AUTOMATED GD&T INSPECTION IN INDUSTRY 4.0*

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ABSTRACT

Geometric Dimensioning and Tolerancing (GD&T) is a type of framework that is used for providing a good communication between the designers, manufacturers, the quality inspection to convey the design specifications effectively and efficiently. The GD&T has been into application since the very start of the machine component assembly designing without being named. However, now almost all industries have been emphasizing on the term GD&T. The most obvious area where many companies struggle is quality inspection. The inspection process is the process that requires a lot of human interaction. Also, the inspection process is the one that strictly requires skilled labor and quality inspector. In many industries, the idea of 3D scanning isn't new at all but the implementation of that is done for creation of 3D CAD or modeling of parts. However, the approach of using 3D scanning for inspection is hardly explored. This study is a reference to using the 3D-scanner through a specific procedure for getting automated inspection. The testing of the framework is done using a very common yet effective example of the stepped bar on which geometric and dimensional inspection was carried out. This new framework/process would be most welcomed into new upcoming industries and also the industries that have been established long back for the quick, easy and a very reliable process that is also known for reducing the human intervention into the process.

KEYWORDS

Automated Inspection, CAD, GD&T, Industry 4.0, 3D-scanning.

I.INTRODUCTION

The constantly growing world with continuous developments and enhancements in advanced manufacturing technology clearly states that the inspection process is very important and crucial in the products being manufactured. The Geometric Dimension and Tolerance (GD&T) inspection process is used in the industries to audit the conformity of parts being manufactured with the exact specifications of the part at the design level [1]. However, because of the new

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trend in manufacturing sector is all towards producing low-volume, high-variety, high-complexity, and enormous products, that the current inspection process feels it difficult to deal with this. This framework review proposes the example of a non-contact digitization-based automated GD&T inspection system [2]. In this review, we will understand that how to defined a Nominal Inspection Frame (NIF) for a nominal CAD model or a digitalized model, in which the GD&T parameters that are required may be defined and specified. The NIF can be used to get an algorithm so that it can extract the information contained GD&T automatically on a model measured using the Reverse Engineering (RE) environment in the software [3]. The proposed approach has to be examined with many applications on dimension tolerance, geometric tolerance, and free-form surface inspection, so as to gather and work the inspection results in the paper review.

The complexity of the parts is dependent on a variety of features i.e., planar, cylindrical, spherical, etc. and therefore more the accuracy in fabricating these features the more chance to get a good overall accuracy of the assembly. For evaluation of each part, the features of these need to be divided into most archaic level. Now, measurement of the exactness of the variation a technique or instrument must be introduced. Geometric Dimensioning and Tolerancing (GD&T) characterizes the features straightness, flatness, circularity, and cylindricity as form error [4]. Generally, the orientation error is given by angularity, parallelism, and perpendicularity and location attributes are positioned by concentricity & symmetry [5]. In this study, the accuracy of the features chose in each part is given by its specific attributes. The fabricated parts accuracy is considered very important to understand if its profile is impacting on its neighboring brink of the intended profile. Coordinate Measuring Machine (CMM) is a common practice for inspection process across industries. These CMM is known for giving the sampling points of the features very efficiently that help to improve the inspection process. But this process is time consuming as it is a point contact that give the sample points and also requires a skilled person for operation. Inside the industries there is always an urgency for the inspection of the parts that require good GD&T to guarantee the high quality of the fabrication done. Indeed, this is very unachievable and slow process performed through a conventional CMM.

Because of the ongoing fast growth of the industries there are a lot of products that have some features that are connected with some application in the final assembly of the product; one small error in the feature that could result in a very pricey errors as well as time consuming for the destined assembly. This will also result in improper functioning of the assembly line and hamper the efficiency of the entire system. Hence for the components like this 100% inspections should be aimed but with then use a conventional CMM the machine provides with only the sampling points. So as to perform a deep inspection which includes all the GD&T features 3D-sacnners like devices are in demand for obtaining the points on the part surface data. In the recent progress of the industries, the 3Dscanners are taken into considerations for an alternative to the traditional inspection process. This paper reviews a suggestion for a framework for the inspection process of the part features done with the help of 3D-scanning.

This framework of the process includes all the steps right from scanning the part with the geometrical features that are done through the GD&T process of inspection and goes on till the last step which is giving the detailed report of the part whether the part was accepted or rejected depending of the tolerance limits provide. After this the framework is validated using an engineering component.

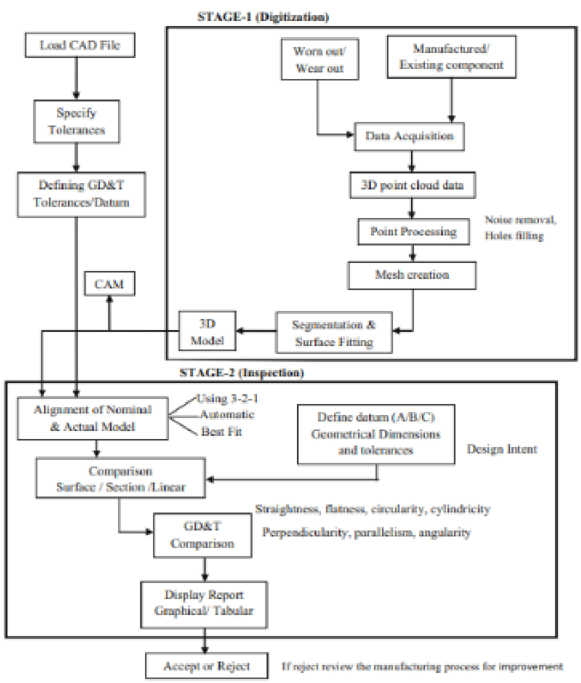

Figure 1: Framework for Automated Inspection (img Source: J. Inst. Eng. India Ser. C DOI 10.1007/s40032-016-0337-7)

II.AUTOMATED INSPECTION FRAMEWORK

The performance of an inspection is mostly dependent on a perfectly planned strategy so a very well managed framework for inspection is required to receive the most accurate and quick results of the inspection process. Therefore, it is necessary for the framework to affirm the features of GD&T that will work very efficiently against complex workpieces that involve many essential from features. A self-explanatory flowchart of the framework is recommended in this paper for the automation of inspection. (Figure 1) The given framework is more specifically divided into two important stages namely; first stage, digitization of the object; second stage, detail inspection that includes section, surface; these stages are joined in with the GD&T inspection [6].

(a)Stage 1 (DIGITIZATION)

Stage 1 is responsible for the conversion of the surface model from the given part physically present. Inside the industries many of the manufactured products have the need to be inspected so that the specific product will complete its task without reworking or wastage of the part. The first stage starts of with collection of the data so as to select a perfect scanner, then preparing the part that is to be scanned; scanning the part to capture all the important geometric features of the component like the steps, slots, holes etc. [7]

The scanners grab holds the surface cloud points that will be defining the structure of the geometry of the manufactured part; these 3D cloud points are actually the x, y, z co-ordinates that give the detailed features of the part. Post this process the processing of the cloud points is done to remove the noise present in the capture and to reduce points. The removal of these points is a necessary step as it acts as a filter to the points that are not useful and also helps the system to handle the points more effectively; hence speeding up the process also. The scanning is carries out a number of times to gather the complete information about the part, these multiple scans are the reasons behind having noise and some background points that aren't as useful for the process [8]. This is the primary reason for getting the noise points deleted as it will interfere with the point mapping process.

As there are multiple scans involved in the process it is essential for the 3D-scanner to integrate the data from each scan obtained from different views. This involves a registration process that determines the data transformation taken from two different scans and then can be integrated into the same co-ordinate system. The integration is more like an overlapping of the different scans into one picture i.e., representation of surface from the cloud points of two or more scanning [9]. Once this is done then is the last step of the stage one is to segregate the regions that are useful to us from the data gathered using automated or manual methods. Post this process a useful 3D-model is generated that can be used for Computer Aided Manufacturing or for the Inspection process. After all, the above steps 3D surface model is made which can either be used for Computer Aided Manufacturing (CAM) or the inspection process.

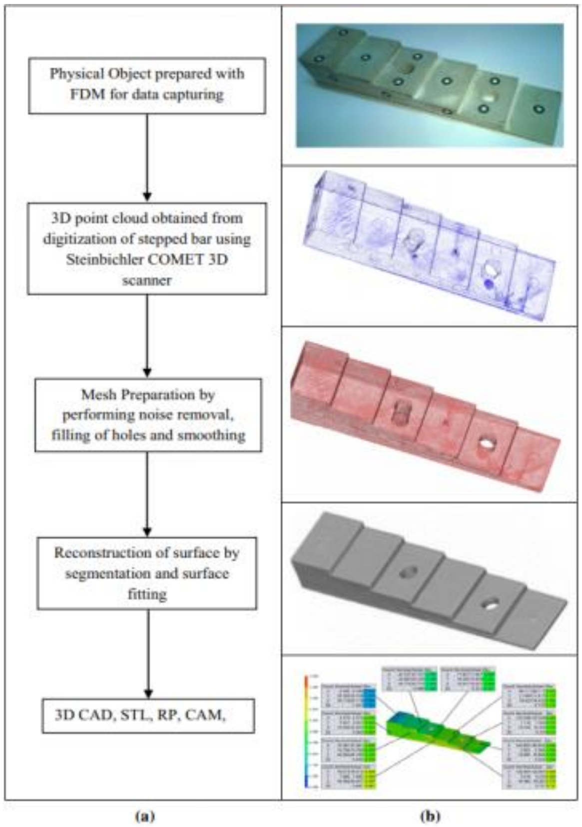

Figure 1: (a) Flowchart used for creation of surface model (b) Steps in pictorial format (img Source: J. Inst. Eng. India Ser. C DOI 10.1007/s40032-016-0337-7)

(b)Stage 2 (INSPECTION)

Stage Two is used for one of the most important aspect of the company's quality assurance i.e., inspection. This stage is focused on the inspection process on the manufactured component. This process begins with importing the primary/nominal CAD model into the "INSPECT PLUS" software. After importing the definition of the datum is the primary step to perform the GD&T inspection. Once the datum and also the GD&T tolerances are defined it is the time to import the stage one generated CAD model of the part into the "INPSECT PLUS" software. Once both the files are imported into the software the next process into to align both the models. Alignment of these models should be done correctly as any small change or a small misalignment can cause huge changes in the results of inspection. The software aligns them correctly by using different options like 3-2-1 aligning, automatic pre-alignment, and best fit alignment. The 3-2-1 alignment consists of creation of three planes, two vectors, and one point on the nominal part, and post this the corresponding planes, vectors, and points are also created on the stage one generated CAD model [10]. This then sums up the process for preparation of the part for inspection and now the part can be inspected. This inspection is carried out over the geometric features like holes, slots, cylinders, planes, etc. The report of this is generated into tabular as well as graphical representation for all the GD&T tolerances i.e., parallelism, flatness, circularity, etc. whilst also giving the surface and the section reports that are indeed of great use to the industries. Now is just a simple task of comparison and checking if the tolerances are with the range expected on this basis it is decided whether the part is accepted or rejected. That’s the end of stage two.

III.VALIDATION PROCESS

The process of validation of the framework was carried out by using a stepped bar [11]. The process uses a 3D scanner (Comet L3D) from Steinbichler, Germany to gather the important 3D cloud points. The version that was used in the process has a resolution of 1Mpx and 1170 x 880 pixels (Table 1 for more specifications). The stepped bar was digitalized as we had seen in the stage one of the process. Figure 2a give the flowchart of the process of converting the model into STL format for better and easier understanding; for the pictorial representation refer to Figure 2b.

Table 1: Specifications

Sl. No.	Parameters	Value
1	Camera resolution, dpi	1170 x 880
2	Measuring field, mm^3	100
3	Measuring volume, mm^3	92 x 69 x 60
4	Point to point distance µm	100
5	Fastest measurement time, sec	2.5

This completes the stage one of the process; now moving on to the stage two that is very important for the framework; the inspection. The results are shown in the figure 3. After the completion of scanning and making the component digitize the inspection is performed again inside the “INSPECT PLUS” software where it is referenced with the designed CAD model. Now after defining all the important aspects of the inspection i.e., dimensions, geometrical tolerances, and datum the 3D-scanned model is made to align with the original or the nominal CAD [12]. Now all the GD&T is computed are all the results will be available in detailed format.

The Figures 3a, b shows us the in-detail comparison of the nominal part to the scanned part with giving point-to-point average deviation distance on both the top and also the bottom surface of the taken example of stepped bar. Figure 3c shows the variations on the cross-sections in the middle of the stepped bar.

Figure 3d shows the report of the GD&T inspection performed for validation of the framework. It shows us the main four geometrical tolerances of perpendicularity, cylindricity, flatness, and parallelism for the stepped bar surface. (Shown in table 2).

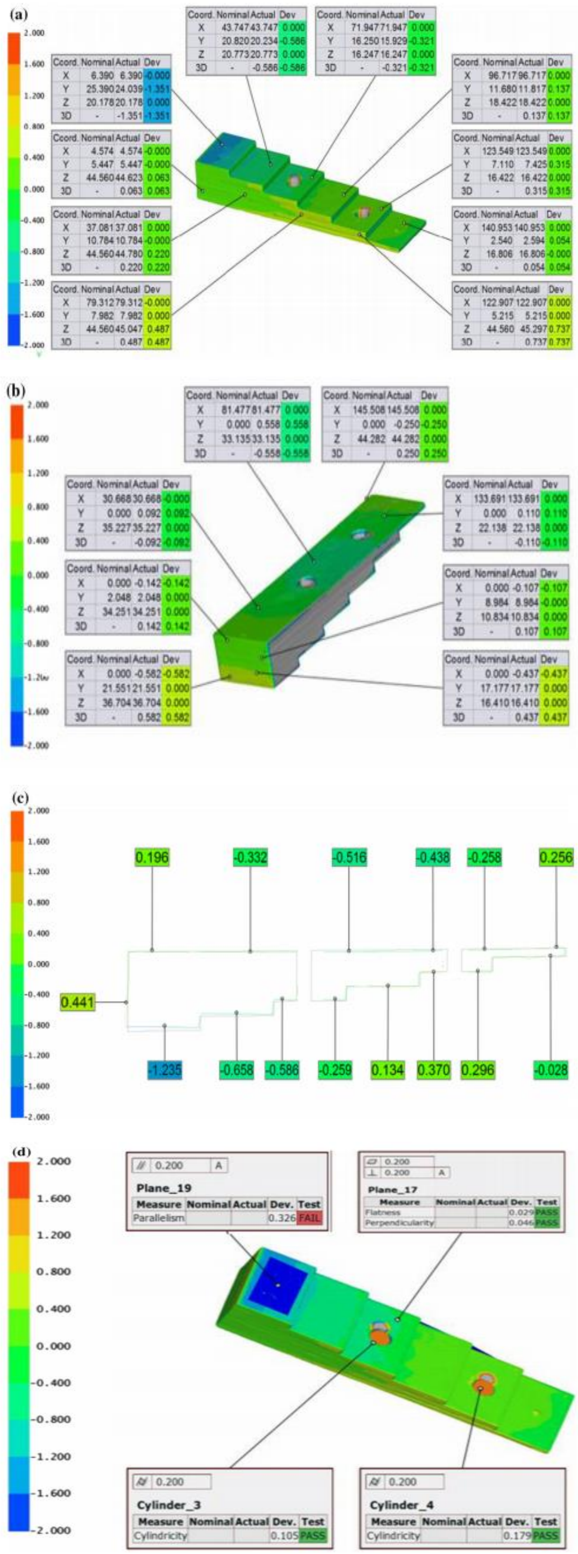

Figure 3: Inspection of stepped bar (a) Upper side Inspection (b) Lower side Inspection (c) Cut Section deviation (d) GD&T inspection (img Source: J. Inst. Eng. India Ser. C DOI 10.1007/s40032-016-0337-7)

GD&T callout	Tolerance mm	Deviation mm	Remarks
Flatness (plane 17)	0.2	0.029	Passed
Perpendicularity (plane 17)	0.2	0.046	Passed
Cylindricity (cylinder 3)	0.2	0.105	Passed
Cylindricity (cylinder 4)	0.2	0.179	Passed
Parallelism (plane 19)	0.2	0.326	(Fail) rejected

Table 2: Geometric Dimensioning & Tolerances Inspection Results

IV.RESULTS

The results that were generated on the scanned model were studied in details by performing some crucial tests that included the GD&T and the coordinate evaluation. Some test also gives a color map for deviation compared to nominal and 3d-generated part shown in figure 3b, c. also generation of the flyer takes place to highlight the deviation areas. The GD&T helps to evaluate whether the scanned model is in the given tolerance zone by comparing it with the nominal CAD model. An assumption of 0.2mm tolerance was taken for better clarity and understanding. The test that was carried out are explained further; the dimensions of stepped bar are shown in figure 4 below.

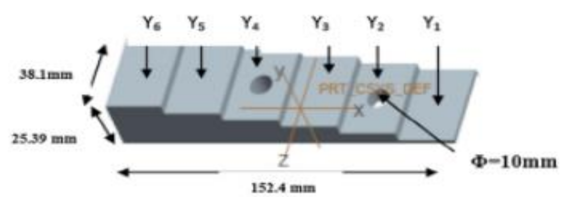

Figure 4: Study of the Stepped bar (img Source: J. Inst. Eng. India Ser. C DOI 10.1007/s40032-016-0337-7)

V.TESTING

The inspection was carried out by using the designed CAD part as a reference to the 3d-scanned part as a test model. The Steinbichler "INSPECT PLUS" software was used for the inspection through GD&T. The example of this is mention in the table 2 by assuming the tolerance value as 0.2mm. The parallelism, flatness, perpendicularity and circularity have been quantified with their deviations. Table 2 shows clearly that perpendicularity, flatness and cylindricity results were seen passed as the deviation is observed in the tolerance limits taken; whilst parallelism result failed as the deviation is not seen within the tolerance limits. In same way using the framework proposed any GD&T features can be quantified.

VI.X-Y-Z LINEAR DEVIATION

In table 3 there is given a representation of the deviation from the nominal CAD along the Y-coordinate. It can clearly be seen in the table that on any coordinates the machine can measure linear deviation i.e., width, thickness, length. In the table there is a comparison of the nominal with the actual model generated in stage one for the top as well as bottom surfaces. For the thickness measurement; the deviation of the bottom surface is referenced along the Y-coordinates for this the top surface deviation is subtracted from the reference also mentions as C – D. If the value obtained of the deviation of thickness is in positive range, then it indicates that these points were higher compared to the nominal CAD model; If the values are found to be negative this tells us that the points were below compared to the nominal CAD model. This framework can also evaluate the deviation on all the section planes given (Shown in figure 3d).

Table 3: Thickness determination along Y axis

	Bottom Surface				Reference/ correction factor C	Top Surface				
Nominal	0	0	0	0	0.1275	25.39	20.82	16.25	11.68	7.11
Actual	0.092	0.558	-0.25	0.11		24.039	20.234	15.929	11.817	7.425
Deviation |D|	0.092	0.558	-0.25	0.11		-1.351	-0.586	-0.321	0.137	0.315
Actual thickness deviation = |C–D|						1.478	0.713	0.4485	-0.009	-0.1875

CONCLUSION

We know that the proper inspection is indeed necessary for having a good product lineup. Also, the traditional method of inspection using all the mechanical instruments like fixtures, gauges etc. makes the process slow and it also demands for skilled labor to produce good and accurate results. As it involves labor which is human intervention it also introduces human errors that in fact also affect the quality and speed of the inspection which also further leads to non-conformity of the product and also affects the market value of the product and the company. The use of the 3D-scanner and digitizing the product for the inspection of components is constantly gathering more and more importance due to its ease of work and easy access to all features in GD&T. The framework introduced in this review has proven to be easy to access for the quality assurance department and also shows to cover all the guidelines of the system. The process can cover all the necessary steps till the last step of acceptance or rejection provided if tolerances are specified. This system also helps in identifying the value of tolerance precisely. The results generated from the automated inspection are not only very accountable but also given in a very simplified and easy to understand format which helps in better reproducing of the results for a good record in the future. Main purpose of this is to eliminate the unnecessarily expensive gauges and fixtures. The reports generated from this inspection are handed over to the Inspection committee for acceptance or rejection of the components. This automated inspection process is very helpful for calculating the geometrical features of GD&T such as circularity, flatness, parallelism, straightness etc. which are indeed difficult and time consuming for any skilled worker performing the job using the traditional tools for inspection. The framework that is introduced in this review is useful for also assessing the calculation of the surface wear and also damage to its dimensions causing dimensional changes of any giving manufacturing component for reconstruction or repairing of it. This framework can also be applicable to inspection in other fields like the impeller and the pump manufacturing industries quality network. Hence this framework if is used and implemented to its fullest capacity can be very useful in the simplification of GD&T inspection process over the traditional inspection methods.

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