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# Dimensional accuracy analysis of samples printed in delta and cartesian kinematic three dimensional printers

## *Delta ve kartezyen kinematik yapıları üç boyutlu yazıcılarda basılan numunelerin boyutsal doğruluk analizi*

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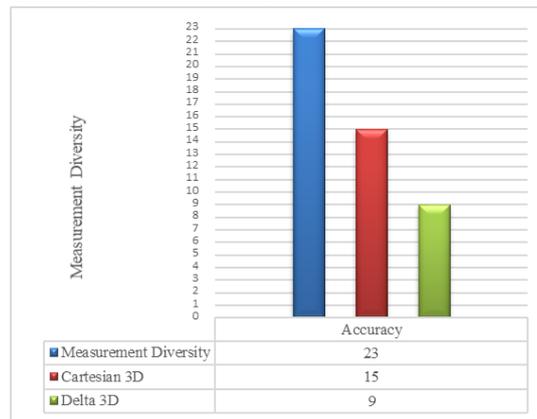
# Dimensional Accuracy Analysis of Samples Printed in Delta and Cartesian Kinematic Three Dimensional Printers

## Highlights

- ❖ *Delta and cartesian 3D printers*
- ❖ *Calibration blocks designed to make measurements in different ways*
- ❖ *Statistical T test verification of measurement results*

## Graphical Abstract

The accuracy of the 4 calibration pieces printed on each printer was measured and statistically tabulated below.



**Figure.** Dimensional accuracy graph of delta and cartesian 3d printers according to t test results

## Aim

In this study, the performances of machines installed in the delta and cartesian kinematic structures, which are mostly used in the kinematic systems of three - dimensional printers, were analyzed.

## Design & Methodology

In this context, in two different machines with these two construction structures, the same boundary conditions and 4 pieces of calibration parts especially in manufacturing features were printed. 23 different elements that constituted the calibration part were measured, tabulated, statistically analyzed, and the acceptable measuremental tolerance ranges of the elements were determined and the accuracy values of the machines were compared.

## Originality

The dimensional linearity of the products printed in 3D printers with two different structures was tried to be compared.

## Findings

As a result of this study, according to T test results, 15 of the 23 measurements on the Cartesian system based three-dimensional printers were obtained as acceptable in terms of tolerance range as well as 9 of the 23 different measurements were obtained as acceptable on Delta system

## Conclusion

Consequently, operation accuracy of the Cartesian system based three-dimensional printers were higher than the Delta system under the same working conditions and manufacturing parameters.

## Declaration of Ethical Standards

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

# Dimensional Accuracy Analysis of Samples Printed in Delta and Cartesian Kinematic Three Dimensional Printers

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*Araştırma Makalesi / Research Article*

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## ABSTRACT

The motion mechanisms of manufacturing and robotic systems are developed in different structures, mainly in cartesian and delta structures having series or parallel movement abilities according to the capacity and construction structure of the system. Different systems are used according to the criteria such as bearing load capacity, sensitivity or cost of the system. In this study, the performances of machines installed in the delta and cartesian kinematic structures, which are mostly used in the kinematic systems of three - dimensional printers, were analyzed. In this context, in two different machines with these two construction structures, the same boundary conditions and 4 pieces of calibration parts especially in manufacturing features were printed. 23 different elements that constituted the calibration part were measured, tabulated, statistically analyzed, and the acceptable measurement tolerance ranges of the elements were determined and the accuracy values of the machines were compared. As a result of this study, according to T test results, 15 of the 23 measurements on the Cartesian system based three-dimensional printers were obtained as acceptable in terms of tolerance range as well as 9 of the 23 different measurements were obtained as acceptable on Delta system. Consequently, operation accuracy of the Cartesian system based three-dimensional printers were higher than the Delta system under the same working conditions and manufacturing parameters.

**Keywords:** Accuracy measurement, delta printer, cartesian printer.

## Delta ve Kartezyen Kinematik Yapılı Üç Boyutlu Yazıcılarda Basılan Numunelerin Boyutsal Doğruluk Analizi

### ÖZ

İmalat ve robotik sistemlerinin hareket mekanizmaları, sistemin kapasite ve konstrüksiyon yapısına göre seri veya paralel yapılarda olmaktadır. Sistemin yük taşıma kapasitesi, hassasiyeti veya maliyeti gibi kriterlere göre farklı sistemler kullanılmaktadır. Bu çalışmada üç boyutlu yazıcıların kinematik sistemlerinde çoğunlukla kullanılan delta ve kartezyen kinematik yapılarında kurulmuş makinelerin performansları analiz edilmiştir. Bu kapsamda, öncelikle iki farklı konstrüksiyon yapısına sahip sistemde, aynı sınır şartları ve imalat özelliklerinde her birinden 4 adet kalibrasyon parçası basılmıştır. Kalibrasyon parçasını oluşturan 17 farklı şekilden, iç ve dışa basım karelerde 2 yönden diğer şekillerde ise tek yönlü olmak üzere toplamda 23 adet farklı ölçüm alınarak tablolanan, istatistiksel olarak analiz edilmiş, kalibrasyon parçasını oluşturan şekillerin kabul edilebilir ölçüsel tolerans aralıkları belirlenerek makinelerin doğruluk değerleri kıyaslanmaya çalışılmıştır. Yapılan çalışmalar sonunda; T testi sonucuna göre kabul aralığı kriterlerinde kartezyen yapılı üç boyutlu yazıcının 23 farklı ölçümünden 15'inin kabul aralığı değerlerinde olduğu, delta kinematik yapılı üç boyutlu yazıcının ise 23 farklı ölçümden 9'unun kabul aralığı değerlerinde olduğu sonucuna varılmıştır. Kartezyen kinematik yapılı üç boyutlu yazıcının çalışma doğruluğunun delta sistem üç boyutlu yazıcıya göre daha yüksek olduğu ölçüm değerlendirme sonuçlarına göre söylenebilir.

**Keywords:** Doğruluk ölçümü, delta printer, kartezyen printer.

### 1. INTRODUCTION

Different kinematic structures, mainly cartesian, series and parallel, are used in robotic system constructions. Cartesian systems are the robotic structures that move along the basic axes of X, Y, Z, and serial kinematic

systems are the structures with articulated structures that are similar to the human arm. Parallel kinematic systems take place in this group in the delta kinematic systems; the end effector is defined as a closed kinematic chain mechanism that is connected to the base with several independent kinematic chains. Cartesian and delta systems are the most frequently used structures in three-

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dimensional printer constructions. Cartesian systems are widely used for their benefits such as ease of production and maintenance, high reproducibility characteristics, mathematical modeling, computability, and ease of control. Compared to serial and cartesian mechanisms, the use of parallel mechanisms is preferred due to its advantages such as high rigidity, high sensitivity, accuracy, load carrying capacity, and high speed. Besides these advantages, both cartesian and delta systems have disadvantages, as well. Within the scope of this study, the measurement accuracies of 3d printers developed via these two systems after printing were examined. The related studies within the historical development of three-dimensional printer technologies are examined below.

In the development process of 3d printers have been named with many terms like virtual prototyping, rapid prototyping and additive manufacturing in throughout their history. These technologies are included in almost all the business and education life under recent conditions. Rapid modeling of all types of products, whether oriented to artistic, engineering or manufacturing, has become much faster, cost-effective and easy to model and also producible through these machines. The first patent regarding these systems belongs to Charles Hull in 1986 [1]. The recommended system is based on the principle that the parts are directly manufactured from the CAD (Computer Aided Design) model on a plane with the principle of layer and fused deposition. Thus, the production and product development processes have shortened [2]. Through the developed method, shortening of both the design and manufacturing processes, layered production that has started as the rapid prototyping (RP) system has converted 3-dimensional printing technologies into a rapidly developing commercial product [3-8]. The rapid development of these technologies has directed the manufacturers to develop hobby machines and improve the processes. In this context, one of the most rapidly developing and most widely used modeling technologies is the fused deposition method (FDM). The main advantages of this method for industrial technologies are that the materials with various characteristics can be used (PLA, ABS, HIPS, PET etc.), it is easy to change the material, maintenance and consumable costs are low, it allows production with a tolerance up to averagely  $\pm 0.1$  mm, toxic substances and harmful gases do not form during the production, it allows the production of complex parts, and it is operated at low temperature ranges [9]. Annual sales of rapid prototyping systems using the FDM technique have increased approximately by 13.9% worldwide [10]. The technological development of three-dimensional printers, widespread internet access, and cheap computer use have made it a new open design tool that can accelerate self-managing sustainable development [11]. FDM is the most widely used 3D printer technique in the world [12]. There are some studies in the literature regarding the measurement and calculations of dimensional accuracy and surface roughness of the parts manufactured in three-dimensional

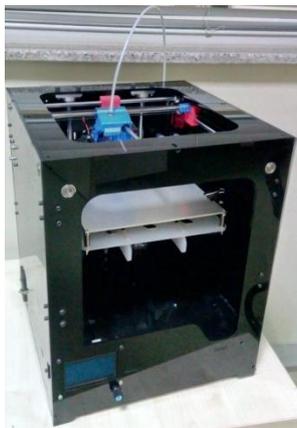
printer machines using the FDM technique. Sudin M.N. et al., [13] investigated the dimensional accuracy of the machine by producing parts with 400 MC machines operated by using the FDM method. As a result of the study, they found that the machine and the elements printed in circular geometric shapes such as cylinder, sphere and holes were less sensitive. Bakar et al., [14] examined the limits of the Prodigy Plus three-dimensional printer operating via FDM method and performed the measurements and calculations of dimensional accuracy and surface quality of the parts produced on this lathe. In his study, Dyrbus [15] examined the dimensional accuracy characteristics of the machine. He had shown in his study that 0.1 mm and 0.4° dimensional accuracy can be obtained in the parts produced by the FDM method. Dixit et al., [16] examined the effect of process parameters by comparing the open source and low-cost three-dimensional printers. Galantucci et al. [17] used the experimental method design to improve the dimensional accuracy in rectangular test samples minimizing the length, width and height changes for both the industrial three-dimensional printer system and the open source code systems. Habeeb et al., [18] examined the tensile strength and porosity of three-dimensional printer machine operated by open source FDM method and asserted that they are comparative to the mid-class commercial products. Also, other studies improving the dimensional sensitivity and surface roughness of open source three-dimensional printers [19-23] are also reported. In the study by Kaygısız, performance analyses of CNC milling machine that was designed and produced for educational purposes were done and in this context, the test samples were processed on the lathe, the measurements of the elements were done, the statistical analysis of the measurements were done, and the accuracy of the lathe was tried to be calculated [24].

## 2. MATERIAL AND METHOD

In the present study, the performances of machines installed in the delta and cartesian kinematic structures, which are mostly used in the kinematic systems of three-dimensional printers, and their measurement accuracies after printing were analyzed. In this context, 4 calibration parts with the same limit conditions and production characteristics were printed by using the Anycubic Kossel delta type FDM three-dimensional printer in Figure 1 and the cartesian-structure FDM three-dimensional printer that was designed and produced by us in Figure 2. Twenty-three different elements forming the calibration part were measured, tabulated, and statistically analyzed and the acceptance range criteria of the elements according to the T test were determined, and the accuracy values of the machines were tried to be compared. Table 1 and 2 shows the properties of both machines.



**Figure 1.** Anycubic Kossel Delta Printer



**Figure 2.** Cartesian Printer

**Table 1.** Technical properties of Anycubic Kossel Delta 3d Printer

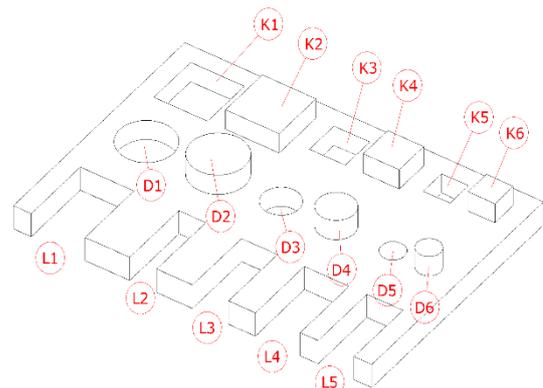
Property	Explanation
Printing Volume	230mm x 300mm
Printer Sizes	380mm (Δ) × 680mm
Printing technology	FDM
Layer resolution	0.1 – 0.4mm
Filament and Nozzle Dia.	1.75mm and 0.4mm
Raw material	PLA – ABS – HIPS etc.
Printing Speed	20-60 mm/s
Connection type	SD Card – USB
Table and Extruder Temp.	100°C and 260°C
Max	
Input Voltage	220VAC – 50 / 60Hz
Weight	7kg

**Table 2.** Technical properties of Cartesian 3d Printer

Property	Explanation
Printing volume	200x200x200mm
Printer Sizes	330x350x410mm
Printing technology	FDM
Layer resolution	0.05 – 0.4mm
Filament and Nozzle Dia.	1.75mm and 0.4mm
Raw material	PLA – ABS – HIPS etc.
Printing Speed	20-60 mm/s
Connection type	SD Card – USB
Table and Extruder Temp.	100°C and 260°C
Input Voltage	220VAC – 50 / 60Hz
Weight	10kg

**2.1. Development of the Measurement Models**

Design of the calibration part to be measured was made using Solidworks program. Figure 3 shows the elements of the designed model and Table 3 shows the relevant sizes. Square, cylindrical, and open-ended rectangles were preferred in the design. In this way, it was aimed to reveal the accuracy ratios of indentation, clearance and elevation printing of three-dimensional printers having two different systems.



**Figure 3.** Model design used in printing

**Table 3.** Design measurement values of the model used in printing

Square	Measure ment (mm)	Circle	Measure ment (mm)	Channel	Measure ment (mm)
K1	15x15	D1	Ø15	L1	15
K2	15x15	D2	Ø5	L2	7.5
K3	10x10	D3	Ø10	L3	10
K4	10x10	D4	Ø10	L4	12.5
K5	7.5x7.5	D5	Ø6.5	L5	10
K6	7.5x7.5	D6	Ø6.5		

### 2.2. Printing of the Measurement Models

The calibration part designed in the Solidworks program was saved as STL and transferred to the Cura program, relevant production codes were formed by entering the below-mentioned printing properties, and the printing process was done. Four calibration parts were printed with each of the same limit conditions and production properties as FDM three-dimensional printers belonging to the two systems. Figures 4, 5, 6 and 7 show Cura and Repedier program images and printing criteria.

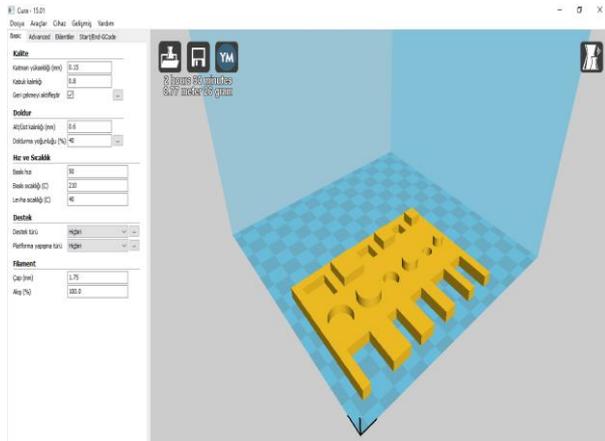


Figure 4. Cura Program Cartesian System Coding Display.

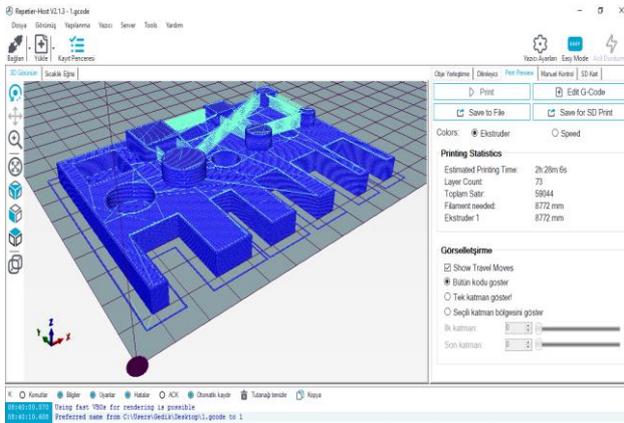


Figure 5. Repedier Program Cartesian System Coding Display.

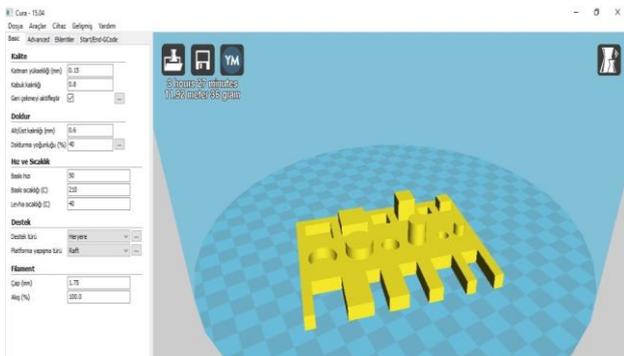


Figure 6. Cura Program Delta System Coding Display.

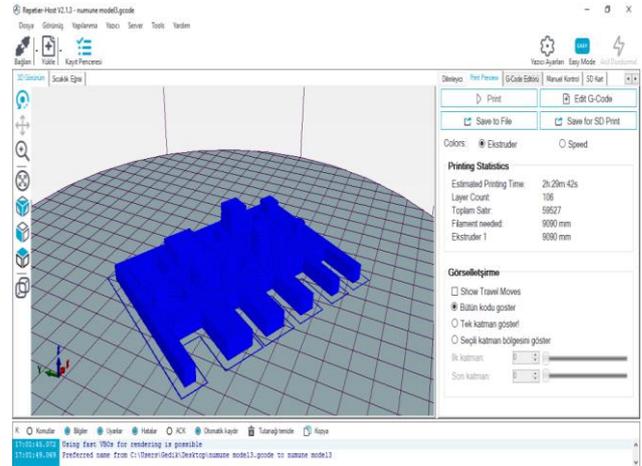


Figure 7. Repedier Program Delta System Coding Display.

Table 4. Printing Process Limit Conditions

Property	Explanation
Layer Height	0.15mm
Crust Thickness	0.8 mm
Lower - Upper Layer Thickness	0.6 mm
Duty rate	40%
Printing speed	50mm/s
Printing temperature	210°C
Plate temperature	40°C
Filament Diameter	1.75 mm
Flow rate	% 100
Material used	PLA

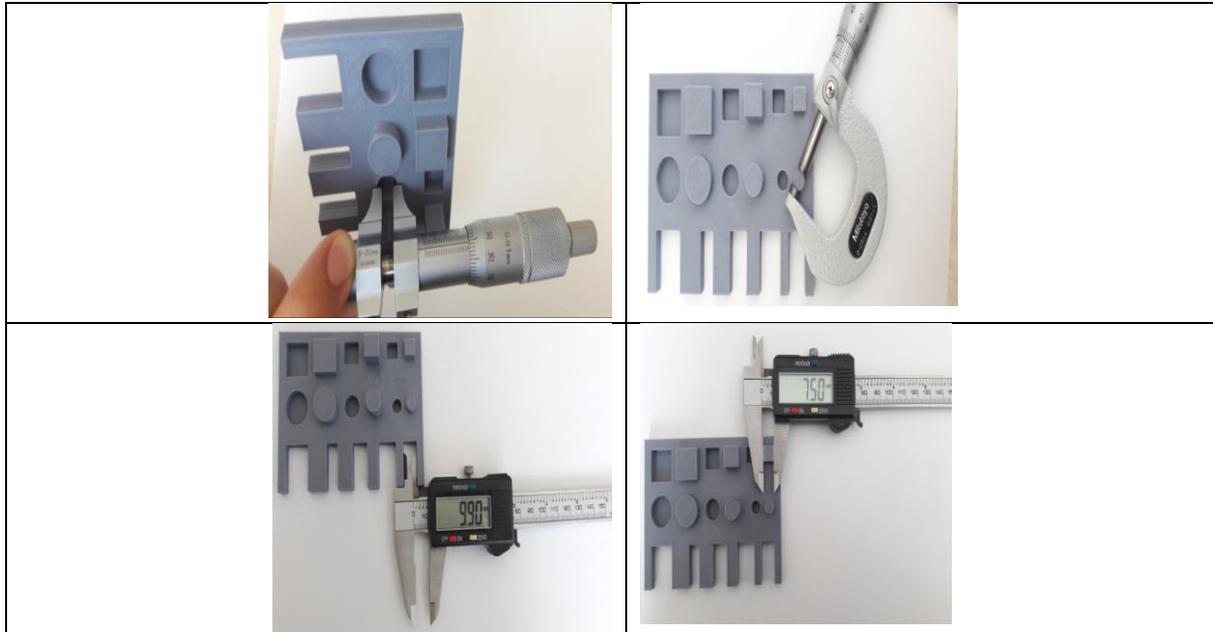
### 2.3. Dimensional Measurement of the Models Printed

In this study, four from each of samples with square hole-square elevation, cylinder hole- cylinder elevation and open-ended rectangular hole designs having 23 different measurements in the Cartesian system three-dimensional printer and Delta system three-dimensional printer were printed.

In order to understand the difference between two different three-dimensional printers, the original measurement was taken from the CAD program and square cube-square holes were measured from the axes of x and y, and open-ended rectangular holes were measured from the x-axis by using a digital caliper with 0.01 mm precision. Cylindrical elevations were measured by using an external diameter micrometer with 0.01 mm precision and the holes were measured by using an internal diameter micrometer with 0.01 mm precision. The samples printed in both three-dimensional printers are measured and the values were formed as specified in Table 5 and Table 6. The mean, deviation, variance, and standard deviation values of the values measured for each machine were calculated in their own table groups. T-test was applied in order to compare the compatibility of this calculation to the values desired between two machines

and its results are presented in Table 7. In the table, the lower limit and upper limit were specified according to the original measurement value as a result of the values measured in both machines and their efficiencies were interpreted according to different printing types due to the specified limit values.

values in the directions specified in K1 (INTERNAL) x and y axes, K3 (INTERNAL) y axis and K5(INTERNAL) x and y axes in square hole printings and it was within the acceptance range in the measurement of K3(INTERNAL) x axis. In square elevation printings, square elevations were not within the



**Figure 8.** Measuring devices used in measurement.

### 3. RESULTS AND DISCUSSION

As a result of the t-test, it was observed according to the value ranges specified in Table 7 that Cartesian system three-dimensional printer was not within the acceptance range values in the directions specified in K1 (INTERNAL) x and y axes, K3 (INTERNAL) y axis and K5(INTERNAL) x and y axes in square hole printings and it was within the acceptance range in the measurement of K3(INTERNAL) x axis.

In square elevation printings, square elevations were not within the specified acceptance range in K2(EXTERNAL) x and y axes, K4(EXTERNAL) x and y axes, K6(EXTERNAL) x and y axes. In cylinder hole printings, D1(INTERNAL) measurement was within the specified acceptance range and D3(INTERNAL) and D5 (INTERNAL) cylindrical holes were not within the specified acceptance range. Regarding the cylindrical elevation printings, D2(EXTERNAL), D4(EXTERNAL) and D6(EXTERNAL) measurements were within the specified acceptance range. In open-ended rectangular hole printing measurements, L1, L2, L3, and L4 were within the specified acceptance range but L5 was not within the specified acceptance range. As a result of the measurement evaluations applied in the cartesian system three-dimensional printer samples, it was concluded that it worked more accurately in square elevation printings, cylindrical elevation printings, and open-ended rectangular printings.

As a result of the test, it was observed according to the value ranges specified that Delta system three-dimensional printer was not within the acceptance range

specified acceptance range in K2(EXTERNAL) x and y axes, K4(EXTERNAL) x and y axes, K6(EXTERNAL) x and y axes. In cylinder hole printings, D3(INTERNAL) measurement was within the specified acceptance range and D1(INTERNAL) and D5 (INTERNAL) cylindrical holes were not within the specified acceptance range. Regarding the cylindrical elevation printings, D2(EXTERNAL), D4(EXTERNAL) and D6(EXTERNAL) measurements were within the specified acceptance range. In open-ended rectangular hole printing measurements, L1, L2,L3 and L4 were within the specified acceptance range but L5 was not within the specified acceptance range. As a result of the measurement evaluations applied in the delta system three-dimensional printer samples, it was concluded that it worked more accurately in cylindrical elevation printings and open-ended rectangular printings.

As a result of this study, according to T test results, 15 of the 23 measurements on the Cartesian system based three-dimensional printers were obtained as acceptable in terms of tolerance range as well as 9 of the 23 different measurements were obtained as acceptable on Delta system. Consequently, operation accuracy of the Cartesian system based three-dimensional printers were higher than the Delta system under the same working conditions and manufacturing parameters. According to the results of the measurement evaluation, it can be asserted that the operation accuracy of Cartesian system three-dimensional printer was higher than Delta system three-dimensional printer.

**Table 5.** Dimensional accuracy of the part properties at different sizes in Cartesian System 3D printer.

CARTESIAN SYSTEM 3D												
Part Feature	Nominal Value	N1	N2	N3	N4	average	deviation	variance	Std. Deviation	Remarks		
SQUARE	K1(INSIDE)	15x15mm	K1x	14,84	14,93	14,91	14,81	14,8725	0,1275	0,0054	0,0736	Exceed Tolerance
			K1y	14,83	14,90	14,90	14,83	14,8650	0,1350	0,0061	0,0779	Exceed Tolerance
	K2(OUTSIDE)	15x15mm	K2x	15,01	15,04	15,06	15,06	15,0425	-0,0425	0,0006	0,0245	Within Tolerance
			K2y	15,06	15,06	15,10	15,08	15,0750	-0,0750	0,0019	0,0433	Within Tolerance
	K3(INSIDE)	10x10mm	K3x	9,86	9,93	9,86	9,84	9,8725	0,1275	0,0054	0,0736	Within Tolerance
			K3y	9,87	9,97	9,84	9,88	9,8900	0,1100	0,0040	0,0635	Exceed Tolerance
	K4(OUTSIDE)	10x10mm	K4x	9,95	9,97	10,06	9,96	9,9850	0,0150	0,0001	0,0087	Within Tolerance
			K4y	10,03	9,98	10,15	9,98	10,0350	-0,0350	0,0004	0,0202	Within Tolerance
	K5(INSIDE)	7,5x7,5mm	K5x	7,32	7,34	7,34	7,33	7,3325	0,1675	0,0094	0,0967	Exceed Tolerance
			K5y	7,31	7,32	7,38	7,32	7,3325	0,1675	0,0094	0,0967	Exceed Tolerance
	K6(OUTSIDE)	7,5x7,5mm	K6x	7,50	7,51	7,53	7,45	7,4975	0,0025	0,0000	0,0014	Within Tolerance
			K6y	7,47	7,52	7,52	7,56	7,5175	-0,0175	0,0001	0,0101	Within Tolerance
CYLINDRICAL	D1(INSIDE)	Ø15		14,8	14,73	14,81	14,72	14,7650	0,2350	0,0184	0,1357	Within Tolerance
	D2(OUTSIDE)			14,85	14,88	14,98	14,86	14,8925	0,1075	0,0039	0,0621	Within Tolerance
	D3(INSIDE)	Ø10		9,8	9,81	9,85	9,81	9,8175	0,1825	0,0111	0,1054	Exceed Tolerance
	D4(OUTSIDE)			9,95	9,91	9,94	9,72	9,8800	0,1200	0,0048	0,0693	Within Tolerance
	D5(INSIDE)	Ø6,5		6,23	6,38	6,48	6,31	6,3500	0,1500	0,0075	0,0866	Exceed Tolerance
	D6(OUTSIDE)			6,43	6,44	6,35	6,38	6,4000	0,1000	0,0033	0,0577	Within Tolerance
OPEN END RECTANGULAR	L1	15		14,74	14,9	14,89	14,84	14,8425	0,1575	0,0083	0,0909	Within Tolerance
	L2	7,5		7,3	7,34	7,45	7,25	7,3350	0,1650	0,0091	0,0953	Within Tolerance
	L3	10		9,91	9,89	9,92	9,83	9,8875	0,1125	0,0042	0,0650	Exceed Tolerance
	L4	12,5		12,36	12,42	12,34	12,29	12,3525	0,1475	0,0073	0,0852	Within Tolerance
	L5	10		9,9	9,92	9,84	9,31	9,7425	0,2575	0,0221	0,1487	Within Tolerance

**Table 6.** Dimensional accuracy of the part properties at different sizes in Delta System 3D printer.

DELTA SYSTEM 3D												
Part Feature		Nominal Value	N1	N2	N3	N4	average	deviation	variance	Std. Deviation	Remarks	
SQUARE	K1(INSIDE)	15x15mm	K1x	14,93	14,90	14,95	14,87	14,9125	0,0875	0,0026	0,0505	Exceed Tolerance
			K1y	14,88	14,88	14,85	14,86	14,8675	0,1325	0,0059	0,0765	Exceed Tolerance
	K2(OUTSIDE)	15x15mm	K2x	15,35	15,31	15,34	15,31	15,3275	-0,3275	0,0358	0,1891	Exceed Tolerance
			K2y	15,32	15,27	15,33	15,33	15,3125	-0,3125	0,0326	0,1804	Exceed Tolerance
	K3(INSIDE)	10x10mm	K3x	9,94	9,96	10,02	9,98	9,9750	0,0250	0,0002	0,0144	Within Tolerance
			K3y	9,88	9,86	9,95	9,88	9,8925	0,1075	0,0039	0,0621	Exceed Tolerance
	K4(OUTSIDE)	10x10mm	K4x	10,24	10,25	10,25	10,23	10,2425	-0,2425	0,0196	0,1400	Exceed Tolerance
			K4y	10,26	10,24	10,26	10,30	10,2650	-0,2650	0,0234	0,1530	Exceed Tolerance
	K5(INSIDE)	7,5x7,5mm	K5x	7,40	7,41	7,37	7,36	7,3850	0,1150	0,0044	0,0664	Exceed Tolerance
			K5y	7,32	7,29	7,30	7,29	7,3000	0,2000	0,0133	0,1155	Exceed Tolerance
	K6(OUTSIDE)	7,5x7,5mm	K6x	7,73	7,72	7,77	7,80	7,7550	-0,2550	0,0217	0,1472	Exceed Tolerance
			K6y	7,74	7,70	7,75	7,74	7,7325	-0,2325	0,0180	0,1342	Exceed Tolerance
CYLINDRICAL	D1(INSIDE)	Ø15		14,9	14,87	14,88	14,78	14,8575	0,1425	0,0068	0,0823	Exceed Tolerance
	D2(OUTSIDE)			15,05	15,06	15,03	15,05	15,0475	-0,0475	0,0008	0,0274	Within Tolerance
	D3(INSIDE)	Ø10		9,94	9,96	9,91	9,87	9,9200	0,0800	0,0021	0,0462	Within Tolerance
	D4(OUTSIDE)			9,95	10,05	10,06	10,01	10,0175	-0,0175	0,0001	0,0101	Within Tolerance
	D5(INSIDE)	Ø6,5		6,4	6,35	6,37	6,35	6,3675	0,1325	0,0059	0,0765	Exceed Tolerance
	D6(OUTSIDE)			6,57	6,54	6,55	6,52	6,5450	-0,0450	0,0007	0,0260	Within Tolerance
OPEN END RECTANGULAR	L1	15		14,94	14,91	14,9	14,9	14,9125	0,0875	0,0026	0,0505	Within Tolerance
	L2	7,5		7,47	7,46	7,4	7,45	7,4450	0,0550	0,0010	0,0318	Within Tolerance
	L3	10		9,93	9,96	9,93	9,94	9,9400	0,0600	0,0012	0,0346	Within Tolerance
	L4	12,5		12,42	12,48	12,48	12,53	12,4775	0,0225	0,0002	0,0130	Within Tolerance
	L5	10		9,9	9,93	9,98	9,94	9,9375	0,0625	0,0013	0,0361	Exceed Tolerance

**Table 7.** Dimensional accuracy of properties of the printed parts in Cartesian system and Delta System 3D printers

General t test			
Sx1_x2	t-test	Lower limit	Upper limit
0.051546	0.776013	14.94288	15.05712
0.063053	0.039649	14.99691	15.00309
0.110082	2.588978	14.93647	15.06353
0.107125	2.217043	14.904	15.096
0.043309	2.366698	9.825782	10.17422
0.051269	0.048763	9.996903	10.0031
0.080988	3.17949	9.972465	10.02754
0.0891	2.581356	9.947838	10.05216
0.067726	0.775183	7.425035	7.574965
0.086959	0.373741	7.463857	7.536143
0.085004	3.029266	7.495628	7.504372
0.077719	2.766368	7.47205	7.52795
0.09161	1.009717	14.863	15.137
0.039176	3.956551	14.75444	15.24556
0.066421	1.543177	9.837401	10.1626
0.040423	3.40152	9.764336	10.23566
0.066714	0.262316	6.477283	6.522717
0.036553	3.966859	6.270973	6.729027
0.060058	1.165543	14.89401	15.10599
0.057975	1.897367	7.319252	7.680748
0.0425	1.235294	9.919765	10.08023
0.049735	2.5133	12.28597	12.71403
0.088325	2.207744	9.67178	10.32822

#### 4. CONCLUSION

In this study, two different types of three-dimensional printers were used. Measurements and evaluation results operation accuracy of the Cartesian system based 3d printer is obtained higher than the Delta system based 3d printer under the same working conditions and same manufacturing parameters. Therefore, it may be recommended to use Cartesian system when printing especially square type structures.

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#### DECLARATION OF ETHICAL STANDARDS

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

#### AUTHORS' CONTRIBUTIONS

**Erkan İNCEKAR:** Performed the experiments and wrote the manuscript.

**Hüseyin KAYGISIZ:** Performed the experiments and analyse the results.

**Sebahattin BABUR:** Made the statistical analysis of the article and analyse the results.

#### CONFLICT OF INTEREST

There is no conflict of interest in this study.

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