Enhancement of Reverse Engineered 3d Model Features through the Integration of Contact and Non-Contact Scanned Data

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***Abstract* - In a modern manufacturing industry, Reverse Engineering (RE) is playing a more important role. The fields like aviation, space flight, automobile, medical and house appliance, its roles are vital. Reverse Engineering takes an existing product, and creates a computer aided design model, for modification or reproduction to the design aspect of the product. Generally, RE classified into two types Contact and Non-contact. RE is often used in the following environment: (i) where a prototype of the final product has been modeled manually and therefore no Computer Aided Design (CAD) model of the prototype exists, e.g. clay model in automotive industry. (ii) Where a CAD is introduced in a company and all existing products must be modeled in order to have a fully digital archive. Particularly, the CAD model of a complex shaped part is modeled because it is difficult to create its CAD model directly. (iii) Where complex shaped parts must be inspected and therefore the RE model created will be compared to an existing CAD model. The structure and the shapes of the products in these fields become complex and irregular, the touch probe (contact) measurement method is widely used in inspection, but it is not suitable for measuring complex part and soft surfaces in Reverse Engineering owing to it is inherent slow speed. To meet this requirement, several non-contact sensors have been developed recently, this type of non-contact scanning to improve measurement speed greatly. In addition, there still exist some other problems in the application of Non-contact. (i) It is unable to measure the edge of a part distinctly due to its working principle. (ii) The accuracy of a laser scanner is relatively low compared to a Contact, it cannot meet the demand of measuring Key features and positional references of some part. (iii) Because of the triangulation principle, blind areas will inevitably be found when scanning complicated part.**

Since both methods having some disadvantages in the complete retrieval of 3D information of a product. So any one single individual method is not suitable for retrieval of complete information of 3D product. Based on the above discussion, this paper aim at integration of Contact and Non-Contact scanned data of a Reverse Engineering to successfully generate a 3D CAD model with enhanced features of an object.

Keywords: Revers eEngineering, CAD Modeling, Digitization, Integration.

INTRODUCTION

Recently, pressure from the competitor has reached the point where rapid product design and optimization need to be embraced within the product development cycle. A short lead-time in product development is strongly demanded to satisfy needs, resulting from the globalization of manufacturing activities and the changes in the market requirements. In engineering areas such as aerospace, automotives, shipbuilding and medicine, it is difficult to create a CAD model of an existing product (3). In these cases, Reverse Engineering (RE) is an efficient approach to significantly reduce the product development cycle. RE is the science of taking the existing physical model and reproducing its surface geometry in three-dimensional (3D) data file on a computer-aided design (CAD) system. RE enables the duplication of an existing part by capturing the component's physical dimensions and features. Many different technologies are used to collect three dimensional data (6).

Even those these are several method of data acquisition as indicated in fig 1.4, the most commonly using method and most widely accepted methods are CMM and laser scanning methods (2). Hence these two methods are considered in this paper. Each technology has its advantages and disadvantages, and their application and specifications overlap.

Following are reasons for RE a part or product (9):

1. Where a prototype of the final product has been modeled manually and therefore no CAD model of the prototype exist, e.g. clay model in automobile industry.
2. Where a CAD is introduced in a company and all existing products must be modeled in order to have a fully digital archive. Particularly, the CAD model of a complex shaped part is modeled because it is difficult to create its CAD model directly.
3. Where complex shaped part must be inspected and therefore the RE model created will be compared to an existing CAD model.

SUMMARY OF LITERATURE SURVEY

Scanned models using vision systems like LSs contain thousands of data points. This brings difficulties into working with the model, as most of these points are redundant. There is much research (Lee et al, 2005 Martin and Varady, 1996) in this field mainly on point-data reduction, which inevitably brings the risk of compromising surface details.

The other main problem with scanned models is the missing information on holes, steps and concave features, which is due to occlusion. While some researchers

(Manzoor Hussain and Menq, 2008) have focused on system calibration for better scanning results,

Lin and Zhang (2006) have developed a method for the optimal arrangement of four laser tracking interferometers for 3D Coordinate Measurement. Although their approach may help in setting the scanning view for optimised results, the method is incapable of extracting a complete scanned model, especially when the model has inward features. This would result in information missing from the part surface.

Son et al. (2002) have proposed an automated laser scanning system which can automatically generate a scan plan by investing a complex free-form part whose CAD model is given (Lee and Woo, 1998). The automated part positioning system can save much time, improve the quality of captured data and the registration process is simplified. Thereby, redundant data processing is drastically reduced and errors caused by human operator can be minimized.

Feng et al. (2001) presented the effects of the scan depth and the projected angle on the digitizing accuracy of a laser/CMM scanning system. Speckle noise in the CCD laser images is considered the primary source of random error.

As well as scanned models using CMM is the not suitable measurement equipment to measure the threaded feature, included angle of on object, this bring estimation of features in a CAD model, due to the loss of point in the topological relationship between the features, While some researchers (Ismail et al, 2009) have focused on feature extraction of 3D model for accurate 3D redesign .

The other main problem with scanned model is the surface defilation in the soft surface, due to the impact load of the CMM probe, researchers (Giovanna Sansoni et al, 2004) in this field mainly on point-data reduction, which inevitably brings the risk of compromising surface details.

Similarly the point data captured from the concave/convex, tapper, sphere and semi-sphere features are created some dimensional inaccuracy, which is due to track slip of the probe ball on this surface, researchers (Jafar jamshidi et al, 2006) in this field introduce a new method to improve feature extraction.

Xie et al. (2005) have presented a multi-probe measuring system integrated with a CMM, astructured-light sensor, a trigger probe and a rotary table. Two types of scanning modes which is multiview scanning mode and rotating scanning mode have been used (Chung and Liao, 2001).

Hong-Tzong Yau et al. (2005) have presented the measure method to get the better data points and the appropriate method to deal with points cloud data. Reverse engineering software is then used to create the free-form surfaces from the point cloud data (Meng and Chen, 1996).

PROBLEM IN THE RE PROCESS

The literature review revels that contact scanning methods are Fast data point scanning, Repeatability for routine operations, Availability of different auxiliaries for different applications and high level of flexibility and accuracy (1). But Tedious programming of complex components, Time consuming when number of required data point is high and Expensive machine/hour work. Similarly the Non-Contact type scanning method are Fast scanning speed (can generate thousand of point in seconds) and Able to digitize freeform surface in short time (4). Data captured by a 3D contact type scanner on it own is set of tessellated geometric in 3D space, which can provide dimensional information from the part; however it is incapable of exposing the topological relationship of those features. These matters become critical when such model has to be verified by non-experts. In addition, the lack of solid model characteristics or surface between feature in this type of model make them unsuitable for computational analyses such as assembly Finite Element Analysis(FEA),stress and heat analyses. **Due to the above** problems the extraction of features are very difficult (or) inaccurate.

OBJECTIVES

Based on the above discussion the objective of this paper becomes integration of Contact and Non-Contact scanned data of a Reverse Engineered product to successfully generate a 3D CAD model with enhanced features (Square extrusion, Cylindrical extrusion, Triangular extrusion, Thread, Sphere, V- notches, Square notches, Concave/Convex surfaces, Blind hole, Through holes, Fillet, Counter sunk and linear dimension x, y and z axis).

PROPOSED METHODOLOGY

There are several methods available in the even though Reverse Engineering application, the contact tough probe method and Non-contact laser scanner method are most widely used. But in the contact method some of features like Concave/Convex surface, threads, sphere and fillet are not completely recoverable. Similarly the Non-Contact Laser Scanner is incapable of providing complete information of features like Blind hole, through hole, Notches and under cut. But a Engineering product will all the combination of features like Square extrusion, Cylindrical extrusion, Triangular extrusion, Thread, Sphere, V notches, Square notches, Concave/Convex surfaces, Blind hole, Through holes, Fillet, Counter sunk. Hence any single individual method may not provide complete solution for Reverse Engineered product. Hence there is a need for a new methodology. (ie) Integration of Contact and Non-contact scanned data. This method will provide complete information of a 3D product

The process flow of the proposed methodology explained in the Fig: 1

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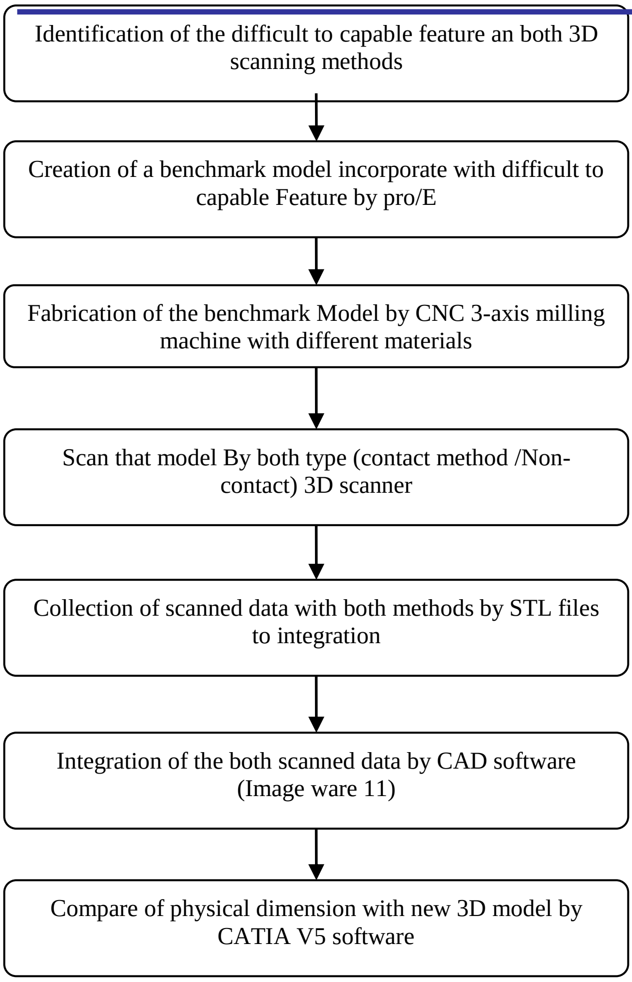

Process flow of the proposed methodology-Fig 1

IDENTIFICATION OF DIFFICULT TO CAPABLE FEATURE

Fortunately in the last several years, many research efforts have been dedicated to reverse engineering technology and the feature extraction problems have been improved significantly. Based on the above literature the following feature are identified on difficult to capable of both scanning method such as contact/Non-contact. The following table1 explains them.

Table1Difficult to measurement by contact/Non-contact type scanning

Difficult to measurement by	
Contact	Non-contact
Extrusion (square, cylindrical, triangle)	Blind hole
Threading	Through holes
Semi-Sphere, notches	Triangular cut
Concave/convex surface	Edges (square, cylindrical)

BENCHMARKMODEL DESIGN

In order to explain the methodology, a standard sample part is designed to represent some common dimensional/geometric feature for 3D scanners (Contact and Non-contact), accuracy evaluation. The model (BMM) is fabricated by using CNC three axis milling machine made up of aluminum material. These models comprises of different features such as Square packets, Triangular packets, Fillet, Chamber, Square protrusion, cylindrical protrusion, Triangular protrusion, Concave surface, convex surface, blind hole, Square key way, V-type key way, Semi Sphere, Threaded surface, Thin wall, circular Notches and through hole are presented in it. These bench mark model are shown in figure 2.and also the legends of BMM explained in table 2. The results obtained from that model can be generalized and used for any real time applications.

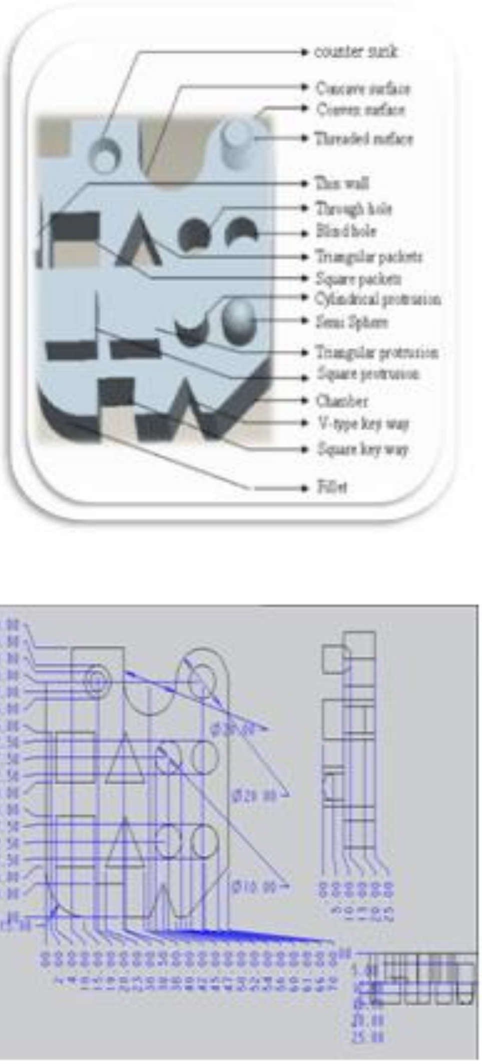

Fig: 2 view of Benchmark model

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Table 2 Legends of benchmark model

CR1	Radius of convex
CR2	Radius of concave
F	Radius of fillet
SKL	Square key way length
SKB	Square key way breadth
VKB	V-keyway breath
VKθ	angle of V-keyway
TL	Taper length
Tθ	Angle of Taper
SPL	Length of Square packed
SPB	Breadth of square packed
TPH	Height of triangular packed
CNR1	Radius counter sunk-1
CNR2	Radius counter sunk-2
TPθ	Angle of triangular packed
RT3	Radius of through hole
RB4	Radius of blind hole
DTH	Depth of through hole
DBH	Depth of blind hole
Sel	Length of Square extrusion
Seb	Breadth of square extrusion
The	Height of triangular extrusion
Teθ	Angle of triangular extrusion
Cr5	Radius of cylindrical extrusion
SSr6	Radius of semi- sphere
Twb	Breadth of the thin wall
Tdp	Pitch of external thread
TdMd	Major diameter of thread
Tdnd	Minor diameter of thread
TdMd	Major diameter of thread
Tdnd	Minor diameter of thread

BENCHMARK MODEL BRICATION

Fig: 3 physical BMM

A benchmark model fabrication is considered on two main think such as types of materials and types of manufacturing techniques, in this paper a benchmark model fabrication made up of aluminum material by using three axes Computer Numerical Control (CNC) milling machine. Based up on the 3D model (pro/E design) the CNC coding are prepared with optimum cutting speed, feet of tool and table movement by CAM software, after that the coding are simulated to verify the output by using trick software, then any changes and corrections are done by CAM software to CNC milling machine, the above figure 3 depicts the physical benchmark model.

EXPERIMENTATION

The dimensions of the various features available in the BMM's are initially measured with help of profile projector (Made: MITUTOYO profile projector (PH 600), Japan. with one micron accuracy) and tabulated. Then this BMM were scanned with help of Contact type (Made: Roland 3D plotter (MDX20) scanner and Laser scanner (Microscribe MX 3D Red light line laser scanner). The dimensions obtained through the above two methods are compared with the dimension obtained by the profile projector, during the comparison, it is observed that Radius of convex, Radius of concave, Radius of fillet, Square key way length, V-keyway length, Angle of Taper, Length of Square extrusion, Breadth of square extrusion, Height of triangular extrusion, Angle of triangular extrusion, Radius of cylindrical extrusion, Breadth of the thin wall, Pitch of external thread, Major diameter of thread, Minor diameter of thread and Radius of semi-sphere. are inaccurate and Semi-sphere, Cylindrical extrusion, Triangular extrusion, Square extrusion, External Threading and Thin wall not able to retrieve through Contact method and the same is indicated in table-3 . Similarly V-keyway breadth, Square key way breadth, Taper length, Length of Square packed, Breadth of square packed, Height of triangular packed, Angle of triangular packed, Radius of through hole, Radius of blind hole, Depth of through hole and Depth of blind hole are inaccurate and Blind hole, Through hole, packed, Chamfer and key way not able to retrieve through Non-contact method and the same is indicated in table-3. In order to obtain the complete information of the 3D product, it is essential to integrate these two scanned data. The integrated data dimensions are indicated in table -3. These are explained step-by-step in following section.

The 3D benchmark model scanned by using both method and The first step of this method measure the physical dimension of 3D models by using MITUTOYO profile projector (PH 600), to improve the scanning accuracy of laser scanner apply the white spray on the surface of the models, after that scanning by laser scanner (Non-contact) and CMM (Contact), Then this scanned raw point are export to Image ware 11 and Rhinoceros 3D Software to generate section and curve of 3D data , the following figure 4 explained the curve data of the benchmark model.

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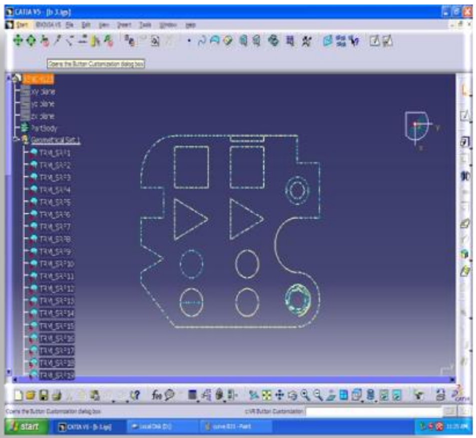

Fig: 4 curve of benchmark model

Using that curve data the accurate 3D point are export to CATIVA V5 surface modeling software to design the individual solid model (such as Contact/Non-contact), and then measure the dimensional information of each method by using drafting option in CATIVA V5 software, finally the two types curve models are fixed in the same coordination (0,0) of Image ware 11, it gives easy to integrated (merging) both types of curve, after that this integrated 3D points are converted into 3D point by using union option then the complete 3D solid model occur by using pad, pocked, shaft and rip options. The following figure 5 explained the details of solid models.

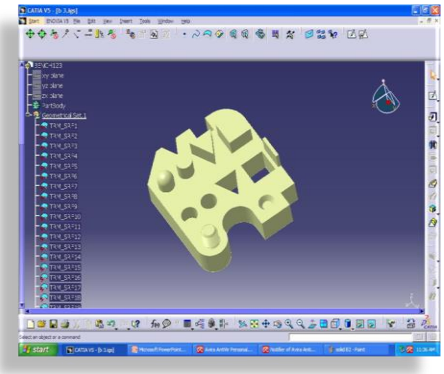

Fig: 5 solid model of benchmark model

In order to reduce human errors, the dimensional of the features available in the 3D bench mark models are initially measured with help of profile projector (Made: MITUTOYO (PH 600) Japan with one micron accuracy) and tabulated. Then the BMM dimensional detailed of Contact, Non-contact and integrated scanned data are measured by using drafting option in Image ware 11 software. The dimensions obtained through the above three methods are compared with the dimension obtained by the profile projector.CAD model of the BMM-III created by the new proposed RE method is explained in the following figure 6. Dimensional comparison of BMM shown in table 3.

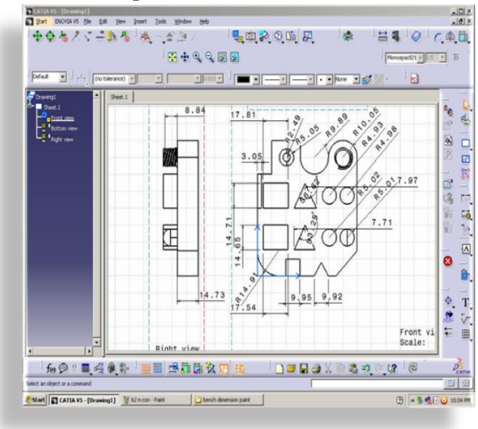

Fig: 6 CAD model of the BMM created by the new proposed RE method

Table 3 Dimensional comparison of BMM

Symbol	Contact		Non-Contact		Physical	Integrated	
	Dimension	deviation (mm)	Dimension	deviation (mm)	Dimension	Dimension	Deviation mm)
CR1	10.021	.033	10.051	.003	10.054	10.051	.003
CR2	9.745	.097	9.831	.011	9.8428	9.831	.011
F	14.52	.406	14.910	.016	14.926	14.910	.016
SKL	9.943	.028	9.953	.018	9.971	9.953	.018
SKB	10.000	.007	9.891	.116	10.007	10.000	.007
VKL	9.812	.116	9.916	.012	9.928	9.916	.012
VKB	7.914	.022	7.740	.196	7.936	7.914	.022
VKθ	50.490	1.150	51.120	.520	51.640	51.120	.520
TL	21.301	.011	21.28	.032	21.312	21.301	.011
TLθ	45.220	.210	45.400	.030	45.430	45.400	.030
SPL	17.812	.026	17.129	.709	17.838	17.812	.026
SPB	14.710	.022	14.291	.441	14.732	14.710	.022
TPH	14.639	.059	13.989	.709	14.698	14.639	.059
TPθ	56.620	.060	56.210	.470	56.680	56.620	.060
RP3	4.918	.008	4.692	.234	4.9262	4.918	.008
RP4	4.975	.009	4.206	.778	4.9841	4.975	.009
DTH	14.714	.013	---	---	14.727	14.714	.013
DBH	9.799	.097	---	---	9.896	9.799	.097
Sel	17.502	.035	17.531	.006	17.537	17.531	.006
Seb	14.340	.011	14.640	.005	14.645	14.640	.005
Teh	14.561	.037	14.593	.005	14.598	14.593	.005
Teθ	51.120	.260	51.290	.090	51.380	51.290	.090
Cr5	4.999	.020	5.0145	.045	5.019	5.0145	.045
SSr6	4.998	.110	5.012	.096	5.108	5.012	.096
Twb	3.053	.015	3.067	.001	3.068	3.067	.001
Tdp	---	---	1.759	.005	1.764	1.759	.005
TdMd	---	---	11.286	.083	11.369	11.286	.083
Tdnd	---	---	9.499	.073	9.572	9.499	.073
CNR1	9.892	.339	10.109	.122	10.231	10.109	.122
CNR2	4.786	.203	4.976	.013	4.989	4.976	.013

This method will provide complete information of a 3D product, the output details of integrated data accuracy is fairly close to our Physical dimension/expected objective of the benchmark model.From these result analyses, we were able to reach the conclusion of the main factors and best type of scanning to every complicated Engineering features, such findings are summarized in table 4, in which we also list the suggested scanning types of each features for achieving the best result in this above benchmark model.

Table 4 summary of best scanning system for benchmark model

Features	Contact	Non-Contact	Integrated
Concave surface	---	✓	✓
Convex surface	---	✓	✓
Fillet	---	✓	✓
Square type key way	✓	---	✓
V-type key way	✓	---	✓
Chamfer	✓	---	✓
Square packed	✓	---	✓
Triangular packed	✓	---	✓
Through hole	✓	---	✓
Blind hole	✓	---	✓
Square extrusion	---	✓	✓
Triangular extrusion	---	✓	✓
Cylindrical extrusion	---	✓	✓
Semi- sphere	---	✓	✓
Thin wall	---	✓	✓
External Threading	---	✓	✓

✓= Easy to capable features in both method

--- = Difficult to capable features in both method

CONCLUSION

A novel method of integration between 3D data captured by Contact and Non-Contact methods is presented. This method is most suitable for Reverse Engineering of a part with all features (Square extrusion, Cylindrical extrusion, Triangular extrusion, Thread, Sphere, semi-sphere, V-notches, Square notches, Concave/Convex surfaces, Blind hole, Through holes, Fillet, Counter sunk and linear dimension x, y and z axis) that will present in any Engineering product. Data captured from Contact and Non-Contact methods, are exported to the CAD software. The models are then registered to the same co-ordinates. The high precision features are extracted by the triangulated mesh of the cloud data obtained from laser scanner and touch-trigger probe. In 3D model the average dimensional deviation in Contact method (.0696) and Non-contact method (.1673) are considerably reduced by integration (.0308) of Contact and Non-contact data. Hence some of the features which is not able to obtain through Contact methods (Radius of convex, Radius of concave, Radius of fillet, Square key way length, V-keyway length, Angle of Taper, Length of Square extrusion, Breadth of square extrusion, Height of triangular extrusion, Angle of triangular extrusion, Radius of cylindrical extrusion, Breadth of the thin wall, Pitch of external thread, Major diameter of thread, Minor diameter of thread and Radius of semi-sphere) and some of the features which is not able to obtain through Non-contact methods (Square key way breadth, V-keyway breath, Taper length, Length of Square packed, Breadth of square packed, Height of triangular packed, Angle of triangular packed, Radius of through hole, Radius of blind hole, Depth of blind hole and Depth of through hole) are able to get all above through integration of Contact and Non-contact data. This method is more superior than direct contact and Non-Contact method made as individually. This new method will provide the enhanced (complete) 3D features of part.

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REFERENCES

[1] Ahmad majdi bin abdul rain, “Integration analysis and design improvement in a Reverse engineering framework”, International conference on engineering education, 2001. pp. 24-31.
[2] Feng. H.Y, Liu Y. & Xi. F, 2001, “Analysis of digitizing errors of a laser scanning system”, Journal of the International Societies for Precision Engineering and Nanotechnology, 2001, pp.185-191.
[3] Giovanna Sansoni, Franco Docchio, “Three-dimensional optical measuremens and Reverse Engineering for automotive applications”, Robotics and computer-integrated manufacturing, 2004, pp. 359-367.
[4] Hong-Tzong Yau, Chun-Yan Chen, &Robert. G. “Registration and integration of multiple laser scanned data for Reverse Engineering of complex 3D model”, International Journal of production Research, Vol. 38, 2000, pp. 269-285.
[5] Hugues hoope, Tony derose and Tom Duchamp, “Surface reconstruction from unorganized points”, University of Washington.
[6] Ismail. A, Soon. C, Abdullahs. & Sopian. k, “Reverse Engineering in fabrication of piston crown”, Europan Journal of Scientific Research, 2009, pp. 136-146.
[7] Jafar jamshidi, Antony roy Mileham and Geraiint Wyn Owen, “Rapid and accurate data integration method for Reverse Engineering applications”, Advances in Integrated Design and Manufacturing in Mechanical Engineering II, 2009, pp. 163-175.
[8] Lin -Liang-Chia Chen, Grier. C. I. Lin, “Reverse Engineering in the design of turbine blades a case study in applying the MAMDP”, International Journal of Robotics and computer Integrated manufacturing, Vol. 16, 2006, pp. 161-167
[9] Lee. S. J and Chang. D. Y, “Laser Scanning probe with multiple detectors used for sculptured surface digitization in Reverse Engineering, “journal of physics: Conference Series, Vol. 13, 2005, pp. 155-158.
[10] Manzoor Hussain. M, Sambasiva. Rao C.H. and Prasad. K.E, “Reverse Engineering : point cloud generation with CMM for part modeling and error analysis”, ARPN Journal of engineering and applied sciences, vol.34, 2008.
[11] Matabosch. C, Fofi. D. and Slvi. J, “Registration of surface minimizing error propogation for a one-shot multi-slit hand-held scanner”, The journal of the pattern recognition society, 2008, pp. 2055-2067.
[12] 12. Son. S, Park. H. & Lee. K, “Automated laser scanning system for reverse engineering and inspection”, International Journal of Machine Tools & Manufacture, 2002, pp. 889-897.
[13] William. B, Thompson. C, and Owen. J.C, “Feature base Reverse Engineering of mechanical part”, IEEE Trans. On Robotics and Automation, Vol.15, 1999, pp. 57-66.
[14] 14. Xie. Z, Wang. J. & Zhang. Q, “Complete 3D measurement in Reverse Engineering using a multi-probe system”, International Journal of Machine Tool & Manufacturing, 2005,pp.1474-1486.