Standardization of Inspection Processes Incorporated in a Precision Machining Centre

S.Pratheesh Kumar, S.R.Devadasan

Abstract— This paper discusses about the gauge repeatability and reproducibility (R&R) studies which are carried out in measurement system analysis (MSA) to find out whether the measurement system variations are within the standard limit or not. Variations of readings in measurement system used in inspection process are due to measuring instrument, method of measurement, material, measurement standards, man and environment. This paper discusses how a measurement system used in inspection process can be standardized so that all the variations in measurement systems are eliminated in an effective manner. The repeatability and reproducibility (R&R) value obtained as a result shows that the measurement system variations in inspection process are within the standard limit.

Key words— Measurement System Analysis (MSA), Repeatability and Reproducibility (R&R.)

I. INTRODUCTION

The inspection processes usually carried out in industries are done by calibrated instruments and by the skilled operators who are professionally trained to carry out inspection. Even then achieving repeatability and reproducibility (R&R) value within the standard limit is a challenging factor because it depends on various other factors. In a Precision machining centre (PMC) standardizing these factors is a challenging one because of the practical difficulties involved in it. In carrying out the measurement system analysis we can find out the stand of the present inspection process [11]. Then by standardizing the inspection process the various factors which affect the R&R value can be controlled and can be achieved within the standard limit. For a standard measurement process the R&R value should be as per the standard limit [11].

They are as follows

i. Less than 10 - measurement process is acceptable
ii. Between 10 to 30 - measurement process partially acceptable.
iii. Greater than 30 - measurement process is un-acceptable

The variation obtained in the measurement system is due to the following factors [3]

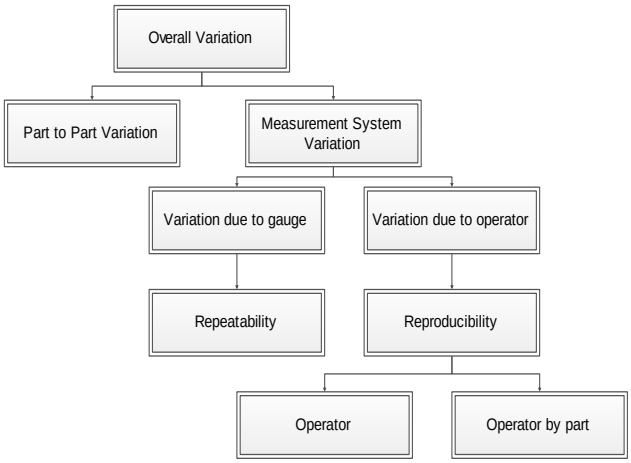

Fig. 1.Causes of Overall Variation

By standardizing the measurement process used in inspection we are going to bring the R&R within the standard limit. In order to carry out this action, we have to first study the entire process of inspection practiced in Precision machining centre (PMC). Then we have to figure out the drawbacks in their process of inspection. After this we have to sort out the things which directly affect the R&R value. Then we have to come with a method to reduce or completely avoid the factors which directly affects the R&R value. Their process of inspection should be analyzed and standardized in such a way that their present level of inspection lead time is not affected by the standardization process. The proposed standardization method should make the measurement process stable and at the same time it should be less time consuming one and should be easily practicable by the inspectors.

In order to standardize the inspection process, the factors affecting repeatability and reproducibility of the measurement system should be avoided.

1.1 Repeatability:

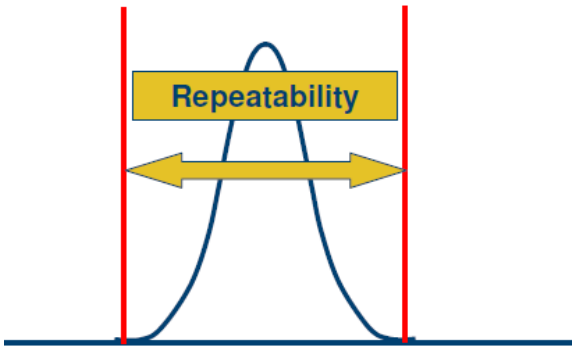

Fig. 2. Repeatability

Repeatability is the variation between successive measurements of the same part, same characteristic, by the same person using the same gauge [12].

1.2 Reproducibility:

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S. Pratheesh Kumar, Production Engineering Department, PSG College of Technology, Coimbatore- 641 004, India.
Dr. S.R. Devadasan, Production Engineering Department, PSG College of Technology, Coimbatore- 641 004, India.

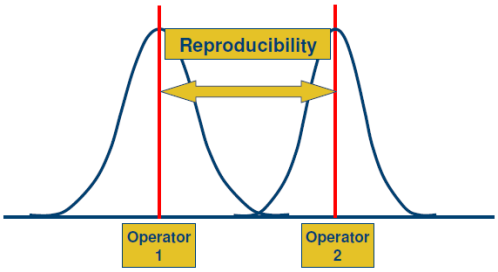

Fig. 3. Reproducibility

Reproducibility is the difference in the average of the measurements made by different people using the same instrument when measuring the identical characteristic on the same pieces [12].

II. CURRENT INSPECTION PROCESS

They following are the two types of inspection process carried out in the Precision Machining Centre (PMC), they are

i. In-process inspection
ii. Final inspection

2.1. In-process inspection:

This is done by the operator who is machining the component. In this the defects are identified during the machining stage itself. All dimensions cannot be checked in this method.

2.2. Final inspection:

This is carried out in a separate lab where the temperature is maintained at 20^0 c. The highly trained professionals are involved in inspection process. The instruments used for inspection are also periodically calibrated. The components produced by them varies based on the order they receive i.e., they don't manufacture the same component repeatedly. So they can't freeze the method of inspection they follow. Because of this reason the inspection method for a single component varies from operator to operator. So this causes the R&R variation between inspectors which becomes as a major problem when the component accepted by one inspector gets rejected by another inspector or vice-versa.

III. CURRENT LEVEL OF STANDARDIZATION

The instruments that are currently used for inspection are categorized by a unique identity number. They maintain the calibration report for each and every Monitoring and Measuring Equipment (MME). In their inspection process they categorize the component by unique identity number and identify each and every dimension in the component by means of ballooning. Then the instruments used for measuring (vernier caliper, micrometer, 2D-height gauge and millimess etc.) which are used for measuring the particular balloon are recorded in a separate sheet.

By the above said method of inspection they can ensure and identify the instruments used for measuring each and every balloons and the inspector who inspected the component.

IV. DRAWBACKS OF CURRENT METHOD

Current level of standardization uniquely identifies the instrument and the inspector who inspects the component. In case of manual inspection they follow the method based on which they have been trained to use the component. So there is no much difference in their dimension in case of same operator or in case of different operator. But in case of automatic and semi-automatic instruments like CMM and 2D-Height Gauge, even though they are trained there are variables in these instruments which they cannot standardize. The variables in these instruments are the stylus system, clamping equipment's used, orientation of the component and the method they used for inspection. Because of these reasons the maintaining repeatability and reproducibility in these instruments is a challenging factor.

The standardizing method should be designed in such a manner to avoid all the variables in the inspection process so that all operators use same stylus system, clamping equipment's, orientation of the component and the method used for inspection [20].

V. R&R VALUE OBSERVED IN CURRENT METHOD

Before moving into standardizing the inspection process we have to find out what are all the major factors that cause the variation in measurement. To find out those factors and their current level of variation in dimensions we conducted the gauge repeatability and reproducibility study on both the CMM and 2D-Height Gauge. The results obtained in the gauge repeatability and reproducibility study are as follows.

They are

Table. 1. R&R value of current inspection process

S.no	Instruments	Gauge R&R (%)
1	CMM	30.30
2	2D-Height Gauge	70.03

The graph is shown below.

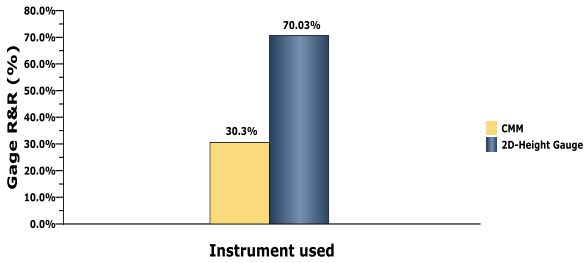

Fig. 4. Graph of current inspection process

From this R&R value we can find out that their current level of standardization lags in minimizing the variation in measurements. Their measurement process is un-acceptable in case of repeatability and reproducibility is concerned.

5.1 Reasons for the unsatisfactory R&R value:

Even though they maintain a controlled environment and undergo the inspection by highly trained professionals their repeatability and reproducibility variations are above the standard limit. Environment and instruments cannot be the reason because they maintain controlled environment and periodically calibrated instruments. The variations in work-piece are not under the control of the measurement system. Variations due to inspectors cannot happen because they are well trained and also they maintain standard measurement units. So the reason for the measurement system variation must be because of the following reasons, they are

1. Stylus system used,
2. Clamping equipment's used,
3. Orientation of the components during inspection,
4. Method they follow for inspection and
5. The total number of settings used for inspection.

All the above said features varies because there is no system in their inspection process to monitor these things and to communicate between inspectors what is the method and system followed for inspection of a particular component. The proposed method must avoid all these features of variation in inspection process in an effective and less time consuming manner.

VI. PROPOSED METHOD OF INSPECTION

Taking all the factors of variation into consideration the right method of standardizing the inspection process is introducing a system in inspection which must avoid all the reasons for the variation in measurement. The system proposed for standardization is introducing the CMM setting sheet and 2D-Height Gauge setting sheet so that it will be integrated in the configuration management records of a particular component. By doing so we can eliminate all the reasons causing variation in measurement system.

6.1. CMM setting sheet:

Table. 2. CMM setting sheet

CMM/SETTING SHEET				
DRAWING NUMBER			TOTAL NO OF SETTINGS	
DRAWING REV NO			DATE	
PROGRAM SHEET NO			M/C NO	
			PGM REV NO	
EQUIPMENT USED FOR CLAMPING	SETTING NO	MME NO/EQUIP NO	SYLUS SYSTEM	REMARKS
PREPARED BY NAME			VERIFIED BY NAME	
PREPARED BY SIGN			VERIFIED BY SIGN	

The orientation of the component in different setting is recorded in the following sheet.

Table. 3. Orientation sheet

SETTING PHOTOS	SETTING NO :		RUN TIME:	min
TOP VIEW				
ISOMETRIC VIEW				
ALIGNMENT		X ORIGIN		
SPATIAL		Y ORIGIN		
PLANAR		Z ORIGIN		
STYLUS SYSTEM NAME				

6.2. 2D-Height Gauge setting sheet:

Table. 4. 2D-height gauge setting sheet

2D-HEIGHT GAUGE/SETTING SHEET					
DRAWING NUMBER			TOTAL NO OF SETTINGS		
DRAWING REV NO			DATE		
SETTING SHEET NO			M/C NO		
			SETTING REV NO		
BALLOON NUMBER	SETTING NO	SETTING SPECIFICATIONS			PROBE USED
		COMPONENT RESTING ON	RESTING SURFACE	PROBE FACING SURFACE	
PREPARED BY NAME			VERIFIED BY NAME		
PREPARED BY SIGN			VERIFIED BY SIGN		

The drop down list of the following columns is listed below. Giving these things as a drop down list reduces the workers time in preparing the setting sheet. This is prepared in an orderly manner based on how the component is inspected.

Table. 5. Drop-down list of setting specification

SETTING SPECIFICATIONS		
COMPONENT RESTING ON	RESTING SURFACE	PROBE FACING SURFACE
V-BLOCK	FV-TOP SURFACE	BALL-1mm
MASTER BLOCK	FV-LEFT SURFACE	BALL-2mm
SURFACE PLATE	FV-RIGHT SURFACE	BALL-3mm
V-BLOCK & MASTER BLOCK	FV-BOTTOM SURFACE	BALL-6mm
MASTER BLOCK & SURFACE PLATE	LSV-TOP SURFACE	POINT PROBE
V-BLOCK & SURFACE PLATE	LSV-LEFT SURFACE	HOOK PROBE
EROVA	LSV-RIGHT SURFACE	DISC-9mm
SPECIAL CLAMPS	LSV-BOTTOM SURFACE	DISC-18mm
---------	RSV-TOP SURFACE	
	RSV-LEFT SURFACE	
	RSV-RIGHT SURFACE	
	RSV-BOTTOM SURFACE	
	TV-TOP SURFACE	
	TV-LEFT SURFACE	
	TV-RIGHT SURFACE	
	TV-BOTTOM SURFACE	

VII. STANDARDIZATION LEVEL OF PROPOSED METHOD

The proposed standardization setting sheet eliminates all the varying parameters in inspection carried out by CMM and 2D-height gauge. The setting sheet is used to record how the operator inspects the component. During his inspection the operator enters all the data regarding his inspection in the sheet. This sheet will be filed in the inspection records, so that when another operator inspects the same component he makes use of this setting sheet to inspect the component. This makes the second operator to follow the inspection procedure of the first operator. Thereby whenever the component is inspected by the inspectors they follow the same process of inspection. This will eliminate the repeatability and reproducibility variations in the inspection process.

7.1. In case of CMM:

The variables recorded in CMM setting sheet are as follows, they are

1. Clamping equipment and the monitoring and measuring equipment (MME) number.
2. Each and every orientation of the component is recorded by means of their setting number and the total numbers of settings are also recorded.
3. Probe used and type of stylus are also in the stylus system.
4. Program used for inspection are recorded in program sheet number.
5. The CMM used for inspection are also recorded in machine number and
6. The orientation and alignment of the component is photo graphed and recorded.

7.2. In case of 2D-height gauge:

The variables recorded in 2D-height gauge setting sheet are as follows, they are

1. The balloon numbers inspected in which orientation is recorded.
2. The orientation of component in recorded in setting specification.
3. The probes used for inspection is recorded and
4. The clamping equipment, machine number and drawing number are also recorded.

This sheet introduced in the inspection record assures that every operator in the inspection team inspects a particular component in the same manner using the same varying parameters. Drop down list are made in this setting sheet to avoid time taken for an operator in preparing this sheet. This makes the varying parameters constant during inspection. Thus when the varying parameters are eliminated we can reduce the variations in readings to the greater extend.

VIII. R&R VALUE FOR PROPOSED METHOD

After the inspection process is standardized by the proposed method the variations in readings between an operator and between different operators is figured out by a gauge R&R analysis. The results obtained are shown below.

Table. 6. R&R value of proposed inspection process

S.no	Instruments	Gauge R&R (%)
1	CMM	4.77
2	2D-Height Gauge	7.42

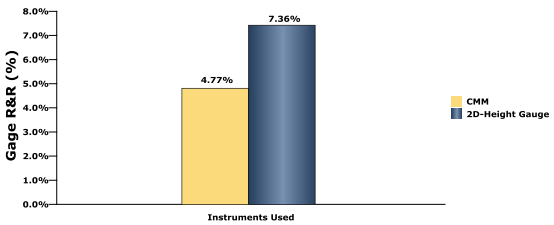

Fig. 5. Graph of proposed inspection process

The results of gauge R&R analysis shows that the process of the inspection done with the setting sheet has successfully eliminated all the variables in the inspection system. Now the inspection process they carry out in Precision machining center (PMC) are acceptable as per the international standard.

IX. COMPARISON OF GAUGE R&R RESULTS

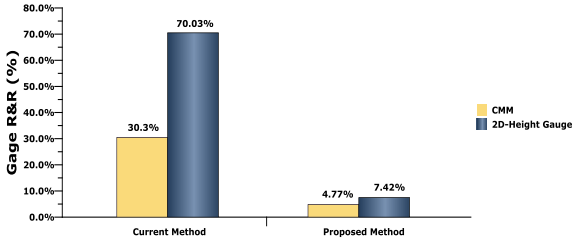

Fig. 6. Comparison of current and proposed method

The results obtained in the gauge R&R analysis before the standardization and after the standardization are given in the following graph.

X. TIME STUDY

The time taken for the inspection in the current and the proposed method were analysed and recorded to find out how the standardisation process has affected the time taken for inspection. Randomly five different components were taken for time study both in automatic and semi-automatic instruments and the results of them are shown below.

10.1 In CMM:

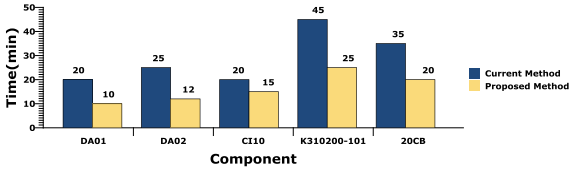

Fig. 7. Time study in CMM

10.2 In 2d-Height Gauge:

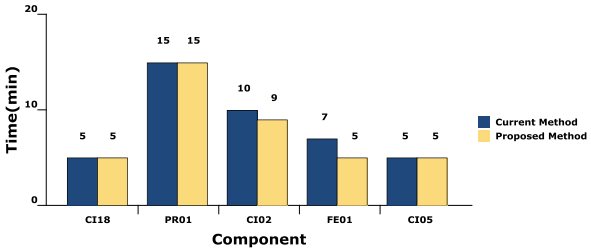

Fig. 8. Time study in 2D-height gauge

Both the graphs show that the time taken for inspection has not been increased because of standardization on the contrary the time taken has been considerably reduced.

XI. DRAWBACKS ELIMINATED BY PROPOSED METHOD

The variables in the inspection process occurring between operators and even within an operator are completely avoided by the proposed method. The variation of readings are also very much reduced within the standard limit of variations. The R&R value obtained both in CMM and 2D-Height Gauge are within the standard limit. So the measurement system they use is made acceptable to international standards.

XII. ADVANTAGES OF THE PROPOSED METHOD

The inspection process is said to be acceptable to international standard only

when their gauge R&R analysis shows that their variations in readings obtained are within the standard limit [10]. Now the proposed method of standardization has made it. It also eliminated all the process variables in inspection in a simple manner and at the same time it efficiently standardized the process. This method is widely encouraged by the operators because of the ease in following the method. Thus the proposed inspection process has suited well as tool to standardize the inspection process in Precision Machining Centre (PMC).

XIII. SCOPE FOR FUTURE WORK

The proposed method has made the process of the inspection in Precision Machining Centre (PMC) acceptable to international standard but even the process can be still improved. In the proposed method even though all the variable in inspection process are standardized the method in which an operator inspects the component is not fully standardized so concentrating in this area can further reduce the variations in measurements.

XIV. CONCLUSION

The result of this work shows that the inspection process in Precision Machining Centre (PMC) is standardized. The proposed method has eliminated all the process variables like measuring instrument, method of measurement, material, measurement standards, and environment. Implementing other methods for standardizing the inspection process will make the standardization very complex to be followed by the inspectors and at last the standardization will end in failure. This method gave an excellent result and at the same time it is very simple and less time consuming to be followed by the operators.

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S. Pratheesh Kumar scholar of M.E. Production Engineeering, Department of Production Engineering, PSG College of Technology, Coimbatore, India.

Dr. S.R. Devadasan Professor, Production Engineering Department, PSG College of Technology, Coimbatore, India.