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Experimental Investigation and Optimization of Coaxiality Error Analysis with CNC Turning Process on Delrin for Assembly Fit

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Abstract*: This paper mainly deals with the machining operation like turning operation, Material Removal Rate and Surface Roughness are the important parameter which is to be considered for quality product. The material selected for the experiment is DELRIN 500. Turning is one of the important processes that is widely used to create cylindrical components and it is also used for surface finish the product to make it smooth. Nowadays, plastic materials are widely used for making variety of components. To make a component with high dimensional accuracy, turning operation is used. The main concerns of turning are tooling cost and the effect of process on machinability characteristics. It can be seen that the output responses value has a minimum roughness average and a high degree of geometrical quality precision. High degree surface finish is induced by medium speed, feed rate, and small nose radius. The coaxial error was minimized by using medium speed, feed and larger nose radius. Experimentally found that third specimen (RPM -750) (FEED -0.08 mm/Rev) and (NOSE RADIUS 0.8) obtained minimum geometrical error along with minimum Surface roughness. Delrin is a crystalline plastic that offers an excellent balance of properties that bridge the gap between metals and plastics. Delrin possesses high tensile strength, creep resistance and toughness. It also exhibits low moisture absorption*

Keywords: turning operation

I. INTRODUCTION

Polymers (plastics) are organic materials having long chain car-bon molecules. Polymer molecule is formed by number of monomers. As per intermolecular bonding, plastics can be classified as thermoplastics and thermosets. Thermoplastics can be recycled by melting; hence, it is widely used. Polyethylene (PE), polystyrene, polypropylene (PP), Polyvinylchloride (PVC), nylon (polyamide), Teflon is some examples of thermoplastic materials. Thermosets, before moulding, are in partially polymerized state. Cross-linking of molecular chain takes place in polymerization process. After polymerization, if thermosets are heated, it does not melt. Epoxies (EP), Phenolic (PF), Polyurethane (PUR), unsaturated polyester are examples of thermosets. Generally, polymer and polymer composite materials are used in production of plastic components. Plastics like Nylon, Teflon, and Polypropylene have good mechanical properties. These polymer materials have increasing applications for specialty purposes where their toughness, rigidity, abrasion resistance and heat resistance are important. Therefore, it is widely used in the ap-plications like gears, cams, bearings, bushes, valve seats, etc. On the other hand, polymer materials have few limitations over bimetals. Such as melting point of polymers is comparatively low, therefore applications of polymers in high working temperature are not favorable. Thermal expansion of polymers is ten times as that of metals, hence it is one of the constraint need to be consider in application. Polymers deformation occurs in plastic materials under heavy stresses.

II. METHODOLOGY

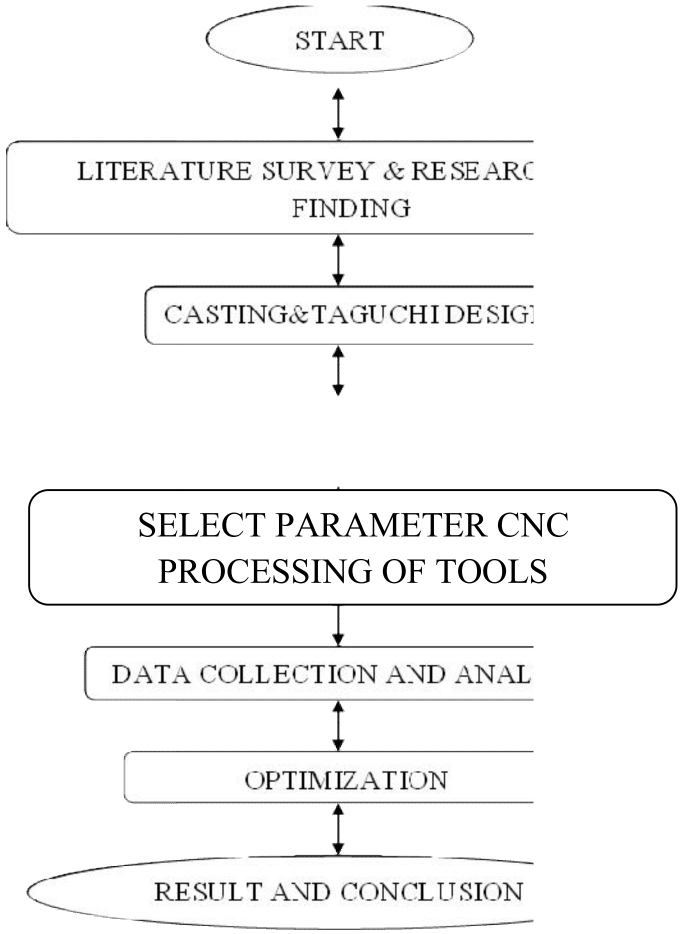

Fig 1: Schematic view of processes of turning in CNC

III. LITERATURE REVIEW

TITLE: Determination of optimum parameters for multi-performance characteristics in turning by using grey relational analysis

Kereszteset.al [3] studied machinability of polymers such as PA 6 (Mg), PA 6 (Na), POM C (Polyoximethylene), HD 1000 (UHMWPE). It is found that PA 6 (Mg) is toughest material in the view of cutting force and the cutting resistance. Cutting force decreases substantially by increasing feed rate and depth of cut. With increase in feed rate and depth of cut, amount of decrease in cutting force for remaining polymers are stated in descending order: PA 6 (Na), POM C, HD 1000.

Salles et.al [4]studied effects of machining on surface quality of Ultra High Molecular Weight Polyethylene (UHMWPE). It is found that as higher the feed rate then higher the surface roughness. Cutting speed doesn't affect much on surface roughness

TITLE: Optimization of Machining Parameters for Nylon 6 Composite in CNC Lathe Using PCA-Based TOPSIS

Pawade [5] studied effects of machining on surface flatness of Nylon and Polypropylene (PP) during precision turning. For lower values of surface flatness, surface quality is considered as better. It is found that, for both polymers, feed rate is an effective parameter in precision turning for both polymers. With increase in feed, cutting speed and depth of cut, there is increase in surface flatness. Larger degree insert clearance an-gle gives better surface quality than the smaller degree insert clearance angle.

IV. EXPERIMENTAL SETUP

TAGUCHI DESIGN

Basically, experimental design methods were developed original fisher. However experimental design methods are too complex and not easy to use. Furthermore, a large number of experiments have to be carried out when the number of the process parameters increases, to solve this problem, the Taguchi method uses a special design of orthogonal arrays to study the entire parameter space with a small number of experiments only. The experimental results are then transformed into a signal – to – noise (S/N) ratio to measure the quality characteristics deviating from the desired values. Usually, there are three categories of quality characteristics in the analysis of the S/N ratio, i.e., the – lower – better, the – higher – better, and the – nominal – better. The S/N ratio for each level of process parameter is compared based on the S/N analysis. Regardless of the category of the quality characteristic, a greater S/N ratio corresponds to better quality characteristics.

Therefore, the optimal level of the process parameters is the level with the greatest S/N ratio Furthermore, a statistically significant with the S/N and ANOVA analyses, the optimal combination of the process parameters can be predicted. Finally, a confirmation experiment is conducted to verify the optimal process parameters obtained from the parameter design. There are 3 Signal-to-Noise ratios of common interest for optimization of Static Problems. The formulae for signal to noise ratio are designed so that an experimenter can always select the largest factor level setting to optimize the quality characteristic of an experiment. Therefore, a method of calculating the Signal-To-Noise ratio we had gone for quality characteristic.

V. EXPERIMENTAL ARRANGEMENT AND PROCESS PARAMETERS LEVELS

Machine Tool: Batliboismarturn CNC lathe.
Work specimen material: DELRIN
Size of material: Φ25mm X 100 mm.
Tool material: Carbide-TAEGUTEC-TT-5100-0.2,0.4& 0.8 inserts.
CNMG 120404-HACNM6431 PC9030
Environment: Coolant not used.
Metal removal rate calculation: Through weight.
Machining time measurement: From CNC machine is shown in figure 4.3.

Brand	Batliboi
Model Name/Number	Sprint 16 TC
Swing Over Bed	400 mm
Turning Dia	225 mm
Turning Length	300 mm
Power Chuck	165mm

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VI.OPTIMIZATION TECHNIQUE

In this paper, Taguchi method is used to determine the machining parameters with optimal machining performance in the high speed vertical milling process

Orthogonal array experiment

Signal-to-noise ratio

Single characteristic optimization

Investigating the process parameters by ANOVA

TABLE 1: PROCESS PARAMETERS AND THEIR LEVELS

LEVELS		SPINDLE SPEE (N) (RPM)
1		750
2		1000
3		1250

TABLE 2: EXPERIMENTAL DATA INPUT&OUTPUT

SL.NO	SPEED (N) (RPM)	FEED (mm/Rev)	NR mm	MT Sec	RA micron	MRR gm/sec	COAXIAL ERR
1	750	0.04	0.2	192	0.499	0.036	0.16
2	750	0.06	0.4	155	0.523	0.046	0.18
3	750	0.08	0.8	137	0.429	0.048	0.15
4	1000	0.04	0.4	159	0.442	0.052	0.20
5	1000	0.06	0.8	133	0.408	0.059	0.14
6	1000	0.08	0.2	121	1.066	0.058	0.17
7	1250	0.04	0.8	143	0.445	0.050	0.18
8	1250	0.06	0.2	124	0.684	0.058	0.20
9	1250	0.08	0.4	113	0.816	0.070	0.19

TABLE 3: OPTIMAL CONTROL FACTOR ANOVA-CO-AXIAL ERROR

LEVEL	SPEED	FEED	NR
1	15.76	14.93	15.10
2	15.48	15.32	14.43
3	14.43	15.43	16.15
Delta	1.33	0.50	1.72
Rank	2	3	1

TABLE :4

Source	DF	Adj SS	Adj MS	F-Value	P-Value	% OF CONTRIBUTION
SPEED	2	0.001156	0.000578	1.86	0.350	32
FEED	2	0.000156	0.000078	0.25	0.800	4
NR	2	0.001689	0.000844	2.71	0.269	47
Error	2	0.000622	0.000311			17
Total	8	0.003622				100

VII. RESULT

OPTIMAL CONTROL FACTOR FOR TURNING PROCESS

1. Machining Timing- A_2 (RPM -1000) B_1 (Feed -0.04 mm/Rev) C_3 (NR-0.8)
2. Surface roughness- A_3 (RPM -1250) B_2 (Feed -0.06 mm/Rev) C_1 (NR-0.2)
3. MRR- A_2 (RPM -1000) B_1 (Feed -0.04 mm/Rev) C_3 (NR-0.8)
4. Co-Axial Error - A_2 (RPM -1000) B_3 (Feed -0.08 mm/Rev) C_1 (NR-0.2)

PERCENTAGE CONTRIBUTION OF PROCESS PARAMETER

1. Machining Timing - Feed-63 %
2. Surface roughness -NR -40%
3. MRR-Feed-74 %
4. Co-Axial Error -NR -47%

VIII. SN RATIO GRAPHS FOR MATERIAL REMOVAL RATE

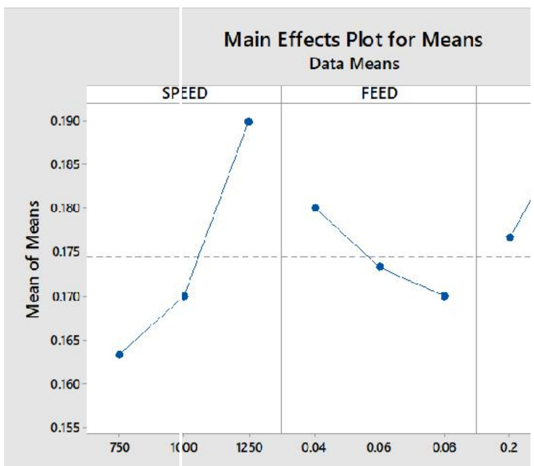


FIG:2 GRAPHICAL REPRESENTATION OF SPEED VS MEAN VALUE

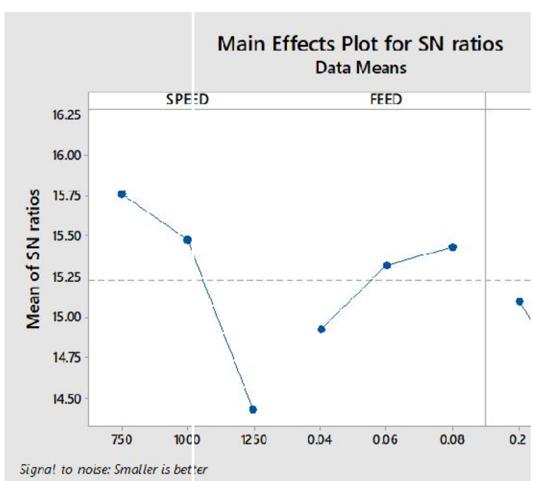
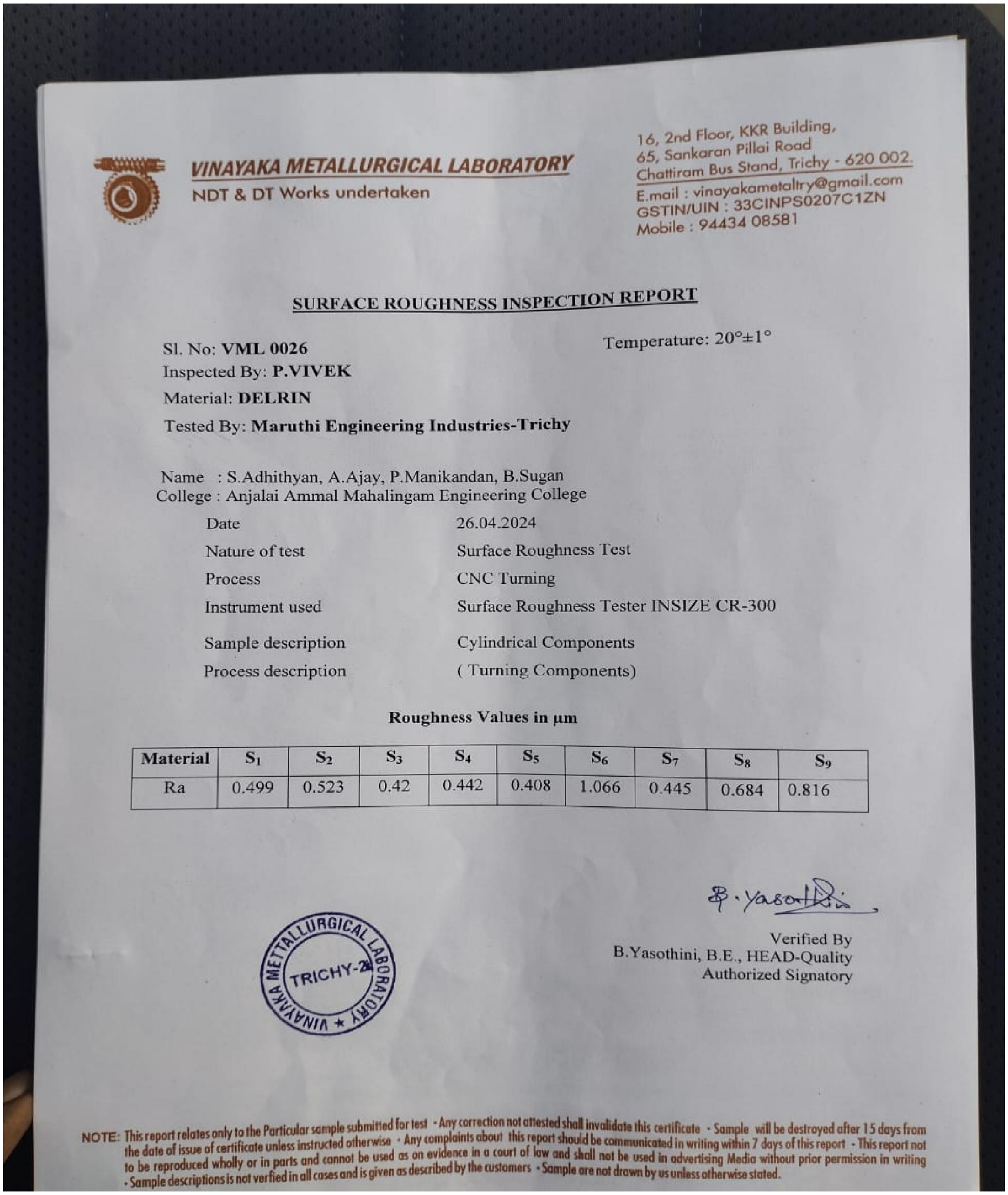


FIG:3 GRAPHICAL REPRESENTATION OF SPEED VS SN RATIO

IX. CERTIFICATE



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Mobile : 94434 08581

SURFACE ROUGHNESS INSPECTION REPORT

Sl. No: **VML 0026**
Temperature: 20°±1°
Inspected By: **P.VIVEK**
Material: **DELRIN**
Tested By: **Maruthi Engineering Industries-Trichy**

Name : S.Adhithyan, A.Ajay, P.Manikandan, B.Sugan
College : Anjalai Ammal Mahalingam Engineering College

Date	26.04.2024
Nature of test	Surface Roughness Test
Process	CNC Turning
Instrument used	Surface Roughness Tester INSIZE CR-300
Sample description	Cylindrical Components
Process description	(Turning Components)

Roughness Values in µm

Material	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9
Ra	0.499	0.523	0.42	0.442	0.408	1.066	0.445	0.684	0.816

VINAYAKA METALLURGICAL LABORATORY TRICHY-2

B. Yasothini
Verified By
B.Yasothini, B.E., HEAD-Quality
Authorized Signatory

NOTE: This report relates only to the Particular sample submitted for test • Any correction not attested shall invalidate this certificate • Sample will be destroyed after 15 days from the date of issue of certificate unless instructed otherwise • Any complaints about this report should be communicated in writing within 7 days of this report • This report not to be reproduced wholly or in parts and cannot be used as on evidence in a court of law and shall not be used in advertising Media without prior permission in writing • Sample descriptions is not verfied in all cases and is given as described by the customers • Sample are not drawn by us unless otherwise stated.

FIGURE:9.1 ROUGHNEES

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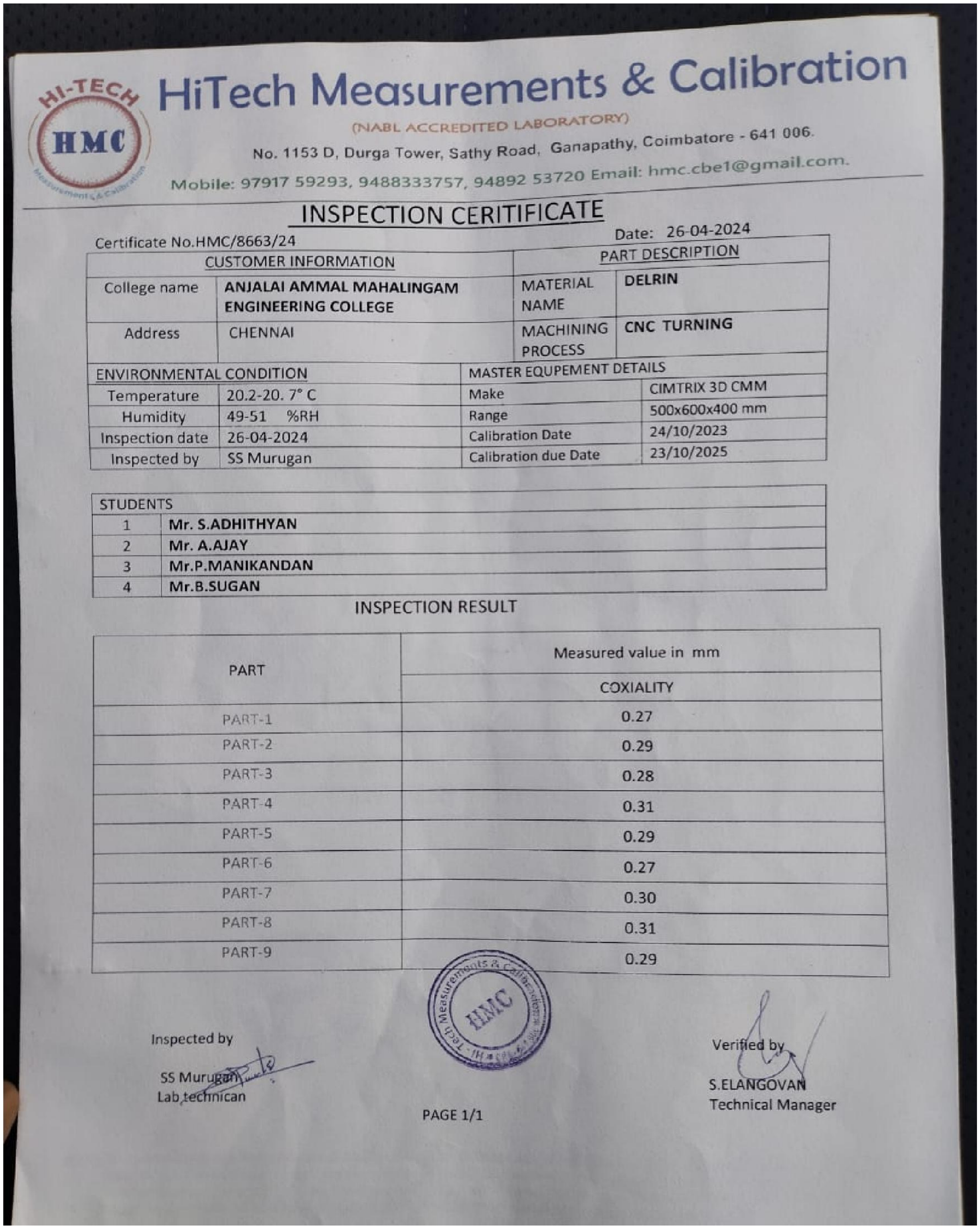

HiTech Measurements & Calibration
(NABL ACCREDITED LABORATORY)
No. 1153 D, Durga Tower, Sathy Road, Ganapathy, Coimbatore - 641 006.
Mobile: 97917 59293, 9488333757, 94892 53720 Email: hmc.cbe1@gmail.com.

INSPECTION CERITIFICATE

Certificate No.HMC/8663/24 Date: 26-04-2024

CUSTOMER INFORMATION		PART DESCRIPTION	
College name	ANJALAI AMMAL MAHALINGAM ENGINEERING COLLEGE	MATERIAL NAME	DELRIN
Address	CHENNAI	MACHINING PROCESS	CNC TURNING

ENVIRONMENTAL CONDITION		MASTER EQUPEMENT DETAILS	
Temperature	20.2-20. 7° C	Make	CIMTRIX 3D CMM
Humidity	49-51 %RH	Range	500x600x400 mm
Inspection date	26-04-2024	Calibration Date	24/10/2023
Inspected by	SS Murugan	Calibration due Date	23/10/2025

STUDENTS	
1	Mr. S.ADHITHYAN
2	Mr. A.AJAY
3	Mr.P.MANIKANDAN
4	Mr.B.SUGAN

INSPECTION RESULT

PART	Measured value in mm
	COXIALITY
PART-1	0.27
PART-2	0.29
PART-3	0.28
PART-4	0.31
PART-5	0.29
PART-6	0.27
PART-7	0.30
PART-8	0.31
PART-9	0.29

Inspected by
SS Murugan
Lab technican

PAGE 1/1

Verified by
S.ELANGOVAN
Technical Manager

FIGURE:9.1 COAXIAL ERROR

X. CONCLUSION

Based on this above tabulation the result it is concluded that the effects of turning parameters on the surface roughness and geometrical precision on delrin by using carbide ceramic inserts surface roughness of determanin,The spindle speed, feed rate and depth cut were the factors while machining and geometrical error were recorded as responds. The

Taguchi Design was used to develop the model of this experiment and the analysis of the result was performed by using ANOVA. It can be seen that the output responses value has a minimum roughness average and a high degree of geometrical quality precision. High degree surface finish is induced by medium speed, feed rate, and small nose radius. The coaxial error was minimized by using medium speed, feed and larger nose radius. Experimentally found that the third specimen (RPM -750) (FEED -0.08 mm/Rev) and (NOSE RADIUS 0.8) obtained minimum geometrical error along with minimum Surface roughness.

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