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Condition Monitoring of CNC Machine Tool Accuracy with Renishaw Equipment

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Abstract:Present work deals with the accuracy of manufacturing machines and the possibility of regular diagnostic of machining centers in order to improve the quality and productivity of machining process of a CNC MCV-400 machine usingLaser calibration and Ballbar tests with the help of Renishaw equipment.The accuracy of machine tools is a critical factor that affects the quality of manufactured products which is one of the most important considerations for any manufacturer. The consistent performance of the machine tool is constrained by the errors built in the machine or occurring on a periodic basis on the account of change in temperature and cutting forces. Condition monitoring techniques have been utilized to identify, predict and compensate these errors and to improve machine tool accuracy.

Keywords:Accuracy, Ballbar test, Condition monitoring, Laser calibration, machine tool.

I. Introduction

Computer numerically controlled (CNC) machine tools have played an important role in accuracy machining. In recent years, machine tool builders have been under increasing pressure from the manufacturing industry to provide a higher contouring accuracy for a multi axis CNC machine tool.Calibration is a set of operations which establish, under specified conditions, the relationship between values of quantities indicated by a measuring instrument or measuring system, or values represented by a material measure or a reference material, and the corresponding values realized by standards [1]. It determines the relation between the output of the machine tool, instrument or test device and the value of the input quantity, attribute or measurement standard. Calibration is the only comprehensive indicator which depicts a detailed picture regarding accuracy of machine tools which is one of the most important indices to assess the quality and capability of machine tools. Accuracy parameter significantly affects all criterion of machine performance including quick acting, energy efficiency, metal consumption, reliability and durability. On basis of calibration results a qualification or capabilities are ascertained to permit the machine tool, for further processing of compatible accuracy requirement. The results of calibration make possible either the assignment of values of measure and to the indications or the determination of corrections with respect to indications [2]. Calibration of machine tools is important for both acceptance testing and error characterization and for compensation etc. [3-7].

Basically there are only three common methods reported which are well known and in practice for calibration of machine tools. The first method is direct or parametric method and quite popular for quantifying various error terms independently. Second method is known as volumetric calibration method and able to quantify the error between actual and commanded motion at specific desired point in workspace of a machine tool. It uses some sort of kinematic reference standards such as double ball bar, disk etc. and mostly used for acceptance testing and for the periodic checks. Third method is based on measuring an artifact or standard part, such as ball plate, cubic box, tetrahedron etc. and known as artifact calibration method or hybrid calibration method [8]. This method is also applicable for acceptance testing and periodic checks. The parametric method is the only well-known method which is reliable and provide realistic information about elemental accuracy of machine tools and most popular and appreciated by the machine tool builders and the users for error characterization and error compensation.

II. Experimental results

A. Laser Calibration

Renishaw Laser interferometer systems are used for comprehensive accuracy assessment of machine tools, co-ordinate measuring machines and other position-critical motion systems. They offer the ultimate in high accuracy, repeatable

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and traceable measurement, using externally mounted beam splitters Laser system measures accuracy of straightness of machine movement by measuring deviation of target points from reference axis. Using Renishaw laser system, the straightness of main tool movement of CNC machine in direction of X, Y and Z axis is performed. Measurement is performed on a length of 400 mm from outmost position towards machine bed. According to machine producers specification this deviation should be less than 0.02 mm on 300 mm length as shown in figure 1. Experiment was carried out under controlled environmental conditions to minimize the effects of random errors and to get the reliable results since the measurement is sensitive by operating temperature and its gradient.

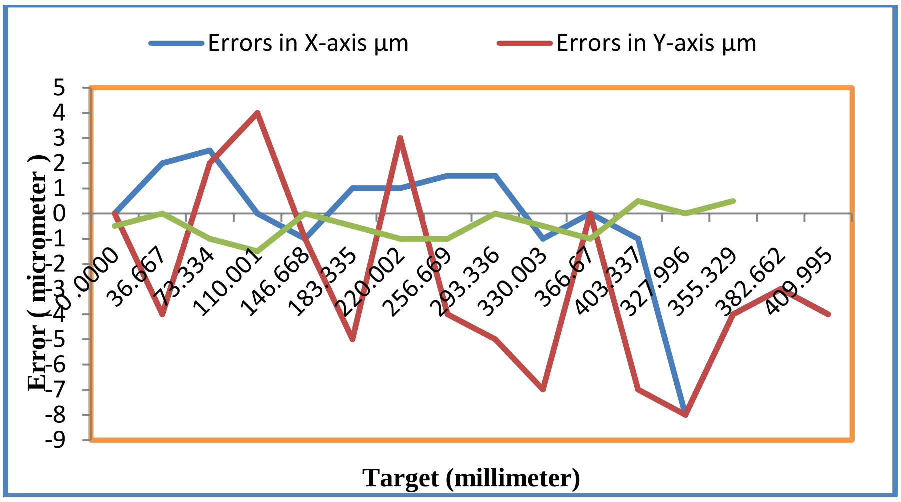

Figure 1: Linear Displacement Graph for X, Y & Z-axis

B. Ballbar Test

Quick Check10 Ballbar is a linear displacement sensor based tool that provides a simple, rapid check of a CNC machine tool's positioning performance to recognized internationals standards. QC10 Ballbar system is a CNC machine tool diagnostic system. The QC10 Ballbar and its software are used to measure geometric errors present in a CNC machine tool and detect inaccuracies induced by its controller and servo drive systems. Errors are measured by instructing the machine tool to 'Perform a Test' which will instruct it to scribe a circular arc or circle. Small deviations in the radius of this movement are measured by a transducer and captured by the software. The resultant data is then plotted on the screen, to reveal how well the machine performed the test.

Parameters	Particulates
Radius	150.0000mm
Sample rate	19.23Hz
Feedrate	1000 mm/min
Run direction	**CCW/ CW**
Plane under test	**XY**
Start angle	0°
End angle	360°
Overshoot angle	180°

Table 1: Test parameters of Ballbar test

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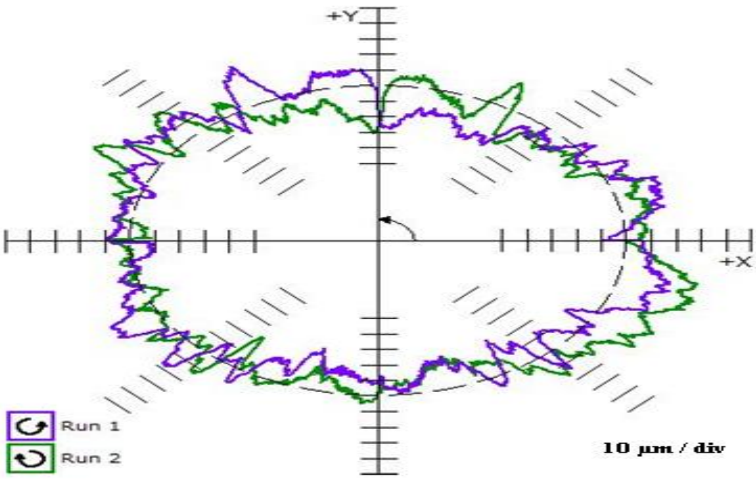

Figure 2: Percentage & Diagnostics Output

BALLBAR DIAGNOSTICS TABLE		Machine: Quick check			
Date: 2013 Apr-27 14:04:18		Instrument: Renishaw Ballbar QC10			
Error	**Magnitude**		**Independent Circularity**		**Ranking**
Backlash X	► 0.5	◄-0.7 µm	0.7 µm	2%	10
Backlash Y	▲6.2	▼2.9 µm	6.2 µm	16%	1
Reversal spikes X	► -3.1	◄ -2.6 µm	3.1 µm	8%	4
Reversal spikes Y	▲-1.2	▼- 1.8 µm	3.0 µm	8%	5
Lateral play X	► -0.3	◄ 0.7 µm	0.4 µm	1%	12
Lateral play Y	▲-0.6	▼0.1 µm	0.4 µm	1%	13
Cyclic error X	↑2.9	**1.7** µm	2.9 µm	8%	6
Cyclic error Y	↑2.9	2.6 µm	2.9 µm	7%	7
Servo mismatch	0.50 ms		4.2 µm	11%	2
Squareness	15.7 µm /m		1.6 µm	4%	9
Straightness X	-1.0 µm		0.5 µm	1%	11
Straightness Y	-3.6µm		1.8 µm	5%	8
Scaling mismatch	7.5µm		3.7 µm	10%	3
Cyclic pitch X	16.0000 mm				
Cyclic pitch Y	16.0000 mm				
Calculated feedrate	498.3 mm/min				
Center offset X	28.3 µm				
Center offset Y	-12.7 µm				
Circularity	12.7 µm				

Table 2:Ballbar diagnostics table

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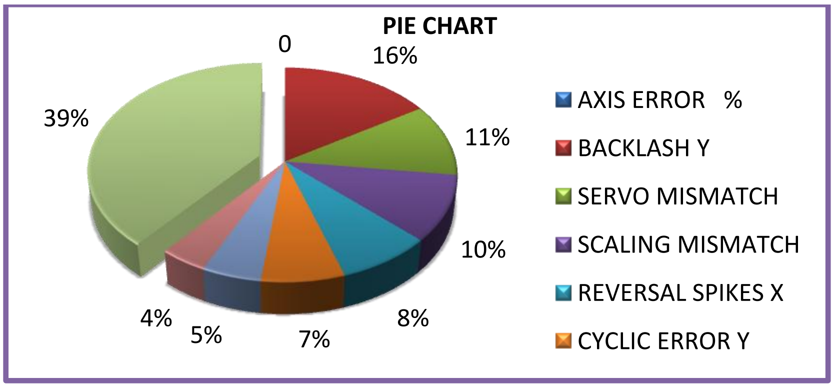

Figure 3: Pie Chart for Geometric errors

The backlash error of Y axis is approximately 6.2 µm which suggests a play in the drive system, the cause of the play may be a play in the radial bearings, the ball nut or the ball screw. Table 2 shows the largest contributor to the circularity error is the scaling mismatch, which represents the over travel of the one axis over the other and since the value of the scaling mismatch error is positive, then it can be concluded that the X axis is traveling more than Y axis by approximately 3.7µm. The value is positive which means that the X axis is traveling more than the Y axis. The other problem is the cyclic error. The most obvious reason for the cyclic error is that the ball nut, radial bearings, and the follower pulley are not in line. So, when looking at the ball nut from the direction of movement of the axis, the ball nut will be moving in circles instead of being steady. This will be interpreted as sinusoidal error in the plot with approximately constant wavelength. These are the largest errors that were identified by the test; other machine errors have a relatively small contribution that makes them not of a great importance at this stage.

C. Reconditioning of machine axes column assembly

After calibration reconditioning of CNC machine involves mainly repairing or replacement of following defective parts and makes the machine to run properly with proper alignment.

- Dismantling of all axes column assembly, electrical cabinet and guarding
- Radial bearings, the ball nut or the ball screw are replaced
- Replacing ball screw arrangement and guide ways
- Z-axis guide ways parallel grinding, after grinding hardness
- Z-axis ball screw servicing, end support bearing replacement
- Y-axis slide turcite replacement, wiper lip replacement in all three axis
- Lubrication cartridges, hose pipe replacement
- X-axis cable carrier replacement
- Spindle surround coolant nozzles and hoses replacement
- Spindle draw bar servicing work, disc springs and collets replacement
- New Z-axis pneumatic accumulator fitted
- All pneumatic hoses replacement work
- Table clamp/de-clamp seals replacement work
- Cylinder arm self-aligned bearings replacement, bush re-worked and fitted
- All geometrical readings noted down

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III.RESULTS AND DISCUSSIONS

Followinf bargraph shows the quality improvement and produtivity improvement after conducting tests during the months of February, March,April and May.

A.Quality improvement

The graph clearly shows the comparison of qaulity of the products during the months of February, March,April & May. From the above data it is clear that the number of rejection parts has been decreased after condition monitoring and helps in better accuracy and performance of the machining process.

- ❖ The values are taken from company record

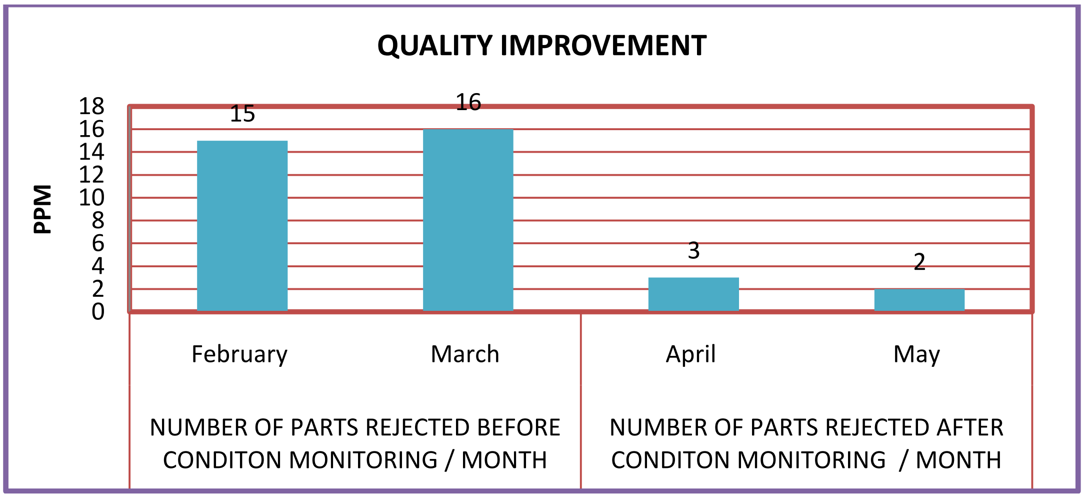

Figure 4: Quality Improvement of MCV-400 Machine Before and After Condition Monitoring

B .Productivity improvement

- ❖ The values are taken from company record

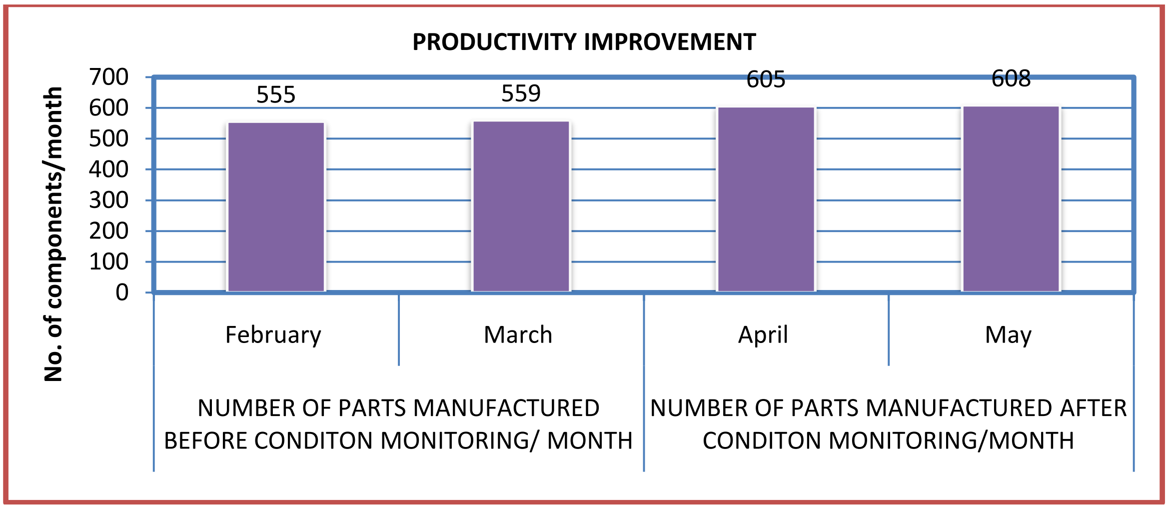

Figure 5: Productivity Improvement of MCV-400 machine before and after Condition Monitoring

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The graph clearly shows the comparison of productivity of the products during the month of February, March,April & May. From the above data it is clear that the machining process achieve quality of the product which helps in increase in production by reducing breakdown of the machine process.

IV. CONCLUSION

Condition Monitoring helps in calibrating the CNC machine by implementing the direct method for error quantifications. This method was quite reliable, authentic and simple for measuring the geometric errors. Determining a machine tool's capabilities before machining and subsequent post-process part inspection, can greatly reduce the potential for scrap, machine downtime and as a result, lower manufacturing costs. Process control and improvement is the key to raising quality and productivity. The results obtained in this work showed that the geometric test with geometric defects can be a low cost, easy to use and reliable method to verify the performance of machine accuracy. Improve performance through targeting maintenance and correct linear positioning errors using error compensation. The quality and productivity of the process has increased after condition monitoring.

V. ACKNOWLEDGEMENT

This project work is intended to develop the Condition Monitoring methodslike Laser Calibration and Ballbar Test for MCV-400 CNC Machines in Automotive Axles Limited, Mysore with the main objective to improve the quality and productivity of machining process.

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