and ease of use of the 3D scanner have contributed to its widespread appeal.

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