Imperial Journal of Interdisciplinary Research (IJIR)
Vol-2, Issue-9, 2016
ISSN: 2454-1362, http://www.onlinejournal.in

Design & Development of Auto Gauging Machine for Outer Ring of Needle Bearing

S. V. Yadav[1] & Prof. (Dr.) V. R. Naik[2]
[1]M.E. (Mech) P.D.D. student, Textile & Engineering Institute Ichalkaranji Kolhapur
[2]Head of Mechanical Department, Textile & Engineering Institute Ichalkaranji Kolhapur

Abstract : *This paper deals with the study of automation used in the gauging system, benefits of automation in gauging, effect on gauging process, effect on cycle time, productivity etc. Manual gauging with vernier caliper, micrometer or height gauge etc. are critical to use for any product with tight tolerance. Also manual gauging takes much time for inspection which affects the productivity. This system use electronic probes for auto gauging method which helps to improve the repeatability & quality of the checking. The results of this study help to calculate the repeatability & cycle time of gauge using automation. Also this study correlates the results with CMM & height gauge to calculate the accuracy of the auto gauging system.*

Keywords- Outer ring of needle baring, Gauging, Linear Variable Displacement Transformer (LVDT) probe, Automation, Repeatability, Cycle time, Coordinate Measurement Machine (CMM).

1. Introduction

The machines are composed of many different kinds of mechanical parts, among which the needle roller bearings are very important. It is a bearing which uses small cylindrical rollers. They are used to reduce friction of a rotating surface. The needle roller bearings have a larger surface area that is in contact with the bearing outer surfaces. The inaccuracy in bearing affects the machine assembly and its performance.

To avoid the problems arises due to inaccuracy of component; it needed to measure its dimension such that it should be in tolerance zone. As the measuring of articles is an essential part of modern life, there is a constant need for knowing the exact inner diameter and outer diameter of bearing and many items, e.g., for production, testing, etc.[1]. The manufacturing environment, by its very nature, relies on two types of measurements to verify quality and to quantify performance: (1) measurement of its products, and (2) measurement of its processes. Therefore, product evaluation and process improvement require accurate and precise measurement techniques[2]. Quality control and quality management consist of a diversity of tasks, measures and activities, which extend over the entire product life cycle for each product must be accompanied in all phases through corresponding quality relevant measures and activities[3]. Since accurate measurement is essential in many fields, and since all measurements are necessarily approximations, a great deal of effort must be taken to make measurements as accurate as possible. Gauge variability plays a key role on quality improvement for the industry. Only a gauge with acceptable repeatability and reproducibility, the adequacy of a product's measurement process can be determined. In many industries, the requirement of having a sound measurement system is part of their total quality assurance programs. Good quality of product can only be achieved through an adequate measurement system. Therefore, making sure the performance of a measurement system is adequate becomes an urgent task for practitioners[4]. Electronic gauging system helps for the good accuracy with repeatability of component and automation for faster rate of inspection of components.

2. Design

The Component drawing for which auto gauging machine is developed is outer ring of needle bearing which is shown in the fig 1.

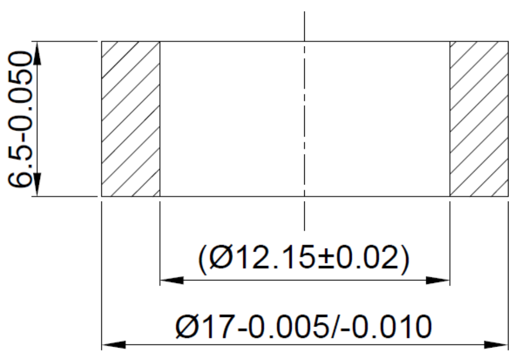

Fig.1.Component drawing

The parameters to be checked are outer diameter & height.

Outer diameter = Ø17 -0.005/-0.010 mm

Height = 6.5 +0.0/-0.050 mm

Present theories and practices:

The present practice of inspection of the outer ring of needle bearing are manual with the help of vernier caliper, micrometer. The method used is the sampling method for the inspection.

The measurement system used to make measurements on products using physical & visual inspection devises. Some method based air gauging with mechanical or digital display. Some based on contact measurement using electronic probes. Using computer program algorithms a statistical method used to evaluate optimal allocation i.e. measurement based on probe displacement.

Building a dimensional gauge for checking a very tight tolerance on a large part includes many of the same concepts required for any precision measurement. Bearing tolerances are much too tight for hand gauges such as an ID micrometer or a large caliper, and many coordinate measuring machines have neither the capacity nor the accuracy. In many cases, the only option is to build a custom gauge for the family of parts to be measured.

Due to manual inspection there will not be accuracy in inspection and also the time required for inspection of component is more. As the sampling method is used for inspection there is not 100% inspection possible with large quantity.

New concept:

Multigauging systems designed especially for the inspection of various parameters of a component like ID, OD, HEIGHT, WIDTH and OVALITY etc. as per requirement[1]. Here it needs to measure OD & Height only. In new concept LVDT probes are used for measurement. Automation is used for gauging with LVDT probes. The introduction of the automation has revolutionized the manufacturing in which complex operations have been broken down into simple step-by-step instruction that can be repeated by a machine. In such a mechanism, the need for the systematic assembly and inspection have been realized in different manufacturing processes[5]. In current concept the component comes at feeding station by vibratory bowl feeder. Locator automatically picks the component & brings it towards gauging station where gauging takes place & then it brings towards unloading station where unloading of the component takes place.

LVDT probe:

The method used is a comparative type with LVDT (Linear Variable Displacement Transformer) probes for measurement. The LVDT probe takes a measurement with a contact ball point directly.

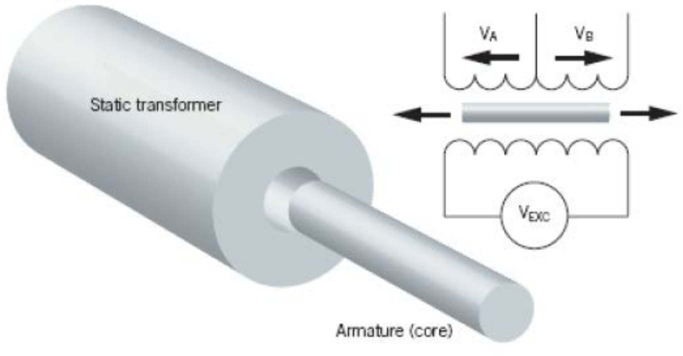

Fig.2.LVDT Probe core

Principle of Operation:

The LVDT probe closely the ideal Zero-order displacement sensor structure at low frequency, where the output is a direct and linear function of the input[4]. A LVDT Displacement Sensor works by moving the core through the body. The position of the core within the body is detected by coils wound on the bobbin. The coils are supplied with an AC signal and then returned an AC signal. The signal is then processed by conditioning electronics to provide a measure of the core position. The body is normally mounted on the static part of an element and the core attached to the moving part. A simplified electrical schematic is shown in the figure 3.

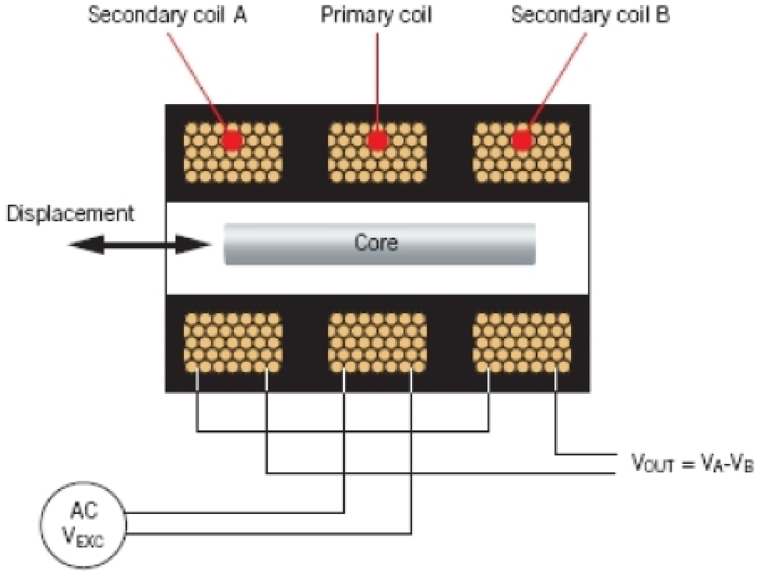

Fig.3.Simplified Electrical Schematic for probe

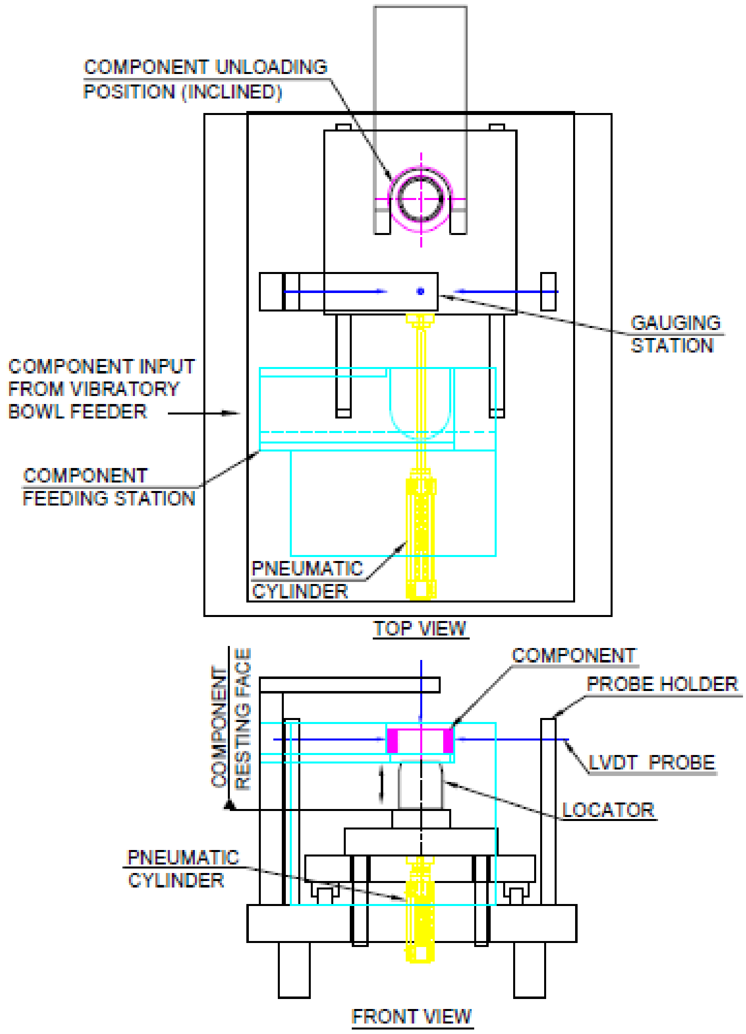

Fig.4.Concept layout

Sequence of operation:

- Component approaches feeding station through vibratory bowl feeder.
- Bottom side locator picks the component with the help of pneumatic cylinder.
- The component brings towards gauging station with the help of second cylinder.
- Gauging takes place at gauging station, and then component moves towards the unloading station in the same stroke of the second cylinder.
- Component gets unloaded at the unloading station by bringing the locator in downward direction with the help of first pneumatic cylinder.
- Unloading plates are provided at unloading station to unload the component.
- After unloading of the component locator goes back to pick next component. Cycle continues.

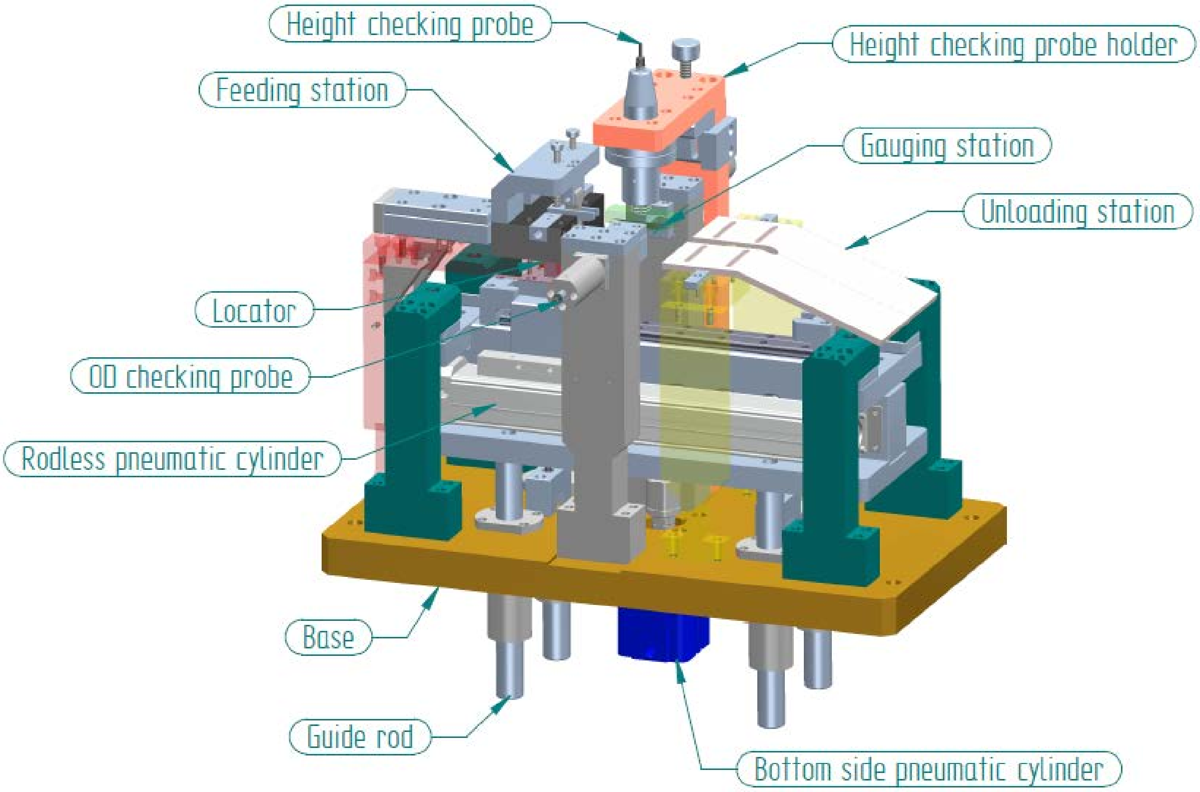

Fig.5.Assembly of auto gauging machine

Components of the machine:

As shown in the fig. the gauging station contains a probe with probe holding arrangement. There are two probes provided for OD measurement while one probe for height measurement. A feeding station is provided where component comes from vibratory bowl feeder.
The function of a fixture is to hold a part in order to keep that part in a desired position and orientation while the part is in manufacturing, assembly, or verification processes[6]. So an ID locator is provided to pick & guide the component at feeding station. Down side pneumatic cylinder is provided for up down movement of the locator. Using this arrangement locator picks & unloads the component at loading & unloading station respectively. Four guide rods are provided for precious movement of the locator.

A rodless pneumatic cylinder is provided to carry the component towards gauging & unloading. For this precious horizontal movement of the locator is mounted on LM guide rail. Two plates in inclined direction are provided with required guide area to unload the component. The vertical pneumatic cylinder goes down with locator assembly by keeping the component at unloading plates. The component goes downward by gravitational force where an arrangement is provided to sort the OK & Not OK components.

3. Design of component handling from feeding station to gauging & unloading station

The component will pick by the locator and this locator & locator holding assembly will carry the component towards a gauging & sorting station. The land available for gauging & sorting machine is 1200 mm X 1200 mm.

The component loading point to unloading points the land available is near about 200 mm. A pneumatic cylinder is required to carry the component automatically. A LM rail will get an accurate travel of component from loading station to gauging & towards unloading station.

Selection of pneumatic cylinder to carry the component:

Load to be moved by pneumatic cylinder:-

A pneumatic cylinder is a component which carries out a movement using compressed air as the medium

The cylinder is required to move the component, locator & locator holder.

Weight of the component = volume x density x g

$$= \frac{\pi}{4}(D^2 - d^2) \times h \times 7.85 \times 10^{-6} \times 9.81$$

$$= \frac{\pi}{4}(17^2 - 12.15^2) \times 6.5 \times 7.85 \times 10^{-6} \times 9.81$$

= 0.111 N

Weight of locator = volume x density x g

$$= \frac{\pi}{4} \times D^2 \times h \times 7.833 \times 10^{-6} \times 9.81$$

$$= \frac{\pi}{4} \times 20^2 \times 6.5 \times 7.833 \times 10^{-6} \times 9.81$$

= 0.157 N

Weight of locator holder = volume x density x g

$$= [(42 \times 60 \times 15) + (12 \times 40.5 \times 45)] \times 7.86 \times 10^{-6} \times 9.81$$

= 4.6 N

∴ Total weight, W = 0.111 + 0.157 + 4.6 = 4.868 N

The pneumatic cylinder needs to carry load of 4.868 N.

As stated above & considering factor of safety 2, a cylinder required to carry a load

= 2 x 4.868 = 9.736 N.

The total stroke required is 200 mm.

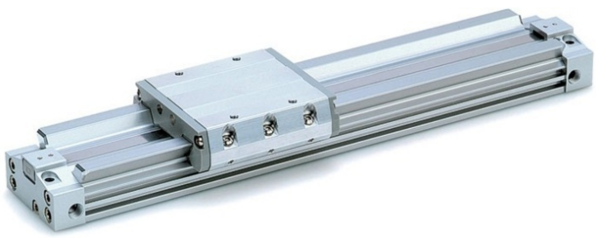

Fig.6.Rodless Cylinder - Mechanically coupled slide

The theoretical force of a pneumatic cylinder can be calculated using the following formula: F = P x A x 10

Where,

F = force acted by pneumatic cylinder in N

P = Pressure in bar

A = Area of the piston in cm

Therefore the minimum diameter required for piston is

∴ $A = \frac{F}{P \times 10}$

∴ $A = \frac{9.736}{6 \times 10}$

∴ A = 0.16 cm^2

i.e. A= 16 mm

$\therefore D = 2 \times \sqrt{16/\pi}$

$\therefore D = 4.514$ mm

Therefore the minimum diameter required for piston of pneumatic cylinder is 4.514 mm.

The model "DGP-25-200PPV-A-B" from festo[7] contains all the required specification for the cylinder required to carry the component from feeding station to gauging & unloading station.

Below are the specifications of model "DGP-25-200PPV-A-B"

Table.1. Specification of rodless cylinder

Model	DGP-25-200PPV-A-B
Type	Linear Drive Basic Version
Piston Dia.	25 mm
Stroke	200 mm
Position sensing	A – via magnet
Mode of operation	Double-acting
Operating medium	Filtered compressed air, lubricated or unlubricated
Theoretical force at 6 bar	295 N
Impact Energy	15 Nm
Basic weight with 0 mm stroke	0.84 Kg
Additional weight per 10 mm stroke	0.036 Kg
Moving load	0.18 Kg

Selection of pneumatic cylinder for lifter assembly:

The main work of the pneumatic cylinder for lifter assembly is to pick the component at loading station and unload at unloading station. As per the design of the system the stroke required is 30 mm.

The total weight that cylinder need to lift is the weight of component, locator, locator holder, LM rail, rodless cylinder, four rod assembly etc.

Load of component, locator & locator holder = 4.868 N

Load of LM rail[9] $= (0.13 + 1.9 \times 0.2) \times 9.81 = 5\ N$

Load of rodless cylinder[7] $= \left(0.84 + \frac{0.036}{10} \times 200\right) \times 9.81 = 15.3\ N$

Load of four rod assembly –

Load of a single rod = volume x density x g

$= \frac{\pi}{4} \times D^2 \times h \times 7.833 \times 10^{-6} \times 9.81$

$= \frac{\pi}{4} \times 25^2 \times 225 \times 7.833 \times 10^{-6} \times 9.81$

= 8.483 N

∴ Load of four rods = 4 x 8.483 = 33.932 N

Now,

Total load = 4.868 + 5 + 15.3 + 33.932 = 59.1 N

Considering factor of safety 2, a cylinder required to carry a load

W = 2 x 59.1

W = 118.2 N

The pneumatic cylinder lifts the lifter assembly in vertical direction. So there is no restriction for area available & a cylinder with rod can be used here.

The theoretical force of a pneumatic cylinder can be calculated using the following formula: $F = P \times A \times 10$

Where,

F = force acted by pneumatic cylinder in N

P = Pressure in bar

A = Area of the piston in cm

Therefore the minimum diameter required for piston is

$\therefore A = \frac{F}{P \times 10}$

$\therefore A = \frac{118.2}{6 \times 10}$

$\therefore A = 1.97\ cm^2$

i.e. A= 197 mm^2

$\therefore D = 2 \times \sqrt{197/\pi}$

$\therefore D = 15.838$ mm

Therefore the minimum diameter required for piston of pneumatic cylinder is 15.838 mm.

The model “ADVU-50-30-A-P-A” - Compact cylinder - 156640 from Festo[9] contains all the required specification for the cylinder required to carry the component from feeding station to gauging & unloading station.

Below are the specifications of model “ADVU-50-30-A-P-A”

Table.2.Specification of double acting compact cylinder

Model	ADVU-50-30-A-P-A Compact cylinder - 156640
Type	Double Acting Basic Version
Piston Dia.	50 mm
Stroke	30 mm
Operating Pressure	0.8 to 10 bar
Theoretical force at 6 bar, advancing	1178 N
Theoretical force at 6 bar, retracting	1057 N
Max. impact energy at end position	0.06 J

4. Manufacturing

The auto gauging machine requires various components; the major components are locator, probe holding plates, base plate, contact tip, locator holder, unloading plates etc. It requires various machines to manufacture them like band saw machine for cutting operation, lathe machine for rough machining, drilling machine, surface grinding machine, cylindrical grinding machine, internal grinding machine, milling machine etc.

5. Trials & Repeatability

The trials have taken on low master, high master & on component. The repeatability of the gauge should be 1.5 μm or 10% of total tolerance whichever is higher.
The trial report & repeatability is as per below table no.1.

Table.3.Trial & Repeatability Report

Master and component repeatability report						
Reading & Repeatability is in Micron						
The gauge is set on Low Master and taken the repeatability on Low & High Master and on Component.						
Check on	Low Master (in μm)		High Master (in μm)		Component (in μm)	
Sr. No.	OD 16.990 mm	Height 6.45 mm	OD 16.995 mm	Height 6.500 mm	OD 17.00 -0.005 /-0.010 mm	Height 6.500 -0.05 mm
1	0.0	-0.9	4.9	49.7	-1.4	21.9
2	0.2	-0.9	5.1	49.2	-1.9	21.1
3	-0.4	-0.9	5.2	49.1	-1.4	21.5
4	0.1	-0.6	5.4	48.5	-1.4	21.0
5	-0.3	-0.8	5.2	47.8	-1.4	20.8
6	0.2	-1.2	5.1	47.8	-1.5	21.6
7	0.0	-1.2	5	47.4	-1.2	20.6
8	-0.2	-1	5.2	47.6	-1.5	20.6

9	0.0	-1	5	47.8	-1.7	20.7
10	-0.4	-1	4.7	47.7	-1.5	20.9
11	0.0	-1.8	5.3	47.8	-1.4	21.1
12	0.0	-2.3	5	47.1	-1.4	21.7
13	-0.1	-2.1	5.3	47.9	-1.3	21.6
14	0.0	-2.5	5.1	47.5	-1.6	21.9
15	-0.2	-1.8	5.1	47.2	-1.5	21.3
16	0.1	-2.3	5.1	47.2	-1.7	21.2
17	0.2	-2.8	5.1	47.1	-1.2	21.4
18	0.4	-2.1	5.2	49.2	-1.3	20.4
19	0.4	-0.9	4.9	46.8	-1.5	20.7
20	0.0	-1.2	4.9	46.8	-1.7	20.5
21	0.1	-1.6	5.2	46.8	-1.4	20.6
22	-0.1	-2.7	5	49.1	-1.7	20.9
23	-0.2	-3.1	5.2	49.3	-1.2	20.5
24	-0.2	-3	5.1	48.5	-1.5	21.5
25	0.0	-3.1	5.2	47.8	-1.4	19.5
26	-0.1	-3.1	5.4	47.8	-1.8	19.2
27	-0.3	-1.6	5	47.4	-1.8	21.9
28	0.1	-3.6	5	47.8	-1.7	21.5
29	-0.2	-3.6	4.8	49.1	-1.5	20.5
30	-0.3	-2.9	4.9	49.3	-1.7	19.4
31	-0.1	-2.7	4.8	48.5	-1.3	18.9
32	-0.4	-2.2	5.1	47.8	-2	18.8
33	-0.4	-2.1	5.1	47.8	-2.1	19.2
34	-0.3	-3.1	5.7	47.4	-1.3	18.9
35	-0.2	-3	4.9	49.9	-1.7	21.4
36	0.3	-3.8	5.1	48.5	-1.9	19.4
37	0.4	-3.7	5.2	47.2	-1.8	18.6
38	0.4	-3.4	4.9	47.2	-1.3	20.1
39	-0.3	-3.1	5.3	47.1	-1.7	20.7
40	-0.4	-3.2	5.3	49.2	-1.8	21.3
41	0.3	-3.9	5.6	49.7	-1.9	21.6
42	0.2	-4.1	5.2	48.2	-2.3	21.4
43	0.1	-4.6	4.8	50.1	-1.6	20.6
44	0.0	-3.9	4.8	48.5	-1.6	20.9
45	0.1	-4.3	5.1	47.8	-1.7	20.5
46	0.2	-3.8	5.2	48.8	-1.8	18.2
47	-0.3	-3.8	4.8	47.4	-1.8	21.4
48	-0.4	-3.7	5.2	47.6	-1.6	19.4
49	0.3	-2.1	5.3	48.4	-1.4	21.5
50	0.4	-2.9	5.3	48.7	-1.8	20.5
Repeatability	**0.8**	**4.0**	**1.0**	**3.3**	**1.1**	**3.7**

Therefore repeatability for OD is

$$\text{Repeatability OD} = \frac{0.8 + 1.0 + 1.1}{3}$$

$$= 0.967\ \mu\text{m}$$

$$\text{Repeatability Height} = \frac{4.0 + 3.3 + 3.7}{3}$$

$$= 3.667\ \mu\text{m}$$

The repeatability of any gauge is given 1.5 µm or 10% of total tolerance whichever is higher. So the repeatability for OD should be 1.5 µm as the tolerance for OD is 5 µm& for Height the repeatability should be 5 µm. From machine the repeatability got is more than the specified. For OD it is 0.967 µm which is less than1.50 µm& that is for Height is 3.667 µm which is less than 10% of the total tolerance of the Height i.e. 5 µm.

6. Result & discussion

Repeatability & Accuracy:

The repeatability of any gauge is given 1.5 µm or 10% of total tolerance whichever is higher. So the repeatability for OD should be 1.5 µm as the tolerance for OD is 5 µm& for Height the

repeatability should be 5 µm. From machine the repeatability got is more than the specified. For OD it is 0.967 µm which is less than1.50 µm& that is for Height is 3.667 µm which is less than 10% of the total tolerance of the Height i.e. 5 µm.
The accuracy of the gauge compared with the digital micrometer & CMM. The accuracy of the gauge is given as ±1.5 µm or 10% of total tolerance. On digital micrometer the accuracy is between +0.0015 mm to -0.0003 mm for OD. And for Height the accuracy is between +0.0020 to -0.0009 mm. On CMM the accuracy for OD is between+0.0011 mm to -0.0003 mm and for Height accuracy is between +0.0020 mm to -0.0015 mm.
For OD accuracy is between ±1.5 µm and for Height accuracy comes between 10% of total tolerance.

Cycle Time:

The production of outer ring of needle bearing is 5000/shift i.e. 5000 components per 8 hrs.

$\therefore \frac{5000}{8} = 625$ per hrs.

i.e. $\frac{3600}{625} = 5.76$per sec.

As per above equations we have maximum total time of 5 seconds to complete a total process of gauging & sorting considering mastering & other miscellaneous time. Therefore the cycle time required for one component inspection with loading & unloading is 5 seconds to achieve the shift production rate. With the automation the cycle time achieved is less than 3.5 seconds per component. The various trials are taken to achieve the cycle time considering the electronic items & their response time.

7. Conclusion

The designed and developed system of auto gauging and sorting is acceptable for measuring specified characteristics of outer ring of needle bearing with desired cycle time.

The system gives acceptable repeatability which requires less than 1.5 µm. The repeatability is 0.9 µm which is less than 1.5µm. While for height repeatability required is 1.5 µm or 10% of total tolerance whichever is higher. The repeatability is 3.6 µm which is less than 5 µm of that is 10% of total tolerance. The machine satisfies the gauging requirement.

Also the machine takes 3.5 seconds to complete the gauging which is less than 5 seconds. So on cycle time also machine satisfies the requirements.

Considering all above points the system performs well and is acceptable for its desired task.

With electronic probe & automation the repeatability of gauging system improves. It gives direct value for component with comparative type gauging. Also it reduced the cycle time for inspection.

8. References

[1] Shreyas A. Dhole, P. H. Kulkarni “ Advanced Automated Electronic Gauging System” International Journal of Science and Research (IJSR), Volume 4 Issue 4, April 2015.
[2] Mr. Rathel R. (Dick) Smith, Dr. Steven W. McCrary & Dr. R. Neal Callahan,“Gauge Repeatability and Reproducibility Studies and Measurement System Analysis: A Multimethod Exploration of the State of Practice” Journal of Industrial Technology, Volume 23, Number 1 - January 2007 through March 2007, pg. - 1-12.
[3] P. H. Osanna, N. M. Durakbasa“Trends in Metrology”Problems Of Engineering Cybernetics And Robotics, Volume 53-2002, pg. – 15-24.
[4] Jeh-Nan Pan “Determination of the optimal allocation of parameters for gauge repeatability and reproducibility study” International Journal of Quality &Reliability Management, Vol. 21 No. 6, 2004, pg.- 672-682.
[5] Tushar Jain and Meenu “Automation and Integration of Industries through Computer Vision Systems” International Journal of Information and Computation Technology, ISSN 0974-2239 Volume 3, Number 9 (2013), pp. 963-970.
[6] Z. M. Biy and W. J. Zhangy“Flexible fixture design and automation: Review, issues and future directions”International Journal Production Research, 2001, Vol. 39, No. 13, 2867± 2894.
[7] Festo Rod less Cylinder (Linear Drive) catalogue.
[8] THK Caged Ball LM Guide
[9] Festo Pneumatic Cylinder (Compact Cylinder) catalogue.
[10] Dr. Henrik S. Nielsen “Taking Dimensional Metrology to the Next Level”HN Metrology Consulting, Inc., Dec. 2010, pg. – 1-6.
[11] P. H. Osanna, N. M. Durakbasa“Trends in Metrology”Problems Of Engineering Cybernetics And Robotics, Volume 53-2002, pg. – 15-24
[12] Michael Yu Wang “Tolerance analysis for fixture layout design” Assembly Automation Volume 22, Number 2 – 2002, pg. 153–162.