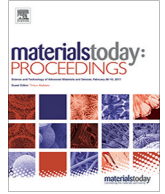




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3D scanning of a carburetor body using COMET 3D scanner supported by COLIN 3D software: Issues and solutions

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ABSTRACT

Nowadays, the industry uses 3D Scanners for reverse engineering, new product design, rapid manufacturing, multimedia, architecture, inspection, and quality control. The scanning process converts a real object into a digital format. This paper's essential purpose is to show the use of a 3D blue light Scanner/COMET 3D to redesign a carburetor body. The paper identifies different issues involved in the processes to help future users. COMET 3D does scanning of the carburetor body by which COLIN 3D software is used for measurements, editing, and analyzing of the acquired point clouds data. This paper also identifies the necessary steps to undertake 3D Scanning and part dimensioning for a carburetor body. It also discusses the error/problems that occurred during the process. The applications of non-contact blue light 3D Scanners are many as they can be innovatively used to redesign an existing part, architecture designing, and reducing production cycle time, biomedical and associated applications. This paper's contribution lies in achieving a step-by-step procedure of scanning any three-dimensional object as this helps in understanding the 3D scanning hardware and support software. It provides good knowledge of how to resolve the issues that can cause an error during the measurement of the surfaces and scan objects.

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1. Introduction

The primary function of the 3D Scanner is to convert a real-life object into digital form. This Scanner collects information about the exact shape and size of the object and records these data [1]. In the fourth industrial revolution, there is an essential requirement for digital manufacturing. A 3D scanner captures the physical object's image by using the concept of the white or blue light without making any contact with the surface of the object. This technology does not disfigure the object surface and is a non-contact device, and even the light (blue/white) is harmless to the human body. 3D scanners develop clouds of data from the object surface. These scanners have sensors and are equipped with one/two cameras, which take several images of the physical object during the measurement. These images are analyzed through a high-end computer, where 3D scanning software calculates point coordinates throughout the visible area under scan [2–4]. This technology's applications are for industrial design, documentation of cultural

artifacts, quality control/inspection, reverse engineering, and prototyping. 3D Scanner technologies have a wide range of applications. Its range starts with designing the smallest tooth gear to one of the national monument [5–7]. Many product development/manufacturing companies are implementing the concept of reverse engineering to reduce the cost and time associated with their product development cycle [8]. In the product design and development process: a designer tries to understand and observe the market, the requirement of the customer and their limitations; quick synthesis of this information to develop some new concept or making further improvement in already existing products; then redesigns, generate prototypes and analyses the same; lastly implements changes in the design step with technologically advanced procedures. This goes on as iteration until we obtain a satisfactory product. Fig. 1 shows the above steps of the product development process, and we analyzed that it requires more time & associated costs to develop a new product. Hence, to reduce the cost, and excess time, it needs a digital data of the product, which is quite convenient for redesigning and analysis through available customized software.

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Fig. 1. Product development cycle time.

In the product development cycle, the product's value is enhanced by changing the design of a product, and a 3D scanner can well accomplish this. Part accuracy and data clarity require a digital definition to support the deliverables [9,10]. There are two ways of 3D scanning, i.e., contact type scanning and non-contact type scanning. Contact 3D scanner requires a physical touch with the object. A coordinate measuring machine (CMM) is an example of a contact type 3D scanner used thoroughly in manufacturing. The disadvantage of a contact scanner is that it requires physical contact with the object, which might damage the object's surface profile like scanning delicate or valuable objects. CMM's are relatively slow compared to other scanning methods due to the slow movement of the probe, mounted on its arm [11]. Non-contact 3D scanners emit radiations (laser)/light (blue/white) and detect its reflection using a camera and a receiver. A 3D scanner creates a point cloud of geometric samples of the surface of the object. This involves a large amount of data, which is in the form of a cluster of points. It describes the coordinates (x, y, and z) of every point of each object's surface.

In some cases, a single scan will not produce a complete model of the object, so for this situation, subsequent measurement is required for the complete scanning of the object. Each line scanned contains many points that will be separated by a certain pitch distance, depending on the camera's resolution. These scanned data are brought into the common reference system (i.e., alignment) and then merged to create a model using the triangulation method [12,13]. 3D digital model created by this technology is effectively used for 3D printing technology [14,15].

SI engines use volatile liquid fuels. The air–fuel mixture is prepared outside the engine cylinder. The process of forming a combustible fuel–air mixture is called carburetion, and the mechanical device which performs this action is the so-called carburetor, as shown in Fig. 2.

A carburetor constitutes of a complex set of passage, i.e., venturi-section, throttle plate, choke valve, fuel metering jet, etc. and the compressible flow varies from laminar to fully turbulent due to rapid changes in operating conditions as well as changes in pressure drop at the throat and atmospheric temperature [16,17]. The mechanism of simple carburetors is based on Bernoulli's principle. According to this theory, as the velocity of air increases, there will be a pressure drop at the venturi throat. This theory is valid only up to a specific range of velocity and pressure. The pressure of air flowing at the throat of the venturi will be less than the atmospheric pressure. Research is also undertaken on COVID-19 pandemic by the applications of different technologies like 3D scanning, 3D printing, Artificial intelligence and others [18–20]. These are helpful to identify and tracking of infected patient and further helpful for their proper treatment process [21–23].

2. Literature review

Irzmańska and Okrasa [24] stated that 3D scanning is used to obtain the human body information in 3D digital form. This technology precisely measures the internal dimensions of footwear. It is the best method for the fitting of footwear, which increases the ergonomic properties. Tredinnick *et al.* [25] discussed the

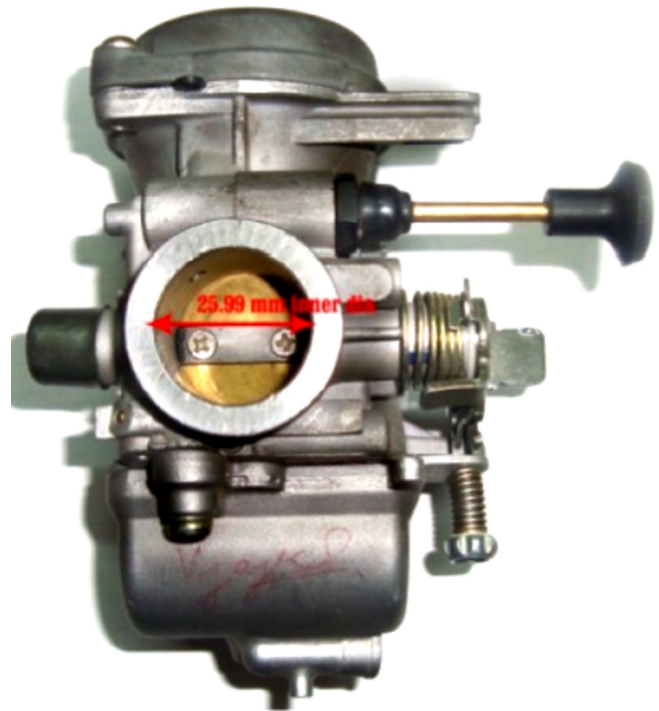


Fig. 2. Carburetor of Bullet 350 CC.

importance of 3D scanning to solve a crime and used technology to document the crime scene for the complete investigation process. The scanned 3D model is precisely used to analyze the crime scene. Lazarević *et al.* [26] presented that 3D scanning is a useful technique used to inspect part during the cutting process. This technology used for precise measurement as compared to coordinate measuring machine (CMM). The results show that the 3D scanning process increases the accuracy of inspection. Haleem and Javaid [27] studied that 3D scanning is successfully used in the medical field to capture information on the outer body surface. The research on this technology is continuously increasing. It is used for design and develops patient-specific implants. It accurately measures the skin area of the individual patient in 3D form. By using this technology, doctors can improve the treatment process.

Maloney [28] shows the capability of 3D scanning to measure the stone defect surface area and is used for the proper estimation of flake mass. Feng *et al.* [29] present that 3D scanning is a novel method to obtain initial geometric imperfections. This technology presents the object in point cloud data. The experiment was conducted, and we identified a reduction of geometric imperfections during the self-balanced process. Andrews *et al.* [30] proposed that 3D scanning is a non-touch measuring technique that is feasible and increases performance. This technology can be used to see the growth of preterm infants. Javaid *et al.* [31] presented that 3D scanning is quite efficient in dentistry, and its applications are to create innovation in dental implants, tools, and devices. It is helpful for the design and development of dentures, braces,

veneers, and aligners. It provides a better understanding of the teaching and learning process. Chen *et al.* [32] identified that laser 3D scanning is useful for identifying and analyzing underground spaces. They presented a semi-automatic laser scanning method for rock mass characterization. For underground mines, this technology has better efficiency and accuracy, which can replace traditional methods. Zhang *et al.* [33] used 3D scanning as an innovative method for road-marking detection and provided elevation accuracy of 0.25 mm and used this technology to precisely detect elevation information.

3. Machine and method description

Structured light 3D scanners use the trigonometric triangulation method, in which light produces a series of linear patterns of light (fringes) onto an object. The edges of each line in this pattern calculate the distance from the Scanner to the object surface. The camera of the Scanner captures the fringe images data. Through these data, the software algorithm calculates the coordinates of various points spaced all over the surface of the object during a single measurement [34]. Thus for complete scanning of an object, surface measurements are merged with the help of “markers” being fixed on the object. The COMET 3D scanner is a fringe projection scanner consists of a camera and a projector, and both are enclosed in a compact housing. The measurement volume of the Scanner is represented by Field of View (FOV) [35]. The size of the field of view depends on both the camera resolution and the selected lenses. The distance between the Scanner and the centre of the field of view is 760 mm. The specifications of the COMET 3D Scanner (5 M 250) are: The projector and camera lens has a focal length of 25 mm, and the resolution is 5 megapixels. The measurement volume of COMET 3D 5 M (250) is 260*215*140 mm³. The rotary table used for the object has a 400 mm diameter and can sustain load up to 100 kg. Bigger rotary tables are also available. Further, this Scanner can also be mounted to a robotic arm for automation. People also use this Scanner as a handheld device.

The unique feature of the COMET 3D sensor is its blue led technology. Its main components are COMET 3D sensor, rotary table, lenses (one camera lens and one projector lens for each field of view), COMET power pack, cable set, dedicated PC or laptop with installed Colin3D/COMET plus software and Code Meter dongle, Tripod. COLIN 3D software provides a powerful software platform for operating the COMET 6 and T-SCAN CS measuring systems, making photogrammetric measurements, and editing and analyzing the acquired data. The program independently identifies ideal strategies for merging individual images (matching) and guiding the user to better results using a completely redesigned, project-oriented user interface. This software is designed for maximum ease of use and has the lesser hassle of setting up parameters, allowing concentrating on the task at hand and helps quick scanning.

In the scanning process of a physical object (carburetor), the object should be kept on a rotary table for data acquisition. Point clouds data refers to millions of points that describe the shape of the object on the computer monitor. The process is very fast, gathering up to 5 million points per second and very precise (to $\pm 0.0005''$). When these point cloud data files are created, they are merged and meshed into one three-dimensional representation of the object and post-processed with suitable software packages for further modeling. For inspection of the object's exact shape and size, the point cloud data can be compared with the designer's CAD nominal data. The result is delivered in the form of a 'color map deviation report' in pdf format, which pictorially describes the differences between the scan data and the CAD data. After com-

plete scanning and meshing of the point's cloud data, the software will save this scanned data file in different formats (STL). Further, this '.STL' file can be opened in CAD/SOLIDWORKS software to develop the model geometry and study the design of the model for reverse engineering. The CAD model enables the precise reproduction of the scanned object, or the object can be modified in the CAD model to correct imperfections.

4. Scanning methodology

To scan the carburetor body, we have used a COMET 3D scanner with blue light technology. The Scanner runs in conjunction with the COLIN 3D scanning software. Through software command, the projector will project a blue light on the surface of the object in the form of Fringes, while the camera will capture this surface in the form of point clouds data. The capturing of the object surface is based on the triangulation method. The first step in the scanning procedure is to connect the measurement device with the PC in which COLIN 3D software is installed. When the Scanner is switched on, blue light emits through the projector lens on the measurement device. Place the object on the measurement device (rotary table). In this system, place the measurement object, as precisely as possible, in the centre of the measuring volume, located at the point of intersection between the fields of view of the camera and the projector. Here we can choose the 36-degree rotation of the rotary table so that the entire object is scanned in 10 rotations of the table for the object's defined position. After the second rotation, a dialogue box appears for aligning the measurements of first and second scanned data. The measurement is carried not in a sequence. After the last measurement, data is selected, and clipping is done for parts that we want to exclude from the measuring object. After creating measurements, editing of the resulting data is done in the “Editing Data” or ‘Processing Data’ for meshing, and best fit alignment of all the measurements.

The significant steps of the scanning process of COMET 3D Scanner with blue light technology are: creating projects, measurement with rotary table, aligning measurement, and editing data. With COLIN 3D software, an option will appear on the right side to create the projects. A new project could be built in the backstage view. Automatically, this view appears when we start using COLIN 3D software. Later, we can open the view by clicking the file button. For scanning an object, one has to select the rotary measurement button. In this system, the said object is placed precisely in the centre of the measuring volume, which is located at the point of intersection between the fields of view of the camera and the projector. Now align the sensor with the rotary table. In the Axis Control box, one can set the axes of the rotary table. This is done using the sliders for the tilt axis and the rotation axis. With single-axis rotary tables, only the rotation axis is available. In the positions, control box one can create and adjust a list of positions for the upcoming measurement sequence. Here, one can choose the 36-degree rotation of the rotary table so that the entire object can be scanned in 10 rotations for the object's defined position. After the second rotation, a dialogue box appears to align the measurements. In scanning, as per the 3D viewer's requirements, the object is placed precisely at the centre of the field of view. At this stage, one has to set parameters after that click next, i.e., a) Quality Level-high, medium or low) Camera Configuration-high, medium or low-resolution) In sensor temperature, we have to check the temperature of Scanner before scanning (i.e., the temperature should be less than 32 °C) otherwise there will be variation during measurement. After clicking next, one has to select the rotary measurement button. At this stage one has to make some more settings: a) Define tilt axis-if the object is tilted at some angle from the rotary table base, then define the tilted axis b) Define rotation axis-In this

one has to define the axis of rotation of table c) Position-in this one has to choose at what angle the object should be rotated for the first measurement, to scan the surface of the object. In this case, ten positions are set, representing every 36° of rotation; the measurement will be carried out. When these parameters are set, click on the next.

After defining the position for rotary measurement, the first sequence of measurement will start, as can be seen in Fig. 3(a). After the second measurement in the sequence of first, subsequently, both the scanned images will appear for alignment of scanned data, as shown in Fig. 3(b). Here one has to choose the common reference point on both the scanned data so that software will automatically align the further measuring data. Fig. 4 shows that when all the measurement sequence data are captured, one has to merge these surfaces by choosing a common reference point and aligning the measurement sequence.

If the measurement sequences are not optimized, then one has to select the global optimization button in data processing, as shown in Fig. 5. Global optimization should be used after all measurements have been made to achieve the best possible positions of all measurements in the overall formation. Measurement data in the 3D viewer is colored to allow a visual assessment of gaps. One can read the respective deviation from the color map as a location with no gaps is colored as green. Red color represents an increasing gap in location. If we use markers in the measurements, yellow color represents the distribution of marker. Measurements with a green color indicate an excellent distribution, which results in reliable alignment via markers. For triangle mesh, one has to choose the mesh creation option. Here, one can mesh the scanned object to optimise the scanned data better, as shown in Fig. 6. If there are holes in the mesh creation, we can fill the holes by defining the maximum and minimum diameter of holes, as in Fig. 7.

Fig. 8 represents the entire scanned surface of the object. After creating measurements, one can edit the resulting data; this includes global optimisation, triangle mesh (mesh creation, mesh editing, edit holes), selection (lasso selection, lasso de-selection, component selection, island selection, edit selection, clip selection), tool (object selection, mirror nominal data). Depending on the application area, one can choose between four optimisation options for creating the triangle mesh, i.e., quality assurance, design, and reverse engineering. Markers used for alignment are still visible in an un-optimised triangle mesh. The stamp out/ fill markers function removes part of the triangle mesh at the marker positions and fills the resulting holes to produce a smooth surface in those places. The option of Smoothing and sharpening meshes is used for smoothing the mesh and sharpening the edges. From the actual measurement object, the Surfaces that are irrelevant to the measuring task can select and remove in COLIN 3D.

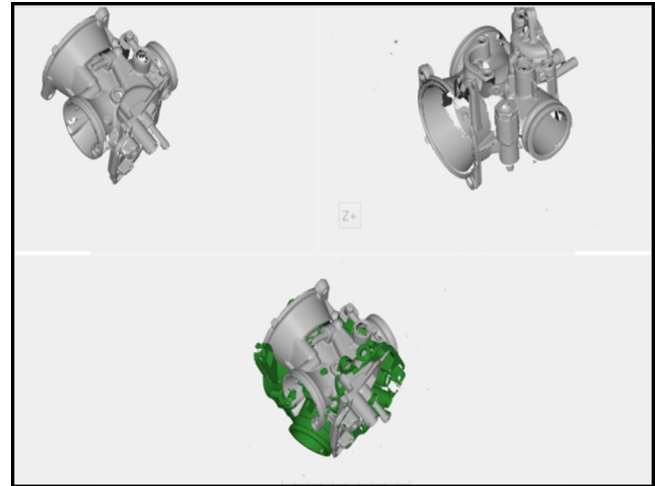


Fig. 4. Merging Scanned Images of Carburetor after the last measurement.

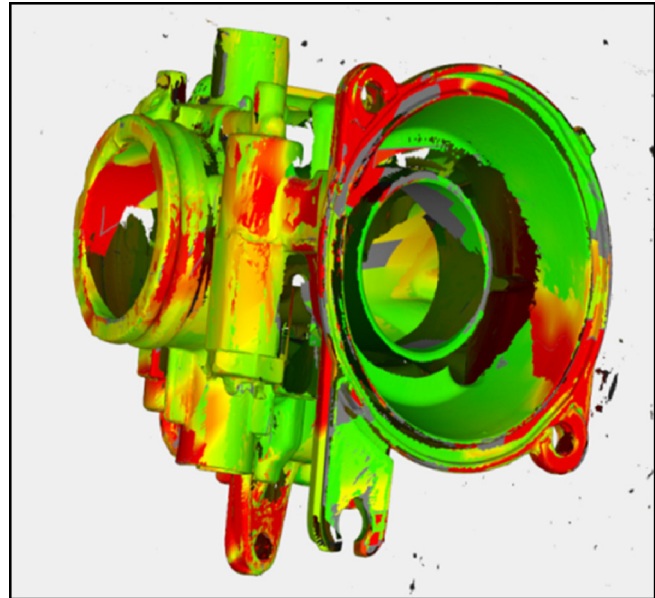


Fig. 5. Global optimisation.

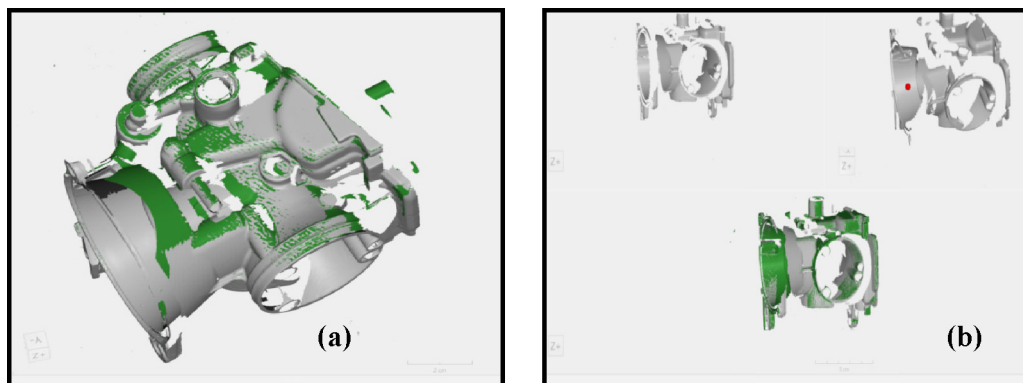


Fig. 3. (a) Measurement sequence; (b) aligning measurement.

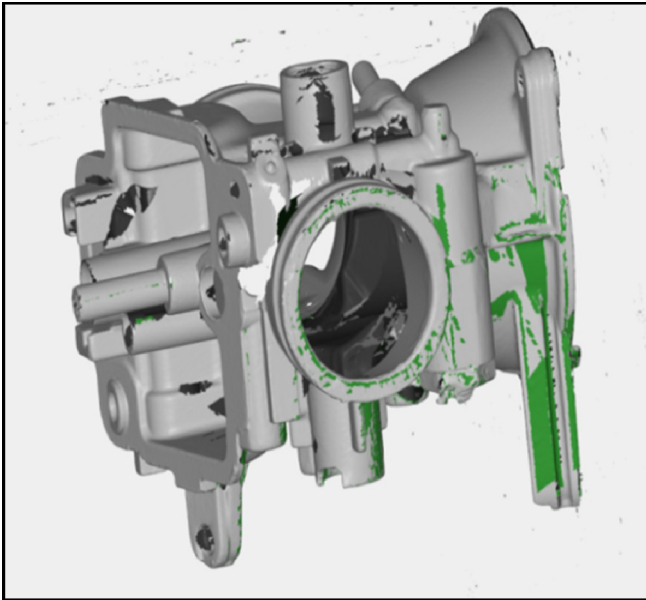


Fig. 6. Triangular meshing and filling holes.

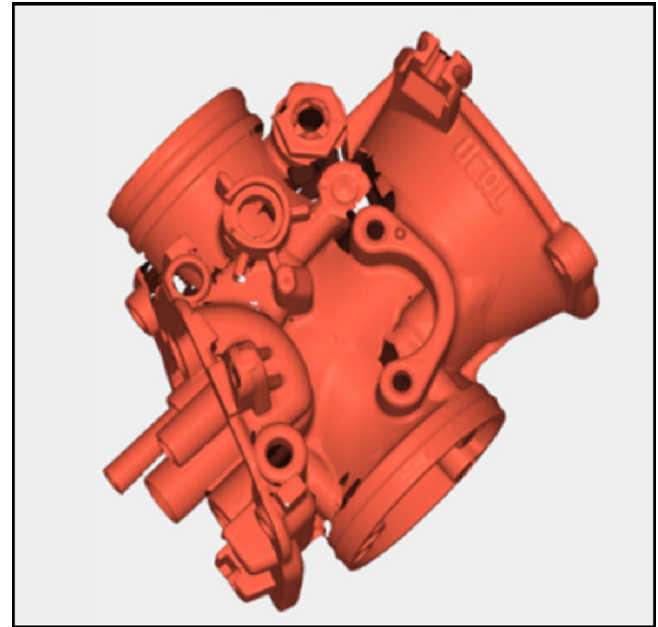


Fig. 8. Complete scan image of the carburetor.

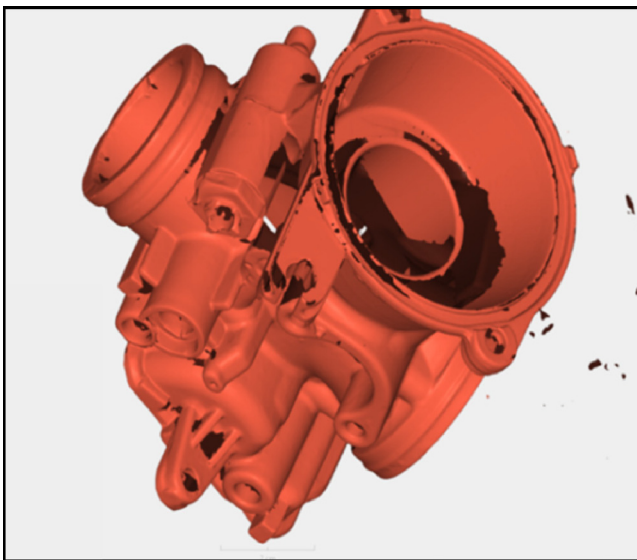


Fig. 7. Editing holes.

With the lasso tool, one can create masks to add or remove data from the selection. With the component selection tool, one can select connected components of triangle meshes. The island selection selects small, isolated data sets from the measurements or the resulting mesh. The maximum island size defines how many measurement points or triangles can be contained at most for selection. After selecting data, one can remove the selected data by clicking the clip selection button. Only visible selected data will be removed. If one has also selected currently hidden data, this data will be retained. With the object selection, we can select objects in the 3D viewer. These objects are then selected in the project tree and coloured in the 3D viewer's highlight colour. Colin 3D offers the option to mirror the nominal data. This might be useful to measure symmetric objects, but CAD data only contains one-half of the objects. When all the measurement is taken and merged into one three-dimensional objects (carburetor), this data is saved into

'STL file format' for further modelling. The STL file is imported into Solid Works (CAD modelling software) to convert this point clouds data into the 3D surface model, as shown in Fig. 9. After the carburetor body's model generation, its dimensioning can be done by using the SolidWorks software, as shown in Fig. 10.

5. Issues in 3D scanning and solutions

During scanning the carburetor body, some error/issues were encountered, and the same are discussed below:

- Reflective surface: The most critical issue while scanning an object is that it cannot scan a highly polished surface. The issue is also with optical materials with dirt, dark, shiny, and transparent surfaces [36]. For this issue, a developer (white spray) is used.
- Material identification: Scanners can only read at the surface level; they cannot determine the material they are scanning.
- Occlusions: The scanner camera cannot capture the surface, in which occlusions are present, i.e., grooves, clog, etc. The remedy of this error can be removed by using a particular type of fixtures, which can place the object at the required angle so that the Scanner can capture these occlusions.
- Point clouds overlap: While Scanning large objects points, clouds data captured from the surface overlap. This will cause un-optimized meshing of the data. The remedy of this issue requires using a high-resolution camera and a wide range of the field of view of camera and projector to capture the surface data.
- Fixtures: Rotating scan motion is hard to make accurate. In the case of a rotating table, it is tough to scan complex objects which are not Omni-directional. For scanning these types of the object requires unique fixtures arrangement for fixing the object at different angles.
- Need a massive processor: For large objects, scanners need an extensive database, which increases the scanning time of an object. For this issue, the processor of the PC in which the scanning software is running possesses high RAM and graphics card.

build 3D parts, customized surgical implants, mechanical bone replicas, anthropology, forensics [37]. In architecture, this helps for 3D visualization of design space, iterations of shape, sections models. It creates significant advancements in fashion and Jewelry design, Quality control, and other allied areas.

7. Conclusion

3D scanners have a wide range of applications in modern manufacturing and quality control. This paper has discussed the scanning process taking the example inspection of a three-dimensional carburetor body. The process of scanning through a COMET 3D scanner with a rotary table requires particular types of fixtures for fixing the body at an angle because three-dimensional carburetor has very complex geometry inside and outer the body. Before scanning the carburetor, one has to clean the surfaces or apply spray developer at the surface to capture the shiny or polished surfaces during measurement accurately. This 3D Scanner is quite sensitive to the surrounding temperature, so this equipment should be kept at normal room temperature. Due to the rise in sensor temperature, the measurement will be interrupted. Overall the 3D Scanner has become very popular due to its speed of measurement, high accuracy, data clarity, and ease of use.

CRedit authorship contribution statement

Abid Haleem: Conceptualization, Data curation, Formal analysis, Writing - original draft. **Pawan Gupta:** Data curation, Writing - review & editing. **Shashi Bahl:** Data curation, Writing - review & editing. **Mohd Javaid:** Investigation, Writing - review & editing. **Lalit Kumar:** Investigation, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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