

MJERENJE I ANALIZA IZMJERA POKLOPCA VIJČANOG KOMPRESORA

MEASUREMENT AND ANALYSIS OF TWIN-SCREW SUPERCHARGER COVER MEASURES

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Sažetak: Koordinatni mjerni strojevi (KMS) omogućavaju precizna mjerenja dimenzija, oblika i položaja u ravnini ili u prostoru. Mjerni sustavi KMS omogućuju rezoluciju očitavanja od 0,1 μm i granične pogreške mjerenja u mikrometarskim razmjerima. Rad prikazuje 3D- mjerenje i analizu izmjera poklopca vijčanoga kompresora.

Ključne riječi: - analiza izmjera
- poklopac vijčanoga kompresora
- 3 D mjerenje

Summary: Coordinate measuring machines (CMM) enable the precise measurement of dimension, shape and location in plane or in space. The measuring system of CMM enables a sensed accuracy of 0,1 μm and boundary failure of measuring in micrometric proportion. The paper presents 3D measurement and measurement analysis for the twin-screw supercharger cover.

Keywords: - analyse of measures
- twin-screw supercharger cover
- 3 D measurement

1. UVOD

3D-mjerenje zasniva se na principu uzimanja točaka s površine mjenog predmeta. Koordinate točaka tvore digitalnu sliku objekta mjerenja u memoriji računala. Tražene mjerene veličine (dužine, promjeri, kutovi, odstupanje od oblika, odstupanje od položaja) dobivaju se na temelju međusobnih udaljenosti i geometrijskih odnosa između dvaju ili više sastavnih elemenata (u ravnini ili prostoru). Odstupanje od oblika, na primjer cilindričnost, definirano je kao razmak između dvaju koncentričnih cilindara unutar kojih su sadržane sve točke mjenog cilindra. Površina cilindričnog elementa bit će pomoću KMS definirana na temelju mjernih točaka čiji će broj biti dovoljno velik da se matematički definira cilindar, ali ni približan svim točkama koje se spominju u definiciji cilindričnosti. Puno mjernih točaka karakteristično je za sva odstupanja od oblika, pa i odstupanja od položaja. Treba još napomenuti da su KMS uglavnom stacionarni mjerni uređaji, smješteni gotovo redovito u klimatiziranim mjernim laboratorijima ili sličnim prostorima.

Mjerna kontrola proizvoda treba biti praktična i ekonomična pogotovo u slučaju većeg broja izradaka. Tada treba koristiti metode statističke kontrole zasnovane na temeljima zakona matematičke statistike.

1. INTRODUCTION

3D measurement has been based on the principle of taking points on the surface of a measuring object. The coordinate of points makes the digital picture of a measuring object in the computer memory. Required measuring values (length, diameter, angle, deviation from the shape, deviation from the position) are based on correlation length and geometrical relation between two or more elements (in 2D or in 3D space). Deviation from shape, for instance cylindricity, is defined as the distance between two concentric cylinders in which all of the points of the measuring cylinder are contained. The cylinder element surface will be defined with the help of CMM on the basis of measuring points whose number will be big enough that they can mathematically define the cylinder, but not even close to those which are mentioned in the definition of cylindricalness. A lot of measuring points are characteristic for all deviations of shape and for all deviation from position. It is necessary to note that the CMM are mostly stationary measuring devices placed almost always in air conditioning measuring laboratories or in similar rooms.

The measuring inspection of products needs to be practical and economic especially in the case of a larger amount of workpieces. Then the methods of statistical control based on mathematical statistic laws should be used.

2. ODABIR MJERNOG STROJA I MJERNA NESIGURNOST

Jedan od važnijih kriterija za izbor KMS jesu dimenzije stroja [1]. Što su veći gabariti, veća je i cijena KMS, dok korištenje manjeg stroja radi ušteda može rezultirati velikom pogreškom da se određene dimenzije ne mogu izmjeriti na tom stroju. Kao vodilju za izbor možemo uzeti da osi X, Y i Z budu dvostruko veće od elementa koji mjerimo. Kontrola proizvodnje ne ovisi samo o strojevima i alatima upotrijebljenima za obradu. Mogućnost kontrolnog programiranja omogućava brzu izravnu CAD usporedbu nominalne i stvarne konture integrirajući mjernu nesigurnost.

KMS na kojem su se vršila mjerenja poklopca vijčanoga kompresora zastupa, između ostalih, MPE_P i MPE_{THP} ISO standarde.

MPE_P ISO 10360-2 standard:

Volumetrična mjerna nesigurnost MPE_P prikazana je na slici 1[2, 3].

Precizna sfera mora biti izmjerena s 25 jednako raspoređenih izmjera.

($R_{max} - R_{min}$ = Oblik kugle).



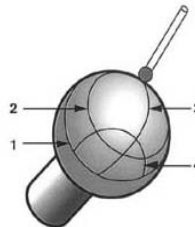
Slika 1. Volumetrična mjerna nesigurnost
Figure 1. Volumetric measuring uncertainty

MPE_{THP} ISO 10360-4 standard:

Volumetrička skenirana mjerna nesigurnost MPE_{THP} prikazana je na slici 2 [2,3].

Precizna kugla skenirana je s 4 različite linije.

($R_{max} - R_{min}$ = Oblik kugle)



Slika 2. Volumetrička skenirana mjerna nesigurnost
Figure 2. Volumetric scanned measuring uncertainty

ISO 10360-2 (2001): KMS ga koriste za linearne udaljenosti. Taj se dio norme odnosi na sve koordinatne mjerne strojeve. Taj standard opisuje dvije osnovne

2. SELECTION OF MEASURING MACHINE AND MEASURING UNCERTAINTY

One of the most important criteria for the choice of CMM is the dimensions of the machine [1]. The bigger the dimensions the higher the price of CMM while the use of smaller machines due to savings may result in a big mistake, because it could happen that certain dimensions on that machine cannot be measured. As guidelines for choice, axis x, y and z have to be two times bigger than the measuring element. Production inspection does not depend only on the machines and tools applied for analysis. Facilitates of inspection programming enable a fast direct CAD comparison of the nominal and actual contour integrating measuring uncertainty.

The CMM measurement of the twin-screw supercharger cover represents among other things, the MPE_P and the MPE_{THP} ISO standards.

MPE_P ISO 10360-2 standard:

Volumetric measuring uncertainty MPE_P is shown in Figure 1[2, 3].

A precise sphere must be measured with 25 equally arranged measures.

($R_{max} - R_{min}$ = Shape of sphere).

MPE_{THP} ISO 10360-4 standard:

Volumetric scanned measuring uncertainty MPE_{THP} is shown in Figure 2 [2,3].

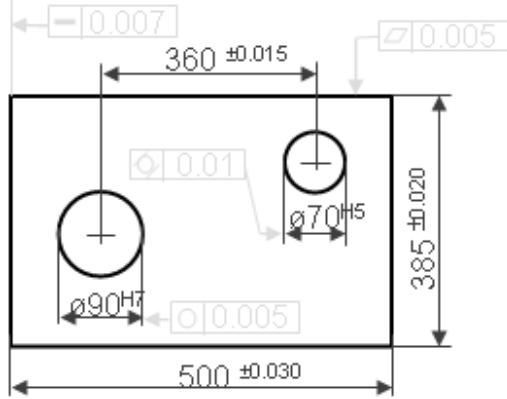
The precise sphere must be scanned with 4 different lines.

($R_{max} - R_{min}$ = Shape of sphere).

ISO 10360-2 (2001): CMM uses it for linear distance. This part of the norm refers to all coordinate measuring machines. This standard describes two basic

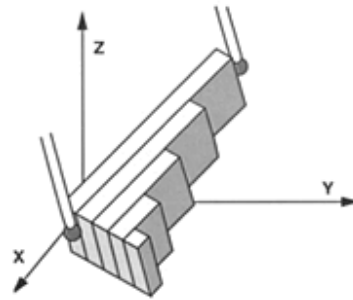
specifikacije KMS.

Volumetrično duljinska mjerna nesigurnost **E** (slika 3.):
 Set od 5 etalona mora biti izmjeren 3 puta s jednim mjerenjem na svakom kraju u 7 različitih smjerova u prostoru.
 Svi rezultati moraju biti unutar specifikacije **E**.
E određuje mjernu nesigurnost KMS kada se mjere udaljenost ili promjer.



specifications of CMM.

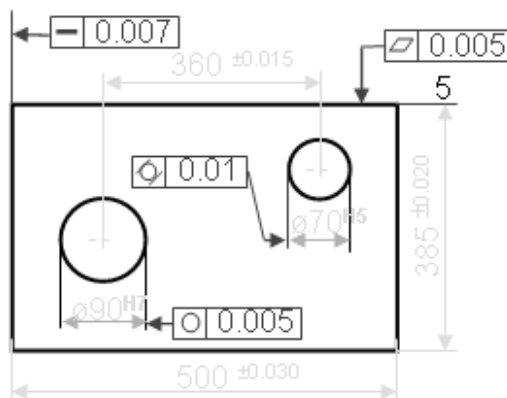
Volumetric linear measuring uncertainty **E** (Figure 3.):
 The set of 5 etalons must be measured 3 times with one measurement at each end in 7 different directions in space.
 All results have to be inside the specification **E**.
E determines the measuring uncertainty of CMM when measurement of linearity or diameter is measured.



Slika 3. Mjerenje udaljenosti ili promjera i set od 5 etalona
 Figure 3. Measurement of linear distance or diameter and set of 5 etalons

Volumetrična mjerna nesigurnost **P** (slika 4.):
 Precizna sfera mora biti izmjerena s 25 jednako raspoređenih izmjera (slika 4).
 Bitno: U prijašnjim standardima mjerna nesigurnost se označavala s **R**, **P** određuje mjernu nesigurnost KMS kod mjerenja oblika, npr. kod mjerenja linijske nepravilnosti, ravnosti, cilindričnosti, itd.

Volumetric measuring uncertainty **P** (Figure 4.)
 The precise sphere has to be measured with 25 equally arranged measures (Figure 4).
 Essential: In previous standards measuring uncertainty was designated with **R**, **P** determinates measuring the uncertainty of CMM of the measurement of shape e.g. of measuring of linearity insecurity, flatness, cylindricalness, etc.



Slika 4. Mjerenja oblika
 Figure 4. Measurement of shape

3. MJERENJE POKLOPCA VIJČANOGA KOMPRESORA

Korištenjem 3D mjernih strojeva postižu se točnija očitavanja i spoznaje o trenutnom stanju izmjera izratka. Uz dobivene informacije može se znatno utjecati na samu proizvodnju. Mjerni stroj na kojem se vrše izmjere kućišta vijčanoga kompresora nosi sljedeće oznake: GLOBAL IMAGE 07.10.07 mjerne točnosti $1,5+L/333$. Korišten je software PC DMIS 3.5 prema programu za mjerenje.

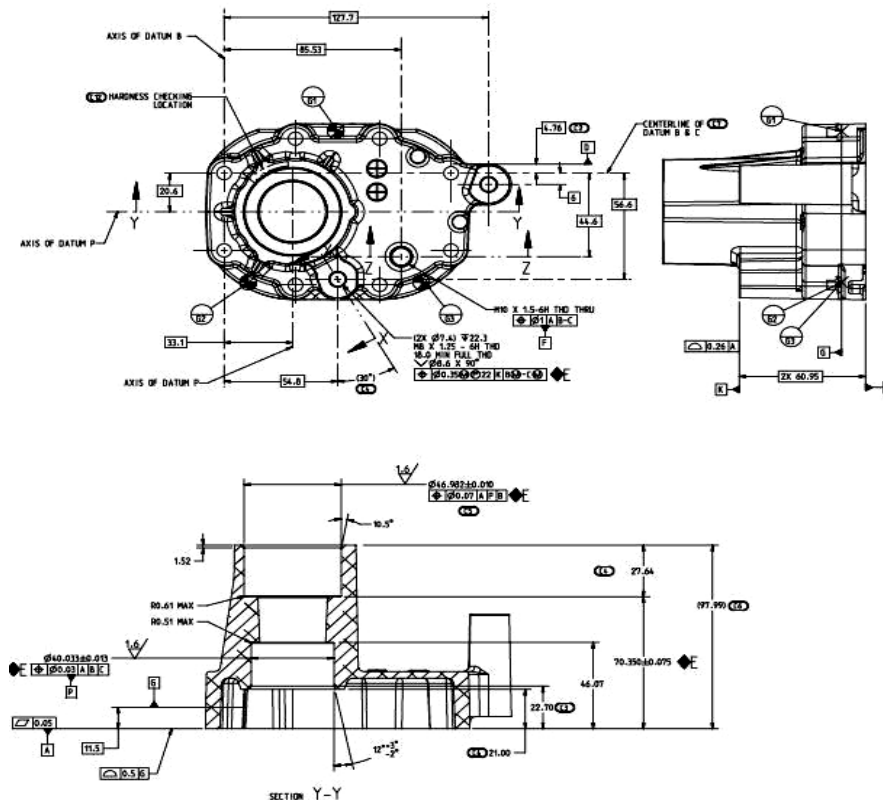
Izradak se pozicionira na KMS tako da se pričvrsti na napravu izradenu specijalno za namjenu stezanja tih izradaka. Naprava mora biti tako koncipirana da omogućuje pristup svim pozicijama koje treba mjeriti [4]. Na slici 5 prikazan je mjerni izradak.

3. MEASUREMENT OF TWIN-SCREW SUPERCHARGER COVER

By using 3D measuring machines, more precise readings and realisations of the current condition of workpiece measures has been achieved. With the obtained information the production can be significantly influenced. The measuring machine on which the measurement of the twin-screw supercharger cover has been performed carries the following indication: GLOBAL IMAGE 07.10.07 with a measuring accuracy of $1.5+L/333$. PC DMIS 3.5 software has been used according to the measuring program.

The workpiece is positioned on the CMM in a way that it is fastened on a special jig made for it. The jig has to be made in a way that it enables access to all the positions that need to be measured [4].

In Figure 5 measuring workpiece is shown.



Slika 5. Nacrt s karakterističnim kotama

Figure 5. Draft with characteristic measures

Nakon namještanja izratka u steznu napravu, aktivira se program za mjerenje. Na završetku mjerenja dobiju se rezultati mjerenja s podacima korisnim za tumačenje izmjera kao što je prikazano u tablici 1. U prvom djelu izvješća nalaze se podaci o šifri obratka, mjeritelju, vremenu mjerenja, oznaci izratka i stroja na kojem se mjeri te njegove mjerne nesigurnosti [4].

After the adjustment of the workpiece in the jig, the program for measuring is activated. At the end of measurement the acquired result of measuring with data is useful for the interpretation of the measurements that are obtained as shown in Table 1. In the first part of the report there are data about the workpiece code, measuring person, time of measurement, identification of the part and the machine on which has it been measured and its measuring uncertainty [4].

Tablica 1. Prikaz rezultata mjerenja
Table 1. Outline of measuring results

STROJ: GLOBAL ADVANTAGE ----- Mjerna nes.: 1,5+L/333 mm ⁻³ MACHINE: GLOBAL ADVANTAGE ----- Measuring unc.: 1.5+L/333 mm ⁻³							
DATE=18.4.2006 TIME=12:01:48 PART NAME : EATON 321537 REV NUMBER : 321537 SER NUMBER : KPL STATS COUNT : 0							
Mjerenje počinje u DCC modu! Measurement starts in DCC mod! Digni ticalo iznad komada! Put probe above of workpiece! Koristi novu napravu! Use a new jig! Baza_A s prednje strane, a baza_B s lijeve Base_A on the front side and base_B on the left te baza_C s desne strane (plus X) and base_C on the right (plus X) Postavi dva čepa M8 za mjerenje navojnih rupa! Set two plug gages M8 for measuring of internal thread							
'Mjerilac:' : 'Measuring technolog:' : 'Broj zahtjeva:' : 04085 'Draft number:' : 04085 'Oznaka komada:' : 1 'Workpiece mark:' : 1 'Vrsta mjerenja:' : 4B 'Type of measurement:' : 4B Mjerna nesigurnost: 1,5+L/333 mm ⁻³ Measuring uncertainty: 1.5+L/333 mm ⁻³ Stroj: GLOBAL ADVANTAGE Machine: GLOBAL ADVANTAGE							
DIM D3= FLATNESS OF PLANE PLA_0A AX MEAS NOMINAL +TOL -TOL DEV OUTTOL M 0.005 0.000 0.050 0.000 0.005 0.000 #-----							
DIM D31B_D32B= TRUE POSITION OF CIRCLE CIR14 AX MEAS NOMINAL +TOL -TOL BONUS DEV OUTTOL X -54.813 -54.800 -0.013 Z -20.646 -20.600 -0.046 DF 8.517 8.525 0.010 0.010 0.002 -0.008 0.000 #----- TP MMC 0.300 0.002 0.096 0.000 --#-----							
DIM D31C_D32C= TRUE POSITION OF CIRCLE CIR2 AX MEAS NOMINAL +TOL -TOL BONUS DEV OUTTOL X 54.799 54.800 -0.001 Z -20.626 -20.600 -0.026 DF 8.517 8.525 0.010 0.010 0.002 -0.008 0.000 #----- TP MMC 0.300 0.002 0.052 0.000 #-----							

4. STATISTIČKE KARAKTERISTIKE UZORAKA ZA KOTU Ø8,525 ± 0,010

U procesu mjerenja mjerene su karakteristične kote koje su definirane kao funkcionalne. Za sve funkcionalne kote analizirani su: histogram procesa, statističke karakteristike procesa, dijagram slijeda procesa, opis faza procesa, itd. Analiza izmjera tj. funkcionalnih kota prikazana je na primjeru kote Ø8,525. Podaci izmjera za kotu Ø8,525 dobiveni na KMS prikazani su u tablici 2 [4].

4. STATISTICAL CHARACTERISTICS SAMPLE FOR DIMENSION Ø8.525 ± 0,010

In the process of measurement, the characteristic dimensions, defined as functional, were measured. For all listed functions a histogram of the process has been analyzed, the statistical characteristics of process, a diagram of process sequence, a description of process phases, etc. an analyses of measure i.e. functional dimensions shown in the example of dimension Ø8.525. Data of measures for the dimension Ø8.525 obtained from CCM are show in Table 2 [4].

Tablica 2. Rezultati mjerenja
Table 2. Results of measuring

Dan Day	Smjena Shift	Uzorak Sample	Sat Hour	Izmjera br. 1 (mm) Measure nr. 1 (mm)	Izmjera br. 2 (mm) Measure nr. 2 (mm)	Izmjera br. 3 (mm) Measure nr. 3 (mm)	Izmjera br. 4 (mm) Measure nr. 4 (mm)	Izmjera br. 5 (mm) Measure nr. 5 (mm)	
1. dan 1 st day	04.03.2006. 04.03.2006.	1. smjena 1 st shift	1	8.00	8,522	8,520	8,524	8,520	8,522
			2	9.30	8,524	8,524	8,520	8,526	8,528
			3	11.00	8,520	8,522	8,526	8,524	8,526
			4	12.30	8,528	8,524	8,526	8,520	8,522
			5	14.00	8,524	8,524	8,520	8,522	8,526
	2. smjena 2 nd shift	6	15.30	8,526	8,522	8,527	8,523	8,522	
		7	17.00	8,523	8,522	8,520	8,525	8,524	
		8	18.30	8,524	8,524	8,523	8,527	8,522	
		9	20.00	8,527	8,524	8,520	8,521	8,526	
		10	21.30	8,523	8,526	8,522	8,528	8,526	
2. dan 2 nd day	05.03.2006. 05.03.2006.	1. smjena 1 st shift	11	8.00	8,526	8,524	8,520	8,522	8,526
			12	9.30	8,524	8,526	8,525	8,520	8,526
			13	11.00	8,523	8,523	8,525	8,530	8,525
			14	12.30	8,526	8,530	8,523	8,525	8,520
			15	14.00	8,522	8,526	8,527	8,523	8,524
	2. smjena 2 nd shift	16	15.30	8,525	8,524	8,525	8,523	8,524	
		17	17.00	8,523	8,524	8,522	8,525	8,530	
		18	18.30	8,524	8,525	8,530	8,523	8,525	
		19	20.00	8,525	8,521	8,523	8,530	8,523	
		20	21.30	8,523	8,525	8,530	8,521	8,523	
3. dan 3 rd day	06.03.2006. 06.03.2006.	1. smjena 1 st shift	21	8.00	8,525	8,526	8,523	8,525	8,520
			22	9.30	8,530	8,520	8,524	8,525	8,523
			23	11.00	8,521	8,523	8,526	8,530	8,523
			24	12.30	8,525	8,521	8,523	8,524	8,520
			25	14.00	8,525	8,525	8,525	8,530	8,521
	2. smjena 2 nd shift	26	15.30	8,524	8,525	8,522	8,525	8,523	
		27	17.00	8,523	8,526	8,523	8,524	8,521	
		28	18.30	8,523	8,521	8,523	8,522	8,525	
		29	20.00	8,525	8,525	8,521	8,523	8,522	
		30	21.30	8,526	8,522	8,526	8,526	8,523	

Aritmetička sredina:

Arithmetic mean:

$$\bar{X} = \frac{\sum_{i=1}^n X_i}{n}, \quad (1)$$

gdje je \bar{X} (mm) aritmetička sredina, n - broj uzoraka, X_i (mm) i -ta vrijednost izmjere u uzorku.

where \bar{X} (mm) is the arithmetic mean, n - the number of samples,

X_i (mm) i the value of the sampling measure.

$$\bar{X} = \frac{8,522 + 8,520 + 8,524 + 8,520 + 8,522}{5},$$

$$\bar{X} = 8,522 \text{ (mm)}.$$

Medijan: medijan je srednja vrijednost ili interval od kojega postoji podjednak broj elemenata s većom ili manjom vrijednosti, te se stoga ne računa, već odabire.

Median: the median is the middle value or the interval from which there is an equal number of elements with an upper or lower value, it is not calculated but selected.

Uzorak 1:

Sample 1:

$$\text{Medijan} = 8,522 \text{ (mm)}$$

Raspon:

Range:

$$R = X_{i\max} - X_{i\min}, \quad (2)$$

gdje je $\bar{X}_{i\max}$ (mm) najveća vrijednost izmjere, $\bar{X}_{i\min}$ (mm) najmanja vrijednost izmjere.

where $\bar{X}_{i\max}$ (mm) is the maximal value of the measure, and $\bar{X}_{i\min}$ (mm) is the minimal value of measure.

Uzorak 1:

Sample 1:

$$R = 8,524 - 8,520,$$

$$R = 0,004 \text{ (mm)}.$$

Standardna devijacija:

Standard deviation:

$$s = \sqrt{\frac{\sum_{i=1}^n (X_i - \bar{X})^2}{n-1}}, \quad (3)$$

Uzorak 1:

Sample 1:

$$s = \sqrt{\frac{(8,522 - 8,522)^2 + (8,520 - 8,522)^2 + (8,524 - 8,522)^2 + (8,520 - 8,522)^2 + (8,522 - 8,522)^2}{5-1}}$$

$$s = 0,00167332 \text{ (mm)}.$$

Primjerom je pokazan izračun statističkih karakteristika za uzorak br. 1. Vrijednosti ostalih uzoraka izračunavaju se jednakim takvim postupkom i prikazani su u tablici 3.

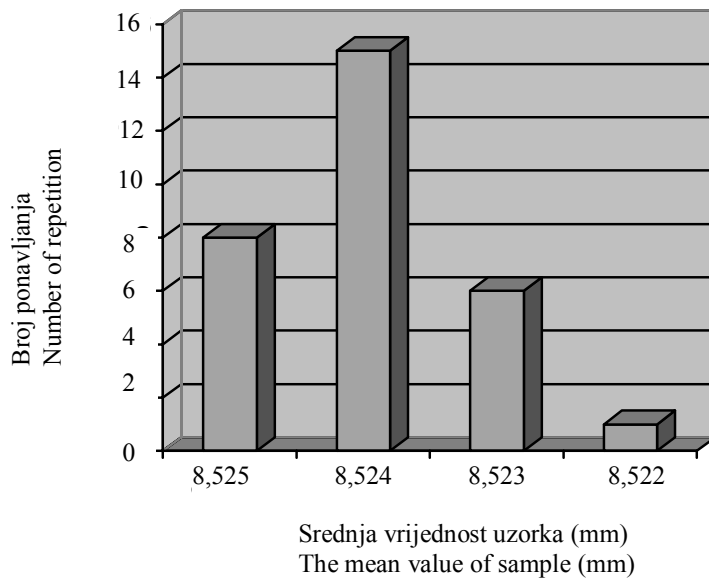
In the example, the calculation of statistical characteristics for sample no. 1 is shown. Values of other samples are calculated by the same procedure and they are shown in Table 3.

Tablica 3. Statističke karakteristike uzoraka
Table 3. Statistical characteristics of samples

Uzorak br. Sample nr.	Izmjerena vrijednost (mm) Measured value (mm)					Srednja vrijednost Mean value (mm)	Medijan Median (mm)	X_{max} (mm)	X_{min} (mm)	Raspon Range (mm)	Standardna devijacija Standard deviation (mm)
1	8,522	8,520	8,524	8,520	8,522	8,522	8,522	8,524	8,520	0,004	0,00167332
2	8,524	8,524	8,520	8,526	8,528	8,524	8,524	8,528	8,520	0,008	0,00296648
3	8,520	8,522	8,526	8,524	8,526	8,524	8,526	8,526	8,520	0,006	0,00260768
4	8,528	8,524	8,526	8,520	8,522	8,524	8,524	8,528	8,520	0,008	0,00316228
5	8,524	8,524	8,520	8,522	8,526	8,523	8,524	8,526	8,520	0,006	0,00228035
6	8,526	8,522	8,527	8,523	8,522	8,524	8,522	8,527	8,522	0,005	0,00234521
7	8,523	8,522	8,520	8,525	8,524	8,523	8,524	8,525	8,520	0,005	0,00192354
8	8,524	8,524	8,523	8,527	8,522	8,524	8,524	8,527	8,522	0,005	0,00187083
9	8,527	8,524	8,520	8,521	8,526	8,524	8,524	8,527	8,520	0,007	0,00304959
10	8,523	8,526	8,522	8,528	8,526	8,525	8,525	8,528	8,522	0,006	0,00244949
11	8,526	8,524	8,520	8,522	8,526	8,524	8,524	8,526	8,520	0,006	0,00260768
12	8,524	8,526	8,525	8,520	8,526	8,524	8,524	8,526	8,520	0,006	0,00248998
.
.
.

Histogram procesa prikazan je na slici 5.

A histogram of the proces is shown in Figure 5.



Slika 5. Histogram procesa
Figure 5. The histogram of process

Statističke karakteristike procesa prikazuje tablica 4.

Statistical characteristics of the process are shown in Table 4.

Tablica 4. Karakteristike procesa
Table 4. Characteristics of the process

\bar{x}_i	Učestalost Frequency	f	d	fd	fd^2
8,525	IIIIIIII	8	1	8	8
8,524	D=IIIIIIIIIIIIIIIIII	15	0	0	0
8,523	IIIIII	6	-1	6	6
8,522	I	1	-2	-2	4
Ukupno: Total:		30		0	18

Iz tablice 4: inkrement $i=0,001$,
mod $D=8,524$ (mm),
kumulativna učestalost $fd=0$,
relativna kumulativna učestalost $fd^2=18$.

From table 4: increment $i=0,001$,
mod $D=8.524$ (mm),
cumulative frequency $fd=0$,
relative cumulative frequency $fd^2=18$.

Aritmetička sredina procesa:

The arithmetic mean of the process:

$$\bar{X}_0 = D + i \frac{\sum fd}{\sum f} \tag{4}$$

$$\bar{X}_0 = D + i \frac{\sum fd}{\sum f} = 8,524 + 0,001 \frac{0}{30} = 8,524$$

Standardna devijacija svih aritmetičkih sredina:

The standard deviation of all arithmetic means:

$$\sigma = i \sqrt{\frac{\sum fd^2}{\sum f} - \left(\frac{\sum fd}{\sum f}\right)^2} \tag{5}$$

$$\sigma = 0,001 \sqrt{\frac{18}{30} - \frac{0}{30}^2} = 0,00077 \text{ (mm)}$$

Također, aritmetička sredina procesa može se izračunati kao:

Also, the arithmetic mean of the process can be calculated as:

$$\bar{X}_0 = \frac{\sum \bar{X}_i}{n} = \frac{8,522 + 8,524 + \dots + 8,525}{30} = \frac{181,706}{30} = 8,524 \text{ (mm)}.$$

Standardna devijacija procesa:

The standard deviation of the process:

$$\sigma = \sqrt{\frac{\sum_{i=1}^n (X_i - \bar{X})^2}{n-1}} \tag{6}$$

$$\sigma = 0,0016$$

Medijan medijana procesa:

The median of the process median:

$$MM = 8,524 \text{ (mm)}$$

Mod procesa:

Process mod:

$$D = 8,524 \text{ (mm)}$$

Raspon procesa:

The range of the process:

$$R_0 = \bar{X}_{\max} - \bar{X}_{\min} \quad (7)$$

$$R_0 = 0,003 \text{ (mm)}$$

gdje je \bar{X}_{\max} (mm) najveća vrijednost izmjere, \bar{X}_{\min} (mm) najmanja vrijednost izmjere.

where \bar{X}_{\max} (mm) is the maximal value of measure, \bar{X}_{\min} (mm) is the minimal value of measure.

Koeficijent varijacije:

Variation coefficient:

$$V_X = \frac{\sigma}{\bar{X}_0} \cdot 100\% \quad (8)$$

$$V_X = \frac{0,0016}{8,524} \cdot 100\% = 0,01877\%$$

Da bi proces bio sposoban treba zadovoljiti uvjet da je polje statističke tolerancije 6σ uže od zadanog polja tolerancije T tj. indeks sposobnosti procesa C_p mora biti veći od 1, znači:

In order that the process will be able to satisfy the condition that the statistical tolerance field 6σ will be more narrow than the given tolerance field T , the process capability index C_p has to be greater than 1, this means:

$$C_p = \frac{T}{6\sigma} > 1 \quad (9)$$

$$6\sigma = 6 \cdot 0,0016 = 0,0096$$

$$T = T_g - T_d = 0,02 \quad (10)$$

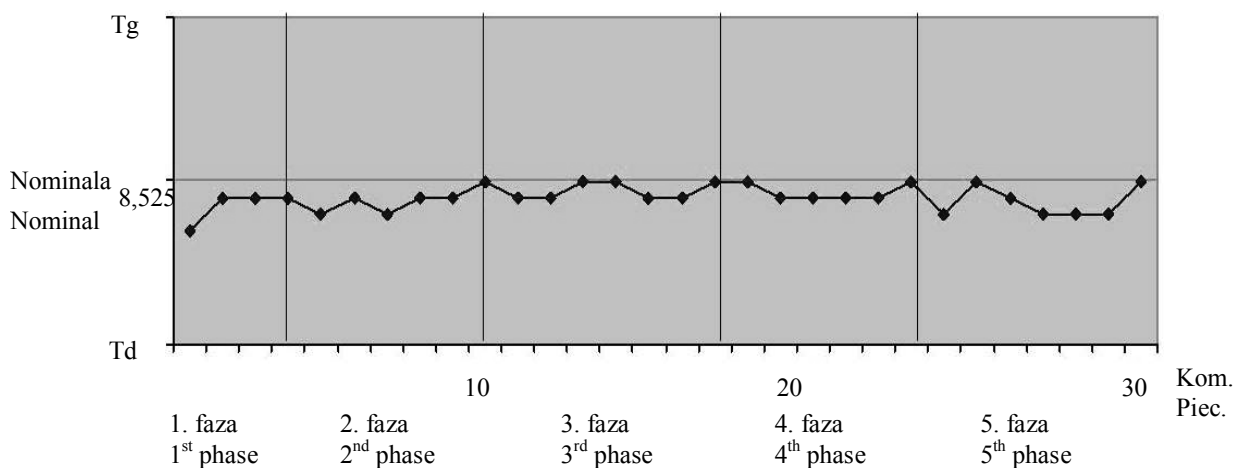
$$C_p = \frac{0,02}{0,0096} = 2,08333 > 1$$

gdje je T_g gornja granica tolerancija, T_d donja tolerancija.

where T_g is upper limit of tolerance, and T_d is lower limit of tolerance.

Dijagram slijeda procesa za kotu $\varnothing 8,525$ prikazan je na slici 6.

The diagram of the process sequence for the measure $\varnothing 8,525$ is shown in Figure 6.



Slika 6. Dijagram slijeda procesa za kotu $\varnothing 8,525$

Figure 6. Diagram of process sequence for dimension $\varnothing 8,525$

Granica statističke tolerancije:

Limit of statistic tolerance:

$$T_S = \bar{X}_0 \pm 3\sigma \quad (11)$$

$$T_{sg} = 8,524 + 3 \cdot 0,0016 = 8,5288 \text{ (mm)}$$

$$T_{sd} = 8,524 - 3 \cdot 0,0016 = 8,5192 \text{ (mm)}$$

gdje je T_{sg} – gornja granica statističke tolerancije, T_{sd} – donja granica statističke tolerancije.where T_{sg} is the upper limit of statistic tolerance, and T_{sd} is the lower limit of statistic tolerance.

Podešenost procesa:

Adjustment of the process:

Potrebno je zadovoljiti uvjet $\Delta=0$.It is necessary to satisfy the condition $\Delta=0$.

$$\Delta = \frac{T_d + T_g}{2} - \bar{X}_0 \quad (12)$$

$$\Delta = \frac{8,515 + 8,535}{2} - 8,524 = 0,001 \text{ (mm)}.$$

 $\Delta \neq 0$ – proces nije podešen i pomaknut je prema T_d . $\Delta \neq 0$ – the process is not adjusted and it is moved toward T_d .

Vjerojatnost pojave izratka kojemu je potrebna dorada:

The probability of workpiece appearance on which repair is needed:

$$z = \frac{\bar{X}_0 - T_d}{\sigma} \quad (13)$$

$$z = \frac{8,524 - 8,515}{0,0016} = 5,625 .$$

Iz tablice, za $z = 5,625$ slijedi $F(z) \approx 0,5$ pa je neusklađenost procesa:From the table, for $z = 5,625$ it follows that $F(z) \approx 0,5$ so the mismatching of process is:

$$q_T = (0,5 - 0,5) \cdot 100 = 0 \text{ \%}.$$

Mod procesa:

Process mode:

$$D = 8,524 \text{ (mm)}$$

Raspon procesa:

The range of the process:

$$R_0 = \bar{X}_{\max} - \bar{X}_{\min} \quad (14)$$

$$R_0 = 8,525 - 8,522 = 0,003 \text{ (mm)}.$$

Vjerojatnost pojave neispravnog izratka kojemu je potrebna dorada toliko je mala da je možemo zanemariti.

The probability that the workpiece appearance will not be satisfied and that it will need such a minor repair that it can be considered to be negligible.

Vjerojatnost pojave škarta:

Probability of scrap appearance:

$$z = \frac{T_g - \bar{X}_0}{\sigma} \quad (15)$$

$$z = \frac{T_g - \bar{X}_0}{\sigma} = \frac{8,535 - 8,524}{0,0016} = 6,875$$

Iz tablice, za $z = 6,875$ slijedi $F(z) \approx 0,5$ pa je neusklađenost procesa:From the table, for $z = 6,875$ follows $F(z) \approx 0,5$ so the mismatching of process is:
 $F(z) \approx 0,5$,

Vjerojatnost pojave škarta ili dorade toliko je mala da je možemo zanemariti. $q_2=(0,5-0,5) \cdot 100\% = 0\%$. The probability of scrap or repair appearance is so minor that it can be ignored..

Neusklađenost procesa:

Process mismatching:

$$q = q_1 + q_2 = 0 + 0 = 0\%$$

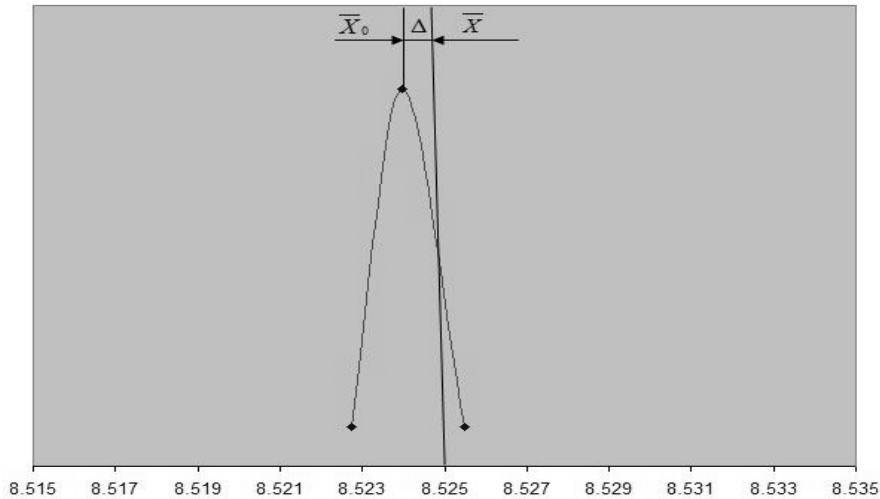
Vjerojatnost prihvatanja uzorka:

Probability of sample accepting:

$$p = 1 - q_1 - q_2 = 100\%$$

Normalna razdioba procesa prikazana je na slici 7.

The process of normal distribution is shown in Figure 7.



Slika 7. Normalna razdioba procesa
Figure 7. Proces normal distribution

Granica 99% vjerojatnosti prihvatanja:

Limit of 99% acceptance possibility:

$$F(z) = 0,490 \quad z = 2,326$$

Gornja dozvoljena aritmetička sredina:

Upper allowed arithmetic mean:

$$\begin{aligned} \bar{X}_{0g} &= T_g - z \cdot \sigma, \\ \bar{X}_{0g} &= 8,535 - 2,326 \cdot 0,0016 = 8,531278 \text{ (mm)} \end{aligned} \quad (16)$$

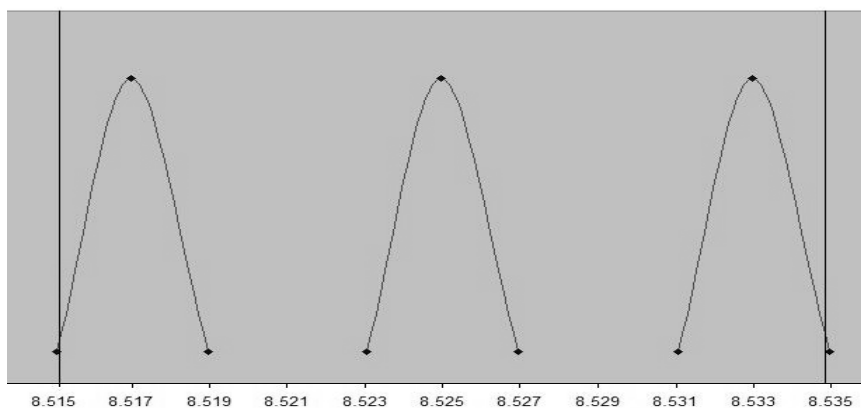
Donja dozvoljena aritmetička sredina:

Lower allowed arithmetic mean:

$$\begin{aligned} \bar{X}_{0d} &= T_d + z \cdot \sigma, \\ \bar{X}_{0d} &= 8,515 + 2,326 \cdot 0,0016 = 8,518721 \text{ (mm)} \end{aligned} \quad (17)$$

Pomak procesa za 99% vjerojatnosti prihvatanja prikazan je na slici 8.

Proces shifting for 99% possibility of acceptance is shown in Figure 8.



Slika 8. Pomak procesa
Figure 8. Proces shifting

5. ZAKLJUČAK

U ovom radu prikazani postupak 3D-mjerenja pomoću mjernog stroja Global Image 07.10.07 imao je za cilj utvrditi točnost proizvodnog procesa izrade poklopca vijčanog procesora. Kod 3D-mjerenja i analize izmjera (funkcionalnih koordinata) za poklopac vijčanoga kompresora utvrđen je stabilan proizvodni proces. Kao primjer mjerne analize u radu odabrana je kota Ø8,525 ± 0,010. Također, i druge izmjere zadovoljile su postavljene zahtjeve.

6. POPIS OZNAKA

aritmetička sredina	\bar{X} - mm
aritmetička sredina procesa	\bar{X}_0 - mm
devijacija svih aritmetičkih sredina	σ - mm
donja dozvoljena aritmetička sredina	\bar{X}_{0d} - mm
donja granica tolerancija	T_d -mm
donja granica statističke tolerancije	T_{sd} -mm
gornja granica tolerancija	T_g - mm
gornja dozvoljena aritmetička sredina	\bar{X}_{0g} - mm
gornja granica statističke tolerancije	T_{sd} -mm
inkrement	i
indeks sposobnosti procesa	C_p
koeficijent varijacije	V_X
kumulativna učestalost	fd
medijan	medijan - mm
medijan medijana	MM - mm
mod	D - mm
najmanja vrijednost izmjere u uzorku	\bar{X}_{\min} -mm
najveća vrijednost izmjere u uzorku	\bar{X}_{\max} -mm
neusklađenost procesa	q
polja tolerancije	T - mm
relativna kumulativna učestalost	fd^2

5. CONCLUSION

This paper presents the procedure of 3D measurement by means of the 3D measuring machine Global Image 07.10.07 aimed to determine the accuracy of the production process of the manufacture of the twin-screw supercharger cover. In 3 D measurement and measures (functional dimensions) and analysis for the twin-screw supercharger cover, the stable production process was determined. As an example of measures analysis in the paper the dimension Ø8.525 ± 0,010 was chosen. Also, other measures satisfy all required demands.

6. LIST OF SYMBOLS

arithmetic mean
arithmetic mean of process
deviation of all arithmetic means
lower allowed arithmetic mean
lower limit of tolerance
lower limit of statistic tolerance
upper limit of tolerance
lower allowed arithmetic mean
upper limit of statistic tolerance
increment
process capability index
variation coefficient
cumulative frequency
median
median of process median
mod
minimal value of measure
maximal value of measure
proces mismatching
tolerance field
relative cumulative frequency

raspon	R - mm	range
raspon procesa	R_0 -mm	process range
standardna devijacija	s -mm	standard deviation
vjerojatnost prihvatanja uzorka	p	probability of sample accepting

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