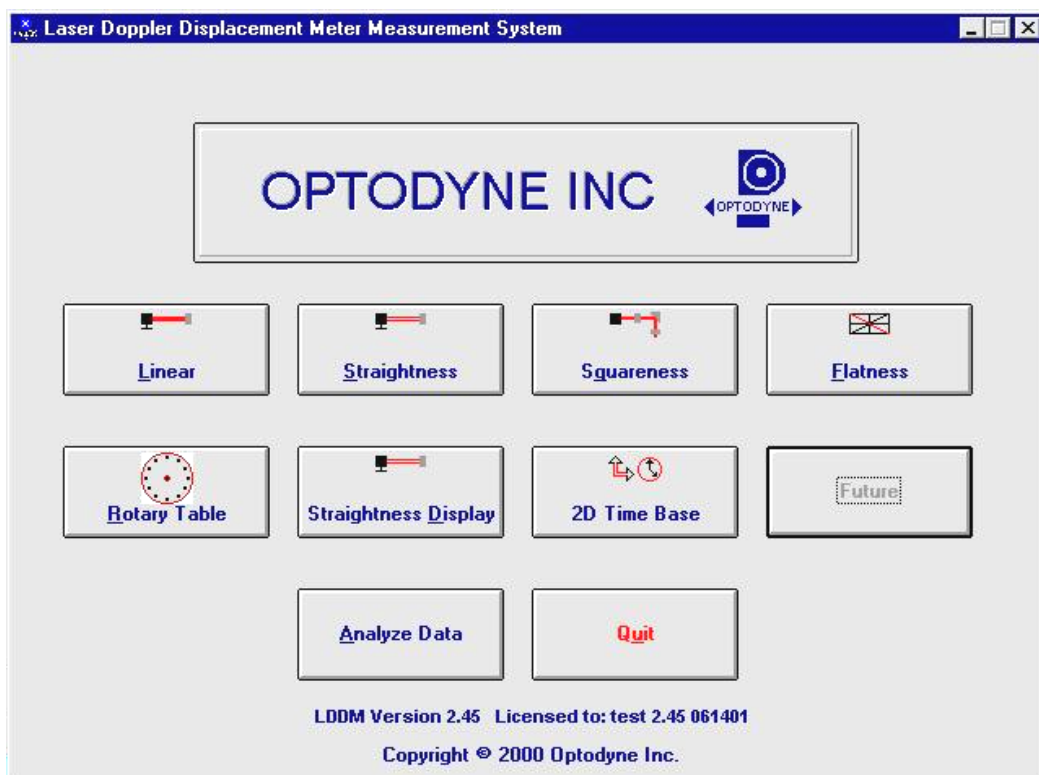


# LASER DOPPLER DISPLACEMENT METER

## LDDM FOR WINDOWS Version 3.0 SOFTWARE MANUAL



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## 1.0 Welcome

Thank you for purchasing the LDDM for Windows software package for your Laser Doppler Displacement Meter. We hope that you find this software package extremely helpful in your usage of the Machine Calibration package that you have purchased.

Easy to install and operate, LDDM for Windows allows for the usage of the LDDM to this fullest ability to reduce your downtime and ultimately save you money. Along with the user-friendly graphical interfaces, and the software's fully automatic data collection ability, we believe that you will find that the LDDM is the easiest to use laser calibration system on the market, without sacrificing laser accuracy.

### 1.1 This Manual and LDDM for Windows

In this manual, you will find descriptions about each choice and action on every screen in the software. You will also find instructions on how to take a measurement run for each type of measurement.

### 1.2 Bolded characters

In this manual, you will find **bolded** characters. When prompted, these bolded characters should be typed where specified.

### 1.3 Using the Mouse

In the **LDDM for Windows** package, only the left mouse button is used. In the program, a single click on the left button is usually sufficient to carry out an action, with a few exceptions. When prompted to click on a button, please move the mouse marker to that particular button, and simply click the left mouse button on it.

### 1.4 Text Boxes:

Instead of clicking on buttons, there are some boxes in the software where you must type in text. Move the mouse to the open box and look for the mouse marker symbol to change into a vertical line which looks similar to an I. There are then two ways to enter text. You may click the left mouse button at the beginning or end of the text, use the **Backspace** key to delete the previous text, and then enter your new text. You may also "Block" the text to be deleted by first moving the I (mouse text marker) to the beginning of the text, holding down the left mouse button, and then moving the mouse to the end of the text. You may then replace the whole text you have "blocked" by typing in your new text.

## **2.0 Installation**

### **2.1 Set up LDDM Program**

To setup LDDM program from Windows 95/98 and Windows Millennium

1. For optimum performance exit all other applications before setting up LDDM program.
2. Insert LDDM CD into CD-Rom driver and wait for the folder to appear from My computer Icon. Double click on setup.exe to install the software.
3. Follow the instructions on your screen to continue through the setup progress.
4. After the setup is installed successfully, an LDDM icon will show in the screen. The LDDM program is ready to run.

### **2.2 Starting LDDM Program**

To start LDDM from windows, run Windows and double clicking on the LDDM icon. The main menu of LDDM program will appear on your screen (see Fig. 3-1). Click on Linear for linear measurement. The measurement program will appear on your screen (see Fig. 4-1).

### **2.3 LDDM software instruction**

There are 2 types interface between the Notebook PC and the LDDM processor module, one is serial interface through the com port and the other is USB human interface. All the software is stored in a CD-ROM. Click on "Setup" to install the software to your Notebook PC.

#### **Serial interface through Com Port**

- 1, Using RS-232 port on your Notebook PC

Boot the Notebook PC first with the RS-232 cable disconnected. Turn on the LDDM processor, connect the RS-232 cable, and start the LDDM program. If the LDDM program couldn't find the interface, check the "device manager", and "Com Port" to make sure the Com Port is available. Also, make sure all the cables are connected properly and reset the Processor by turn-off the power and turn-on again. Many times, the problem is caused by a bad (poor contact) RS-232 cable or poor connection.

- 2, Using USB port with RS-232/USB converter

Make sure the driver for the RS-232/USB converter is installed. Connect the RS-232/USB converter to the Notebook PC, turn-on the LDDM processor, connect the RS-232/USB converter to the RS-232 port and start the LDDM program. If the LDDM program couldn't find the interface, check the "device manager", and "Com Port" to make sure other device, such as external mouse, is not using the same com



port. Sometimes, the external mouse has to be disabled. Also, make sure all the cables are connected properly and reset the Processor by turn-off the power and turn-on again. Many times, the problem is caused by a bad (poor contact) RS-232 or USB cable or poor connection.

### **Direct USB human interface**

Make sure the laser head and ATC sensors are connected to the processor. Connect the USB cable between the Notebook PC and the LDDM processor. Start the LDDM program. For Windows Vista, use “Run as administrator”. If the LDDM hardware is not connected and you want to do analysis, there is a popup screen stating: “Report missing USB device, Yes or No”. Click on No, the main menu will be displayed and click “analysis” to perform data analysis. If all the LDDM hardware is connected, the main menu will be displayed, otherwise a popup screen stating: “Linear USB data device not connected. Continue? Yes/No”. Click Yes to continue and No to exit.

For some Notebook PC with too many USB ports, the voltage becomes marginal or too low, an external USB hub with power should be used. Go to “device manager” and click on “Human Interface Devices”. There should be 6 lines of HID-compliant device and 6 lines of USB Human Interface Device. If any of these are missing or with a yellow exclamation mark on the corner, external USB hub with power should be used.

### 3.0 Main Menu

There are six working choices to be made on the Main Menu (Fig.3-1). They are to choose which kind of measurement you would like to take. Linear measurement can be done with any LDDM system. Straightness can only be used with a dual beam laser head. Squareness can only be used with a quad detector. The angular and flatness sections can only be used with a dual beam laser head. Choose analyze data to look at previously created data files. All types may be viewed with this choice.



Fig. 3-1 Main Menu

Click on **Linear** if you would like to take a linear measurement.

Click on **Straightness** if you would like to take linear and straightness/angular measurements.

Click on **Squareness** if you would like to take a squareness measurement.

Click on **Flatness** if you would like to take a flatness measurement.

Click on **Rotary Table** if you would like to take a rotary measurement.

Click on **Straightness Display** if you would like to display straightness.

Click on **2D Time Base** if you would like to take circular contour measurement.

Click on **Analyze Data** if you would like to view/analyze a previous data measurement.

Click on **Quit** if you would like to exit the program.

## 4.0 Linear Measurements

After clicking the **Linear Measurement Box** on the Main Menu, you will be greeted by the Linear Measurement Data Screen (Fig. 4-1). If the LDDM is not connected to communication port, a message box will appear telling you that the LDDM interface not found. Please check your connections and the LDDM reading on the display should appear.

### 4.1 Linear Measurement Main Display

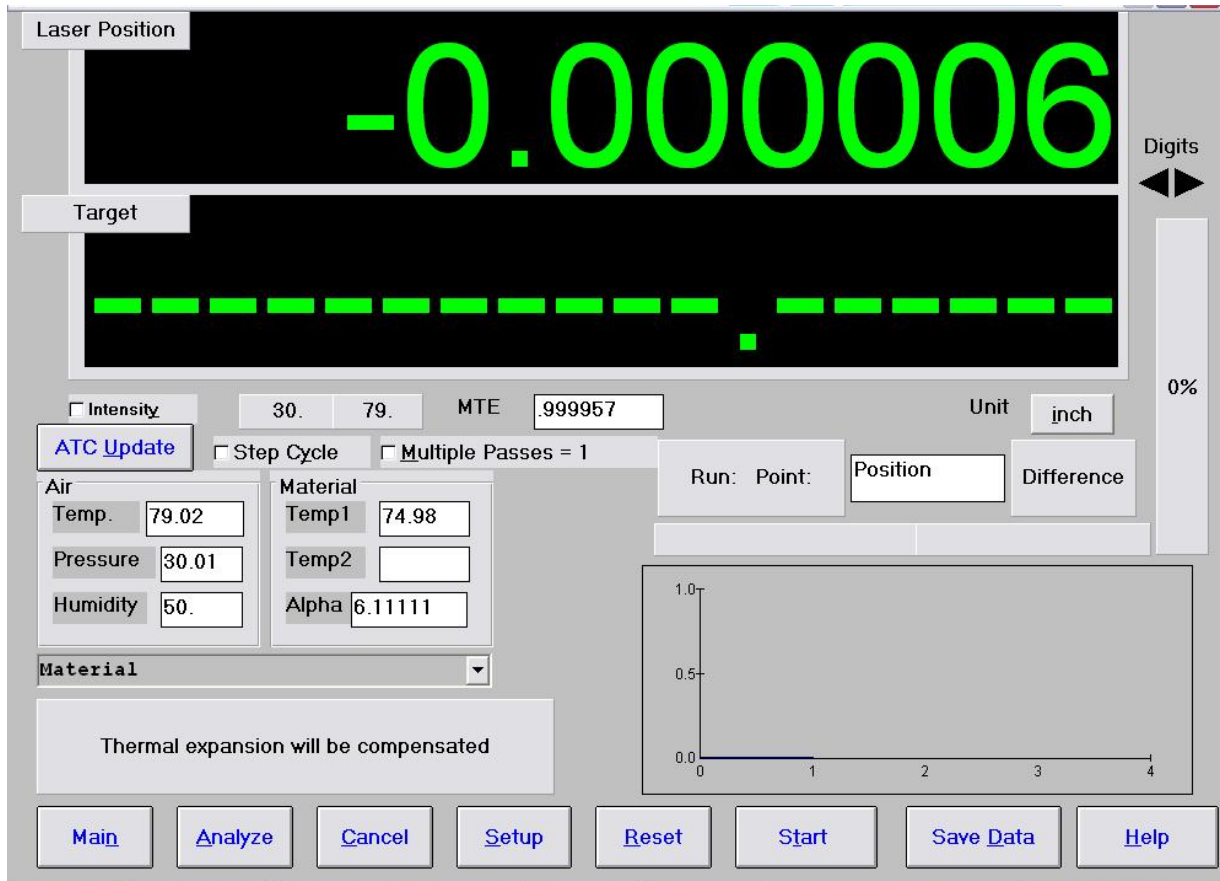


Fig. 4-1 Linear Measurement Main display

Choices on the Main Display are as follows:

**Intensity:** Align your system visually, then check your alignment by clicking on this box. A blue bar will appear in-between the Laser Position window and the Target window. This blue bar will range from between 0 and 100%. Please make sure that the intensity is at least 40% over your whole run. Press the intensity box again to return the system to its original state.

The two boxes next to the Intensity box show the Pressure and Temperature that the Processor Box is reading. If you have an ATC probe, these numbers will be continually changing. If you do not have an ATC probe, the values will be 68 degrees and 29.9 inHg. When the Intensity Box is clicked on, these values will disappear.

**ATC Update:** The ATC update updates the air pressure, air temperature and material temperature readings from the processor box. The MTE value will be calculated from these updated values and Alpha material coefficient. A X mark will appear when the ATC value has been updated correctly for the next measurement.

**Step Cycle Measurement Style:** Normal data collectings are linear cycle. However, for long machine or other situation, it is desirable to collect data by quasi-pilgrim step cycle. Click this box, the data collection will be changed to quasi-pilgrim step cycle (see ISO 230-2).

**MTE:** The MTE value can be manually changed in this box.

**Unit:** This box, when clicked on, will allow the user to change between the inch and metric systems.

**Digits:** Clicking the left arrow will decrease the amount of digits shown (data will still be taken to 6 digits). Clicking the right arrow will increase the amount of digits shown (max 6). To decrease the amount of digits shown, click the right arrow once, and then the left arrow.

**Air/Material Environmental, Alpha Boxes:** Values may be entered in the Air Temperature and Pressure boxes for those people who do not have an ATC probe. Humidity should be entered for all users of the LDDM system. The Material Temperatures are averaged together to get the MTE coefficient value. The material alpha can also be manually changed if the material list does not include the material of the machine being calibrated.

**Run: Point, Position, Difference:** The values in these boxes are during a measurement. They show the Run number that you are taking (up to 7), the point number, the target position, and the difference between the LDDM reading and the target position.

The percentage bar shows how much of the current measurement is done.

For automatic measurements, a stoplight will appear. The green light indicates that the program is ready for the system to go to the next data point. The yellow light indicates that the retroreflector has dropped below the velocity threshold and is waiting for the set delay to complete. The red light indicates that the system is taking the data point.

**Material Box:** The material list and their corresponding alpha values are listed here. Click the mouse on the down arrow and a list of materials are shown. Please choose from the material list or enter your own value to the alpha box above.

The dialog box is just underneath the material box. This box tells you messages and describes the actions you are taking.

Buttons at the bottom of the screen:

**Main:** exits the linear measurement package and loads the main menu.

**Analyze:** exits the linear measurement package and enters the analyze data package. A box will appear asking if the current module should be unloaded. Please type **Yes** unless you are taking a flatness measurement.

**Cancel:** By pressing this button, you can cancel the last data point taken during a run, or you can cancel the whole measurement.

**Setup:** Opens the setup window, where measurement specifications may be edited or viewed.

**Reset:** Using this key allows for the reset of the LDDM. This key will also change the mode of the processor box to the current measurement type, i.e. if the processor is manually switched to a dual-beam mode while the program is in the linear measurement mode, the reset will return the processor to the linear measurement mode.

**Start Measurement:** This button starts the measurement defined in the setup window.

**Save Data:** This button will allow for the data storage of the last measurement taken.

The Laser Position window shows the current position of the retroreflector. This value always shows a value compensated for air temperature, pressure and relative humidity, but may or may not be compensated for MTE (if MTE compensated box is clicked on or off).

The Target window will show a value during a measurement. This value is the next point where data collection will take place.

## 4.2 Linear Measurement Setup Screen (Fig. 4-2)

To input information: Please move the mouse pointer over the box on which you wish to change the information. The mouse pointer will turn in to a vertical bar. Two things may be done:

- 1) Block the text. Hold the mouse button down and move over the text completely. The text being blocked will become inverted in color (white on black). Type in the information to be entered. The original text will be replaced by the new information.
- 2) Click the mouse button while the vertical bar is over the box. Use the arrow keys and the delete key to erase the previous information. Then input the new information.

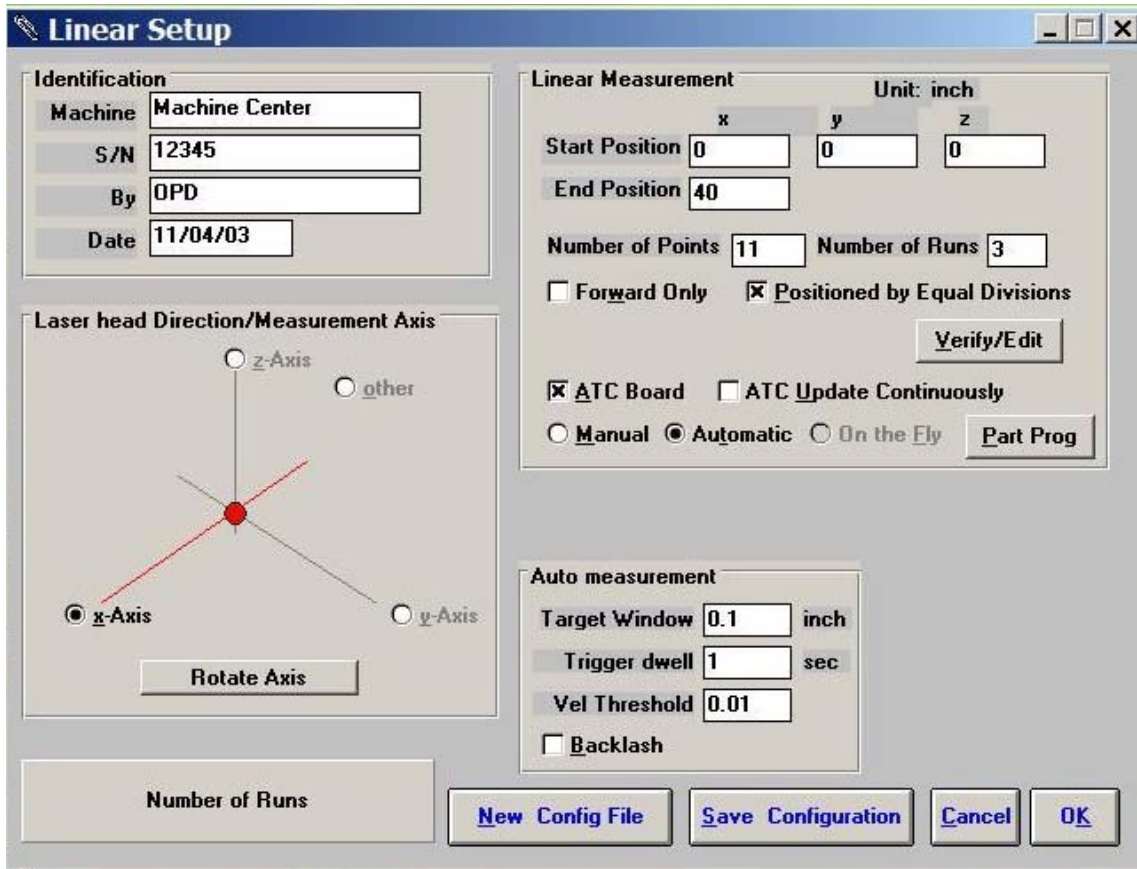


Fig. 4-2 Linear Measurement Setup Screen

#### Identification Box:

The identification of the machine, i.e. the machine type, serial number, the person doing the calibration, and the date, is entered here and is saved in the data file. The date is automatically entered using the computer system date.

#### Laser head direction/Measurement Axis Box:

You may choose either the x-axis, y-axis, or z-axis for on-axis measurements, or if you have the diagonal measurement kit, you may choose other for a volumetric measurement. Click on the circle closest to the type of measurement you would like to take. Click on Rotate Axis to rotate the axes orientation to match with the machine coordinate.

Linear Measurement:

**Start Position:** Enter the coordinate of the machine position that you are going to be starting at (for that given axis). Also enter the Start Position of the laser beam location. These information are used for pitch and yaw angular error calculation.

**End Position:** Enter the final coordinate of the machine position that you will be ending at (for that given axis).

**Number of Points:** Counting the zero point as the first point, please enter the number of points for the run up to 9999 points.

**Number of Runs:** Choose the number of runs for this measurement, 1 through 7.

**Verify/Edit:** Click on this button to see the data acquisition setup. Make sure that your increments are correct. If there are increments to be changed to an irregular interval, you may edit the box.

**Forward Only:** Click the box to an X mark if the measurement is to be forward only. Leave the box blank if it is to be a bi-directional measurement.

**ATC Board:** If you have an ATC board, please click the mouse here and make an X mark. If you do not have an ATC board, please make sure that there is no X mark there. To manually set the speed of light correction, click the ATC board on and off, then enter the barometric pressure in mmHg and the air temperature in °C. The barometric pressure and air temperature values will be reset to 760 and 20 automatically once leave the program to avoid possible double correction.

**ATC update continuously:** If you have the ATC board option marked with an X, you can choose ATC Continuous Update to monitor your material temperature for changes during the measurement. This is only necessary for larger machines, or measurements that take many hours to complete (otherwise the material temperature change should be negligible for most machines). This option will cause the MTE value in the Analysis program to be 1.000000.

Please choose the type of measurement you wish to take:

**Manual:** The Start Measurement button will turn into a "TAKE" button after the measurement begins. At every collection point, this button will have to be pushed.

**Automatic:** The software will collect data every time the retroreflector comes within a "Target Window", drops under a certain velocity and sits still for a designated dwell time.

**Parts Program:** A G-code parts program will be generated to move the machine for the measurement.

**On-the-Fly:** The software will automatically take data as soon as it is sensed that the retroreflector is within the "Target Window" of the target position. There is no On-The-Fly capability for Linear Measurement.

Auto Measurement Box:

**Target Window (automatic and on-the-fly):** For automatic and on-the-fly measurements, being within this value of the target position allows the software to take data. For on-the-fly measurements, the maximum speed is 10 times the target window.

**Trigger dwell (automatic only):** For automatic measurements, the settling time of the machine (typically 3-5 seconds) is entered here. Choose a value of at least 2 seconds less than the programmed machine dwell time.

**Vel Threshold (automatic only):** This is the threshold that the retroreflector must drop underneath so that a data point can be taken.

**Backlash (automatic only):** If the box has an X, backlash at the end and beginning of each run (other than the first point) will be taken. The distance necessary to remove the backlash and allow the software to re-trigger is twice the target window.

**New Config File:** You may load a previous configuration file if you have one for this particular machine.

**Save Configuration:** This updates the LDDM.CFG file so that the data seen on the screen will appear each time LDDM for Windows is run.

**Cancel:** Cancel the above changes and revert to the previous values.

**Ok:** Settings are ok for this measurement. If you saved this setup as the default, it will come up first every time, otherwise the previous setup will re-appear next time the program is run.

### 4.3 Example of a Linear Measurement

Linear Measurement Main Display (See Fig. 4-1):

- 1) Check your units in middle right hand side. If it is not the correct type, click on the **inch/mm** icon.
- 2) Align the laser head visually according to the user's guide. Click the **intensity** button on the middle left hand side and check to see if the laser is aligned over the whole travel. After alignment, click off the **intensity**.
- 3) Click once on the **setup** icon on the bottom row of Icons.



Linear Measurement Setup Screen (See Fig. 4-2):

- 4) Setup your system information on the upper right hand side of the machine. Input the **identification** of the machine you are calibrating. To type the text, please move the arrow of the mouse pointer until it turns into a text cursor (an up and down line). Or please hit the tab key until one of the text boxes is highlighted. Type your machine data in.
- 5) Enter the axis of measurement (or the diagonal) by clicking the appropriate box on the bottom left graph (**X, Y, Z** or **OTHER** for diagonal)
- 6) Enter the **machine coordinates** that you wish to calibrate in the upper right corner.
- 7) Enter the **number of points**, including zero, that you wish to calibrate. E.g. For a ten inch run, with 2 inch increments, enter 6.
- 8) Enter the **number of runs** (typically 7 for NMTBA, or 5 for VDI, ISO and B5)
- 9) Press the **Verify/Edit** button to see the increments. You may manually change these increments if you would like to.
- 10) If you are manually changing the values, make sure that the **Positions Equally Divided** box is clicked off to show: **Positions As Shown Below**.
- 11) Change the # of points as necessary to achieve the correct increment that you desire (Press **Verify/Edit** to check again).
- 12) Choose **Forward Only** or **Bi-Directional** runs.
- 13) Click on the **ATC board** if you have one.
- 14) Click on **ATC Continuous Update** if you are taking a long measurement.
- 15) Choose your type of measurement:

### **Manual**

- you may:
- 1) Hit the **enter key** at each point, or
  - 2) Click the **mouse** on Take at each point

### **Automatic**

To take data automatically, you will have to program the machine controller to do 2 or 3 things: to move in a certain increment with a delay time in-between movements (3-5 seconds recommended), and add a backlash movement that is greater than double the target window at each end (backlash is optional).

The following information will be necessary for Automatic measurements:

**Target Window:** This tells the computer a distance window around the target position where the computer is allowed to take data. This value is related to the backlash needed (see below). A typical value is .001 inch or .02 mm, depending how tight your machine is. The backlash movement of the machine must be at least double this value.

**Trigger Dwell:** Set this value for two seconds less than the machine delay time for each point.

**Velocity Threshold:** This value keeps the risk of false triggering down. A good value to use is 0.01 for inches, 0.1 for metric.

**Backlash:** Check here if you want to account for backlash. The backlash at the beginning and end of each forward/backward run has to be at least TWICE the target window value.

#### 16) Saving the Configuration File:

Save this configuration file by clicking the **Save Config File** Icon. Type the name of the file which you would like the setup saved to (usually the name of the machine). Press **Enter** or **OK** after typing it in.

The program will ask you if you would like to save the file, press **Yes**.

The program will then ask if you want to use this file as your default. If **Yes** is clicked, this setup will be loaded every time that the Linear Measurement Module is loaded. To load a configuration file next time, click on **New Config File**. You may either:

- 1) Click on the file name and press **OK**
- 2) Double click on the file name
- 3) Type the name of the file name, example: **LDDM.1CF** and hit enter.

#### 17) Press **OK** to get back to the main screen.

#### Taking Data Points for a Linear Measurement (Fig. 4-3)

18) Press **ATC update (X)** to update the values.

19) Input the **Humidity Value**.

20) Choose your material from the list given. Press the **Down arrow key** and you will get a list, press the **down arrow key** or **PgDn key** from there to scroll down.

21) Choose the number of digits on the upper right hand side of the screen you wish the screen to display. Click the **right arrow button** to increase the amount (up to six), or click the **left arrow button** to decrease the amount.

22) Move your retroreflector to the beginning of your run. Click on **Start**.

Manual: If you are manually operating the laser/machine, press the designated key to take data as shown (after you move the machine). Also, if you would like to change the target position, you may do so in the value box located in-between the run information.

Automatic: If you are running the automatic program, you will see a stoplight appear. The red means that the conditions for a measurement have been met (inside the target window, and the velocity is lower than the given one), yellow means that the delay is being counted and the green means that the data has been collected and the program is waiting for you to move to the next point (Fig. 4-3)

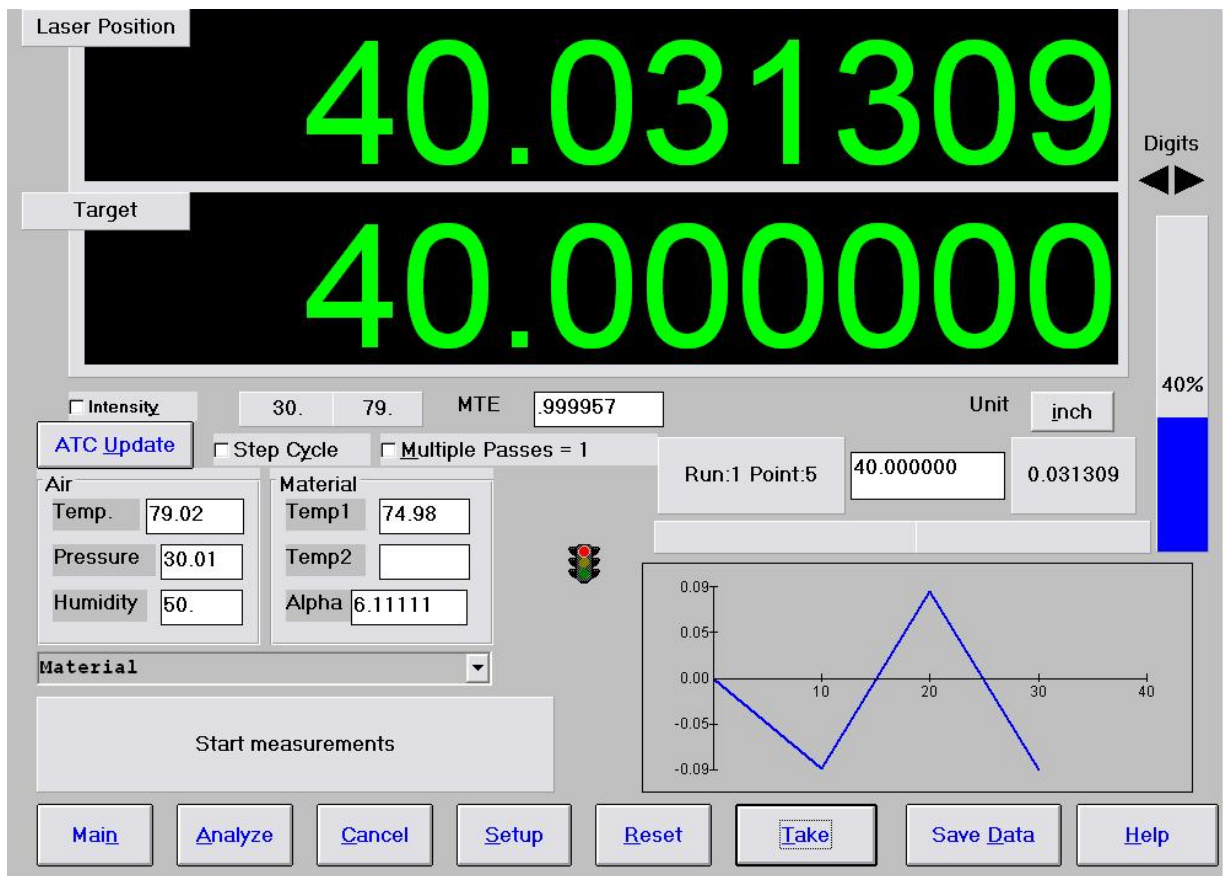


Fig. 4-3 Automatic Linear Data Collection

23) After all the data is taken, press **OK** to save the data, or **cancel** to not save the data.

24) To save data, type in the **filename** to save and hit <Enter> (the extension is automatically saved as .LIN). You may also save collected data by pressing the **save data button**, and follow the procedure above.

25) To analyze the data click on the **Analyze button**. When it prompts you, unload the module, unless you are taking a flatness measurement.

#### 4.4 Linear Data Analysis Menu (Fig. 4-4)

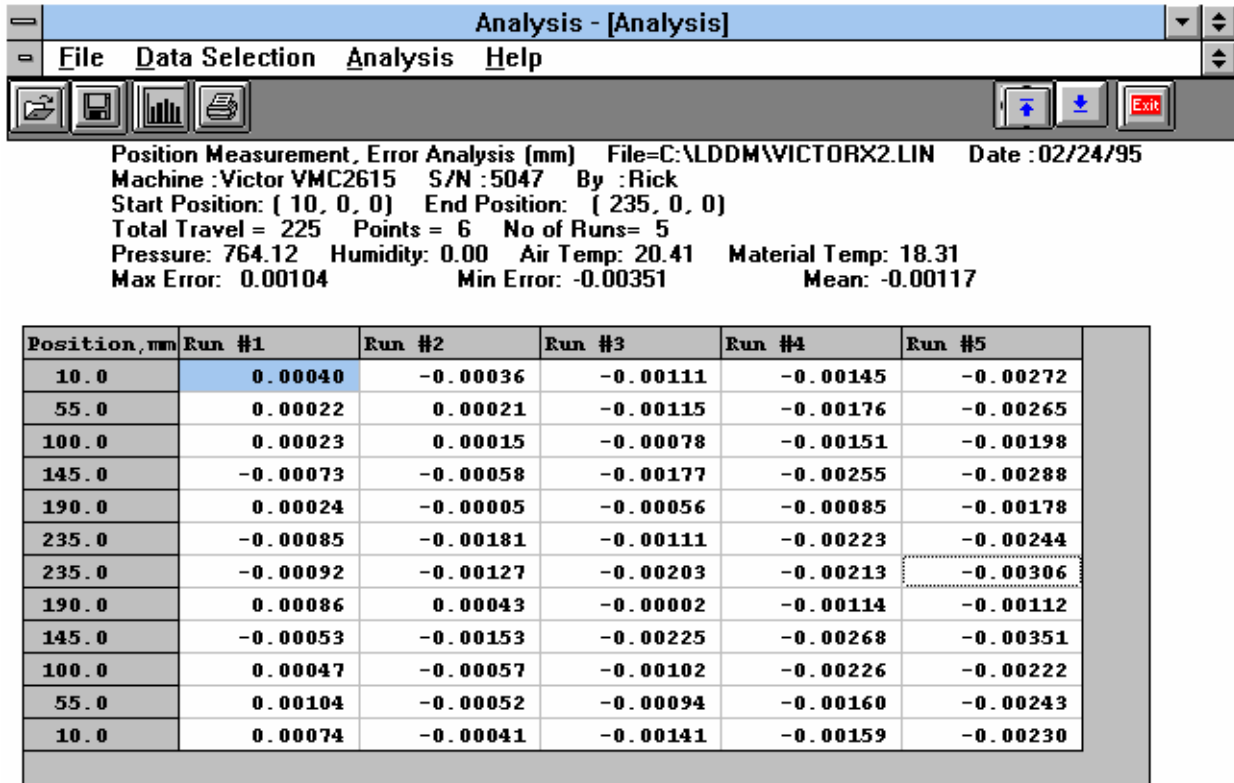


Fig. 4-4 Linear Measurement Data Analysis Table

Under the **File Menu**, you can open a **new** data file, **save** a data file, set your **printer type**, set your **printer style**, or return to the **main menu**. When loading a file, choose the files with the extension of .LIN for linear. You can only **print data** tables using the print function under this heading.

Under the **Data Selection** heading, you can only choose **Displacement** when looking at a linear (.LIN) file.

Under **Analysis**, you can choose **Error**, **NMTBA**, **NMTBA with Zero Shift**, **VDI 3441**, **ISO**, **ASME B5.54** or **ASME B5.57** for different types of data manipulation. After choosing **Error**, you will be given a choice on what you wish to see, **Runs #1-7**, and **forward** or **backward**. Click with the mouse button on which runs you wish to see.

The following icons have the following function in Analysis:



Open a new data file.



Save a data file.



Graph a data file (After graphing, you may also change the scaling of the graph by checking X on adjust grid).



Print a data graph (for printing data tables, use the Print option under the “File” heading)



Moves to the previous screen.



Moves to the next screen.



Exits the program.

## 4.5 Generating a Compensation File

Many machine tool controllers can provide compensations for repeatable position errors on each linear axis of motion. To generate a new compensation file, first set the compensation to zero and set the LDDM™ laser measurement system to measure the position error at an increment corresponding to the compensation file requirement. Second, use the metrology software to collect position error data and to generate a position error table. Third, key in the new compensation file based on the position error table. Finally, use the LDDM™ laser measurement system again to measure the position error with the new compensation file to make sure that the position errors have been compensated. Otherwise, the machine may have large non-repeatability.

For some standard machine tool controllers, software is available to convert the measured error table to a compensation file and load the compensation file through an RS-232 port to the controller.

### 4.5.1 Comp files for various controllers

A button is added in the analysis program for the generation of compensation files compatible to most of the controllers, such as Fanuc and Siemens. First, open the calibration file of the axis to be compensated by click on “analysis”, “open” and enter the file name. Click on “Data Selection”, “displacement” “analysis” and “error”, the

positioning errors will be displayed on the screen. Click on “Save”, a screen will pop up as shown below.

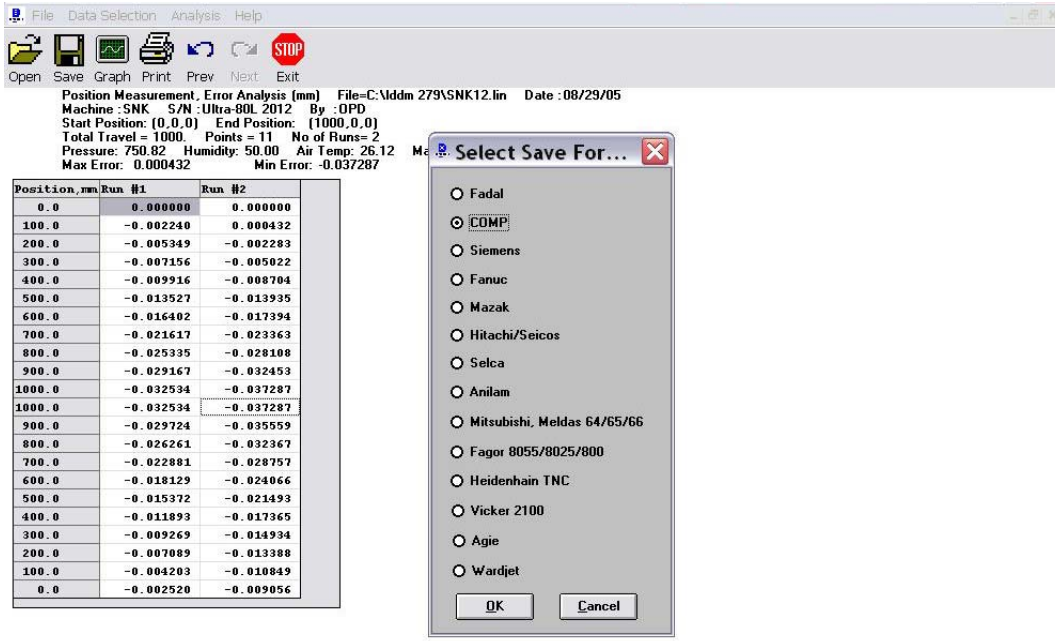


Fig. 4-5 Compensation File Selection Screen

Click on “Fadal”, “ok”, and enter a filename, a comp file with extension .svx, .svy or svz for fadal machines will be generated. Click on “comp” and “ok”, another screen will pop up as shown below.

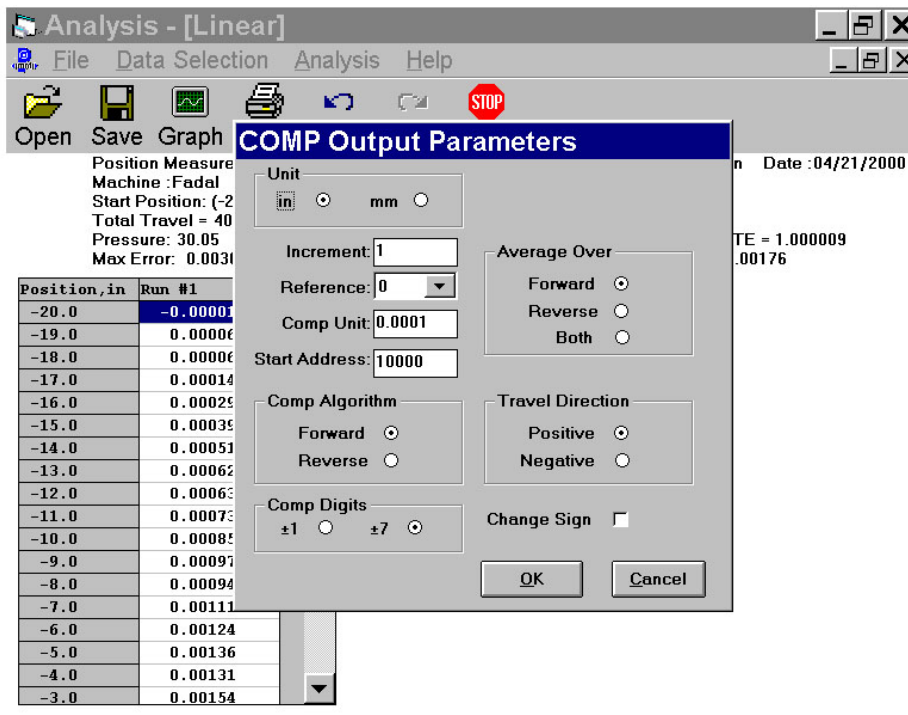


Fig. 4-6 Compensation Input Parameter Screen

Select in or mm unit for the comp file while the data file can be either in English or Metric unit. Select a increment for the comp file. The increment may or may not be the same as the data file. Select a reference point, compensation unit, start address, comp algorithm and travel direction based on the controller's requirement. For multiple-run data, select the average over forward, reverse or both. After all the parameters are selected, click "ok" and enter a filename, a comp file with extension .CPF will be generated. To view the compensation file, click on "file" and "Start Notepad", then enter the file name. A sample comp file is shown below.

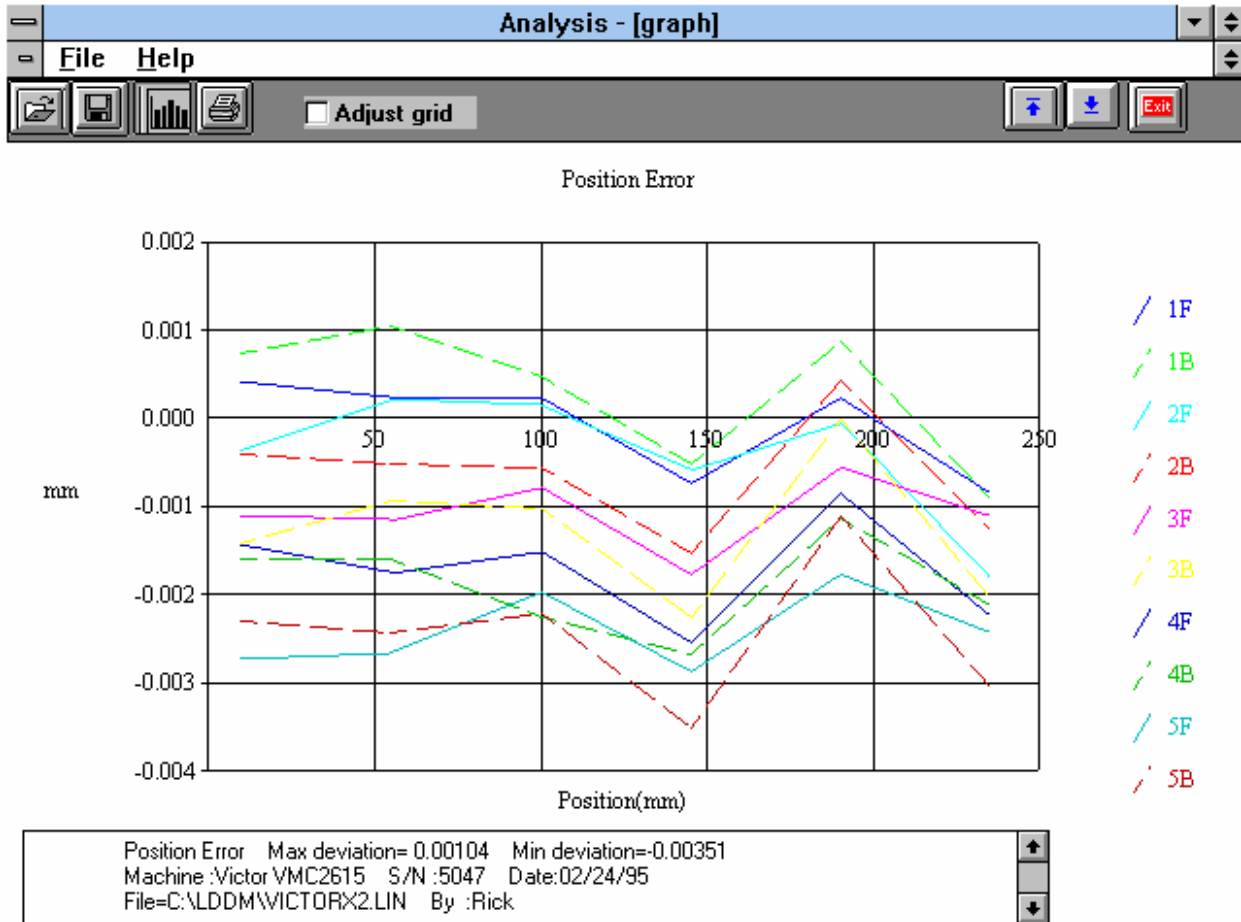


Fig. 4-7 Linear Measurement Data Plot (Individual Plots together)

## 5.0 Straightness/Angular Measurements

The Straightness/Angular Measurement setup is almost the same as the linear measurement, with the difference being the need to define the orientation of the laser head.

After clicking the **Straightness Measurement Box** on the Main Menu, you will be greeted by the Straightness Measurement Data Screen. If the LDDM is not connected to communication port, a message box will appear telling you that the LDDM interface not found. Please check your connections and the LDDM reading on the display should appear.

### 5.1 Straightness Measurement Main Display (Fig. 5-1)

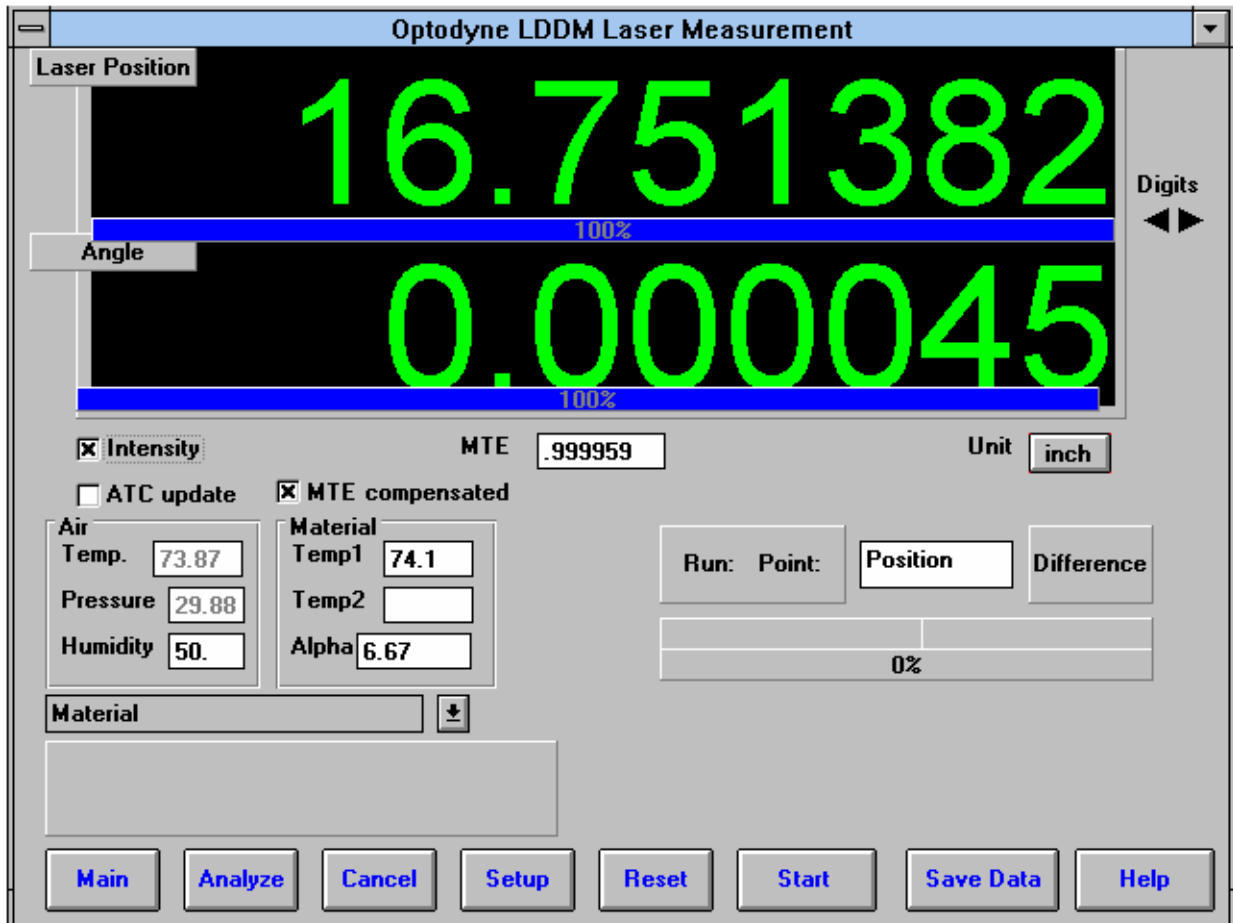


Fig. 5-1 Straightness Measurement Main Display

The display, in the straightness mode, shows the linear distance traveled on the top line, and the difference between LDDM #1 and LDDM #2 for the second line. If this second line value is divided by 1.1 (inches) or 27.94 (mm) then the value is in radians. When



you look at the outgoing laser beam aperture positions on the front of the laser head, LDDM #1 is the one closer to the center of the laser head, LDDM #1 is the one closer to the center of the laser head.

Choices on the Main Display are as follows:

**Intensity:** Align your system visually according to the User's Guide, then check your alignment by clicking on this box. A blue bar will appear the in-between the Laser Position window and the Target window. This blue bar will range from between 0 and 100%. Please make sure that the intensity is at least 40% over your whole run. Press the intensity box again to return the system to its original state.

The two boxes next to the Intensity box show the Pressure and Temperature that the Processor Box is reading. If you have an ATC probe, these numbers will be continually changing. If you do not have an ATC probe, the values will be 68 degrees and 29.9 inHg. When the Intensity Box is clicked on, these values will disappear.

**ATC update:** The ATC update updates the air pressure, air temperature and material temperature readings from the processor box. The MTE value will be calculated from these updated values and Alpha material coefficient. A X mark will appear when the ATC value has been updated correctly for the next measurement.

**MTE compensated:** To show compensation for Material Thermal Expansion, please click the box to show the X mark. If the X-mark does not appear on the screen, the displacement value will show only environmentally compensated values.

**MTE:** The MTE value can be manually changed in this box.

**Unit:** This box, when clicked on, will allow the user to change between the inch and metric systems.

**Digits:** Clicking the left arrow will decrease the amount of digits shown (data will still be taken to 6 digits). Clicking the right arrow will increase the amount of digits shown (max 6).

**Air/Material Environmental, Alpha Boxes:** Values may be entered in the Air Temperature and Pressure boxes for those people who do not have an ATC probe. Humidity should be entered for all users of the LDDM system. The Material Temperatures are averaged together to get the MTE coefficient value. The material alpha can also be manually changed if the material list does not include the material of the machine being calibrated.

**Run: Point:, Position, Difference:** The values in these boxes are during a measurement. They show the Run number that you are taking (up to 7), the point number, the target position, and the difference between the LDDM reading and the target position.

The percentage bar shows how much of the current measurement is done.

For automatic measurements, a stoplight will appear. The green light indicates that the program is ready for the system to go to the next data point. The yellow light indicates that the retroreflector has dropped below the velocity threshold and is waiting for the set delay to complete. The red light indicates that the system is taking the data point.

**Material Box:** The material list and their corresponding alpha values are listed here. Click the mouse on the down arrow and a list of materials are shown. Please choose from the material list or enter your own value to the alpha box above.

The dialog box is just underneath the material box. This box tells you messages and describes the actions you are taking.

Buttons at the bottom of the screen:

**Main:** exits the linear measurement package and loads the main menu.

**Analyze:** exits the linear measurement package and enters the analyze data package. A box will appear asking if the current module should be unloaded. Please type **Yes** unless you are taking a flatness measurement.

**Cancel:** Allows the cancellation of a measurement if it has gone out of alignment, or if something went wrong.

**Setup:** Opens the setup window, where measurement specifications may be edited or viewed.

**Reset:** Using this key allows for the reset of the LDDM. This key will also change the mode of the processor box to the current measurement type, i.e. if the processor is manually switched to a dual-beam mode while the program is in the linear measurement mode, the reset will return the processor to the linear measurement mode.

**Start Measurement:** This button starts the measurement defined in the setup window.

**Save Data:** This button will allow for the data storage of the last measurement taken.

The Laser Position window shows the current position of the retroreflector. This value always shows a value compensated for air temperature, pressure and relative humidity, but may or may not be compensated for MTE (if MTE compensated box is clicked on or off).

The Angle window shows LDDM#1-LDDM#2 at the position of the retroreflector. This value, when divided by 1.1 inches or 27.94 mm, is the angle in radians.

## 5.2 Straightness Measurement Setup Screen (Fig. 5-2)

To input information: Please move the mouse pointer over the box on which you wish to change the information. The mouse pointer will turn in to a vertical bar. Two things may be done:

- 1) Block the text. Hold the mouse button down and move over the text completely. The text being blocked will become inverted in color (white on black). Type in the information to be entered. The original text will be replaced by the new information.
- 2) Click the mouse button while the vertical bar is over the box. Use the arrow keys and the delete key to erase the previous information. Then input the new information.

The screenshot shows the 'Straightness Setup' window. The 'Identification' section contains fields for Machine (Machine Center), S/N (12345), By (OPD), and Date (11/04/03). The 'Laser head Direction/Measurement Axis' section features a 3D coordinate system with x, y, and z axes, and a 'Rotate Axis' button. The 'Straightness Measurement' section includes fields for Start Position (0), End Position (40), 2nd Axis Start, 2nd Axis End, Number of Points (11), and Number of Runs (1). It also has checkboxes for 'Forward Only' and 'Positioned by Equal divisions', radio buttons for 'Dual Beam' and '2 Laser Heads', and a '2nd Axis' dropdown menu. The 'Auto measurement' section has fields for Target Window (0.1 inch), Trigger dwell (1 sec), and Vel Threshold (0.01), along with a 'Backlash' checkbox. At the bottom, there is a 'Points taken during each run' field and buttons for 'New Config File', 'Save Configuration', 'Cancel', and 'OK'.

Fig. 5-2 Straightness Measurement Setup Screen

### Identification Box:

The identification of the machine, i.e. the machine type, serial number, the person doing the calibration, and the date, is entered here and is saved in the data file. The date is automatically entered using the computer system date.

### Laser head direction/Measurement Axis Box:

- 1) Choose which axis the lasers are pointed in (X, Y or Z axis). In Fig. 5-2, it is the X-axis.

2) Double click the **X-axis**, **Y-axis** or **Z-axis** axis button until the red beams are pointing in the direction that the laser is pointed in referenced to the machine. The axis labels on the screen designate the positive direction of the machine. In Fig. 5-2, the laser is pointed in the positive x-axis. Click the Rotate Axis to rotate axes orientation to match with the machine coordinate.

3) Choose the axis of the straightness measurement. The two beams of the laser head are in the same plane of the straightness measurement. In Fig. 5-2, the two beams are aligned with the y-axis.

4) LDDM #1 (beam #1) is designated by the laser beam exiting closest to the center of the laser head. On the machine, visually place the axis that is being measured linearly between LDDM #1 and LDDM #2. If LDDM #1 is on the positive side of the straightness axis, click on the positive straightness axis. If LDDM #1 is on the negative side of the straightness axis, click on the negative straightness axis. In Fig. 5-2, LDDM #1 was found to be in the negative side of the y axis while measuring the x axis linearly.

5) If the laser head is moving, switch the sign of the dot in the straightness axis. In Fig 5-2, if the laser head was moving, the dot would be now placed on the +y axis.

These 5 steps will ensure that your straightness measurement will truly reflect what the ways of the machine are doing to the travel. If you set these steps up incorrectly, the only difference in the measurement will be that the graph should be turned over (change the sign). The actual straightness values will be unchanged.

6) If the laser head is mounted up side down or in a reversed orientation, click the box on **Reverse Orientation**. This will correct the small divergence of the two parallel beams. The value of the beam divergence is set in the LDDM.ini file. A typical beam divergence is 0.0002 m/m or  $R = -0.0002$ .

Straightness Measurement Box:

**Start/End Position:** Please enter the starting and ending coordinates from the machine here for the axis to be measured.

**Number of Points:** Counting the zero point as the first point, please enter the number of points for the run.

**Number of Runs:** Choose the number of runs for this measurement, 1 through 7.

**Verify/Edit:** Click on this button to see the data acquisition setup. Make sure that your increments are correct. If there are increments to be changed to an irregular interval, you may edit the box.

**Forward Only:** Click the box to an X mark if the measurement is to be forward only. Leave the box blank if it is to be a bi-directional measurement.

**Dual Beam or 2 Lasers:** For dual-beam laser head, click on **Dual Beam**, the laser beam separation will shown 1.1 in or 27.94 mm. For 2 laser heads pointing in the same direction, click on **2 Laser Heads** and the **2<sup>nd</sup> axis** same as the 1<sup>st</sup> axis. Then enter the **Laser head separation** in inch or mm ( For standard box, the separation is 2.51” or 63.754 mm). For 2 laser heads pointing in two different directions perpendicular to each other, click on **2 laser heads** and the **2<sup>nd</sup> axis** different from the 1<sup>st</sup> axis. Then enter the **2<sup>nd</sup> axis start position** and **2<sup>nd</sup> axis end position**. For this case, the data collection is based on the 1<sup>st</sup> axis and the 2<sup>nd</sup> axis reading will be collected at the same time as the 1<sup>st</sup> axis. For automatic data collection, it is important that the 2<sup>nd</sup> axis is stopped before ( or within the dwell time ) the 1<sup>st</sup> axis is stopped. To analyze the data, open the .str file then click on the displacement 1 and save. Enter a new file name. The 1<sup>st</sup> axis displacement data will be saved in a .Lin file. Similarly, click on the displacement 2 to generate a .Lin file for the 2<sup>nd</sup> axis.

**ATC Board:** If you have an ATC board, please click the mouse here and make an X mark. If you do not have an ATC board, please make sure that there is no X mark there. To manually set the speed of light correction, click the ATC board on and off, then enter the barometric pressure in mmHg and the air temperature in °C. The barometric pressure and air temperature values will be reset to 760 and 20 automatically once leave the program to avoid possible double correction

Please choose the type of measurement you wish to take:

**Manual:** The Start Measurement button will turn into a "TAKE" button after the measurement begins. At every collection point, this button will have to be pushed.

**Automatic:** The software will collect data every time the retroreflector comes within a "Target Window", drops under a certain velocity and sits still for a designated dwell time.

**On-the-Fly:** The software will automatically take data as soon as it is sensed that the retroreflector is within the "Target Window" of the target position.

Auto Measurement Box:

**Target Window (automatic and on-the-fly):** For automatic and on-the-fly measurements, being within this value of the target position allows the software to take data. For on-the-fly measurements, the maximum speed is 10 times the target window.

**Trigger dwell (automatic only):** For automatic measurements, the settling time of the machine (typically 3-5 seconds) is entered here. Choose a value of at least 2 seconds less than the programmed machine dwell time.

**Vel Threshold (automatic only):** This is the threshold that the retroreflector must drop underneath so that a data point can be taken.

**Backlash (automatic only):** If the box has an X, backlash at the end and beginning of each run (other than the first point) will be taken. The distance necessary to remove the backlash and allow the software to re-trigger is twice the target window.

**New Config File:** You may load a previous configuration file if you have one for this particular machine.

**Save Configuration:** This updates the LDDM.2CF file so that the data seen on the screen will appear each time LDDM for Windows is run.

**Cancel:** Cancel the above changes and revert to the previous values.

**OK:** Settings are ok for this measurement. If you saved this setup as the default, it will come up first every time, otherwise the previous setup will re-appear next time the program is run.

### 5.3 Example of a Straightness Measurement

Straightness Measurement Main Display (See Fig. 5-1):

- 1) Check your units in middle right hand side. If it is not the correct type, click on the icon.
- 2) Click the **Intensity** button on the middle left hand side. Align the laser head/retroreflector according to the user's manual, using the intensity bar reading as a guide. After alignment, click off the **Intensity**.
- 3) Click once on the **Setup** icon on the bottom row of icons.

Straightness Measurement Setup Screen (See Fig. 5-2):

- 4) Setup your system information on the upper right hand side of the machine. Input the identification of the machine you are calibrating. To type the text, please move the arrow of the mouse pointer until it turns into a text cursor (an up and down line). Or please hit the tab key until one of the text boxes is highlighted. Type your machine data in.
- 5) Enter the axis of measurement by clicking the appropriate box on the bottom left graph (**X, Y, Z** and laser head **orientation**). Also choose the axis which best describes the position of the LDDM#1 laser beam on your dual beam laser head, compared to your machine.
- 6) Enter the **machine coordinates** that you wish to calibrate in the upper right corner.
- 7) Enter the **number of points**, including zero, that you wish to calibrate. E.g. For a ten inch run, with 2 inch increments, enter 6.

8) Enter the **number of runs** (typically 7 for NMTBA, or 4 or VDI, ISO and at least 1 run for B5)

9) Press the **Verify/Edit** button to see the increments. You may manually change these increments if you would like to.

10) If you are manually changing the values, make sure that the **Positions Equally Divided** box is clicked off to show: **Positions As Shown Below**.

11) Change the # of points as necessary to achieve the correct increment that you desire (Press Verify/Edit to check again).

12) Choose **Forward Only** or **Bi-Directional** runs.

13) Click on the **ATC board** if you have one.

14) Choose your type of measurement:

### **Manual**

- you may:
- 1) Hit the <Enter> key at each point, or
  - 2) Click the mouse on **Take** at each point

### **Automatic**

To collect data automatically, you will have to program the machine controller to do 2 or 3 things: to move in a certain increment with a delay time in-between movements (3-5 seconds recommended), and add a backlash movement that is greater than double the target window (backlash is optional).

The following information will be necessary for Automatic measurements:

**Target Window:** This tells the computer a distance window around the target position where the computer is allowed to take data. This value is related to the backlash needed (see below). A typical value is .001 inch or .02 mm, depending how tight your machine is. The backlash movement of the machine must be at least double this value.

**Trigger Dwell:** Set this value for two seconds less than the machine delay time for each point.

**Velocity Threshold:** This value keeps the risk of false triggering down. A good value to use is 0.01 for inches, 0.1 for metric.

**Backlash:** Check here if you want to account for backlash. The backlash at the beginning and end of each forward/backward run has to be at least TWICE the target window value.

**On-the-Fly:** For On-the-Fly Measurements the user must enter the number of points and the start/stop coordinates. The user will then move the retroreflector under a certain maximum speed equal to 10 times the target window. The program will automatically take data as the machine moves along.

The following information is necessary for On-The-Fly Measurements:

**Target Window:** The Target Window is set for variable speed control. It is, of course, better if you move your retroreflector slower, but for a quick overall check of an axis, that is unnecessary.

#### 15) Saving the Configuration file

Save this configuration file by clicking the **Save Config File** Icon. Type the name of the file which you would like the setup saved to (usually the name of the machine). Press **<Enter>** or **OK** after typing it in.

The program will ask you if you would like to save the file, press **Yes**.

The program will then ask if you want to use this file as your default. If you press **Yes**, this setup will be loaded every time that the Straightness Measurement Module is loaded.

To load a configuration file next time, click on **New Config File**. You may either:

- 1) Click on the file name and press **OK**
- 2) Double click on the file name
- 3) Type the name of the file name, example: **LDDM.2CF** and hit **<Enter>**.

#### 16) Press **OK** to get back to the main screen.

Taking Data Points for a Linear and Straightness Measurement (Fig. 5-3):

17) Press **ATC update (X)** to update the values if you have an ATC probe hooked up to the Processor Module.

18) Edit the Humidity Value as necessary.

19) Choose your material from the list given. Press the **Down arrow** key and you will get a list, press the **Down arrow**, or **PgDn** key from there to scroll down.

20) Choose the number of digits on the upper right hand side of the screen you wish the screen to display.



21) Move your retroreflector to the beginning of your run. Click on **Start**.

Manual: If you are manually operating the laser/machine, press the designated key to take data as shown (after you move the machine). Also, if you would like to change the target position, you may do so in the value box located in-between the run information.

Automatic: If you are running the automatic program, you will see a stoplight appear. The red means that the conditions for a measurement have been met (inside the target window, and the velocity is lower than the given one), yellow means that the delay is being counted and the green means that the data has been collected and the program is waiting for you to move to the next point (Fig. 5-3)

On-The-Fly: If you are running the On-The-Fly program, you will also see the stoplight appear. The light will turn red when a data point is taken and green when it is ready to take another data point. If you move faster than the target window allows for, you will hear a continuous beeping noise. Please move the retroreflector backwards until the beeping stops, then move it forwards again.

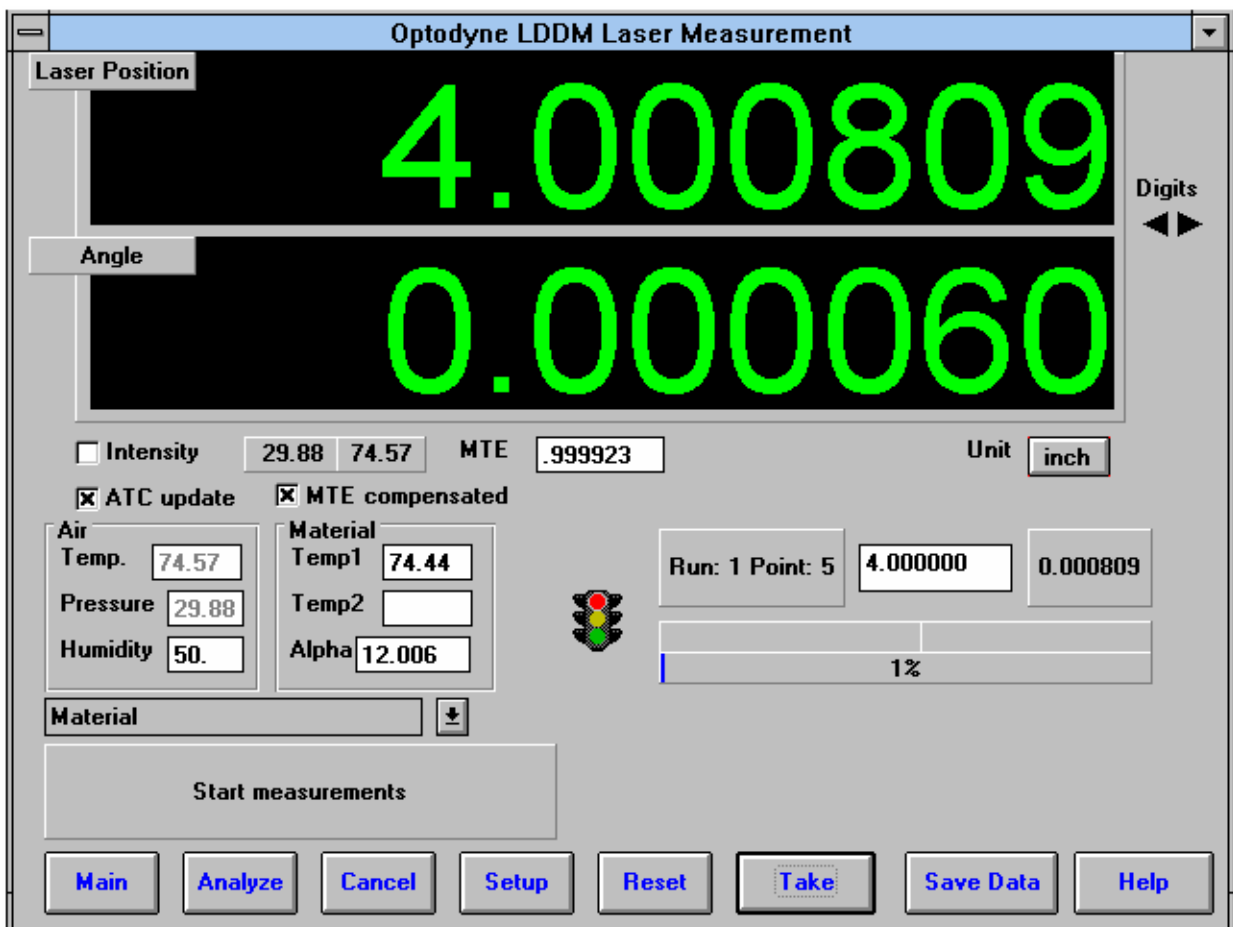


Fig. 5-3 Automatic Straightness/Linear Data Collection

- 23) After all the data is taken, press **OK** to save the data, or **Cancel** to not save the data.
- 24) To save data, type in the **filename** to save and hit **<Enter>** (the extension is automatically saved as .STR). You may also save collected data by pressing the save data button, and follow the procedure above.
- 25) To analyze the data click on the **Analyze button**. When it prompts you, unload the module, unless you are taking a flatness measurement.

#### 5.4 Straightness Data Analysis Menu

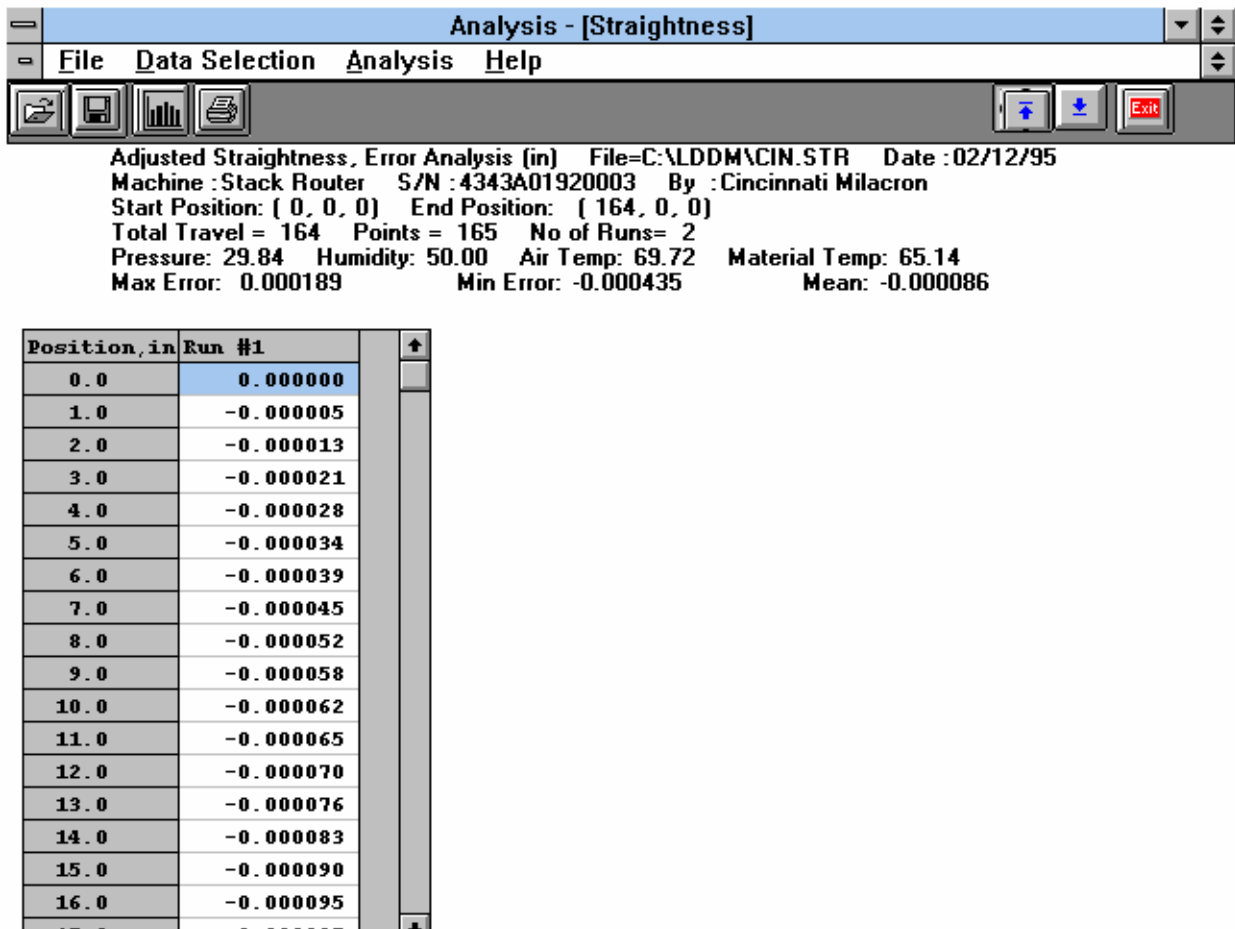


Fig. 5-4 Straightness Measurement Data Analysis Table

Under the **File Menu**, you can open a **new** data file, **save** a data file, set your **printer type**, set your **printer style**, or return to the **main menu**. When loading a file, choose the files with the extension of .STR for straightness. You can only **print data** tables using the print function under this heading.

Under the **Data Selection** heading, you may choose **displacement** data, **angle** data, **straightness** data, and **adjusted straightness** data when looking at a straightness (.STR) file.

Under **Analysis**, you can choose **Error**, **NMTBA**, **NMTBA with Zero Shift**, **VDI 3441**, **ISO ASME B5.54** or **ASME B5.57** for different types of data manipulation. After choosing **Error**, you will be given a choice on what you wish to see, **Runs #1-7**, and **forward** or **backward**. Click with the mouse button on which runs you wish to see.

The following icons have the following function in Analysis:



Open a new data file.



Save a data file.



Graph a data file (After graphing, you may also change the scaling of the graph by checking X on adjust grid).



Print a data graph (for printing data tables, use the Print option under the “File” heading)



Moves to the previous screen.



Moves to the next screen.



Exits the program.

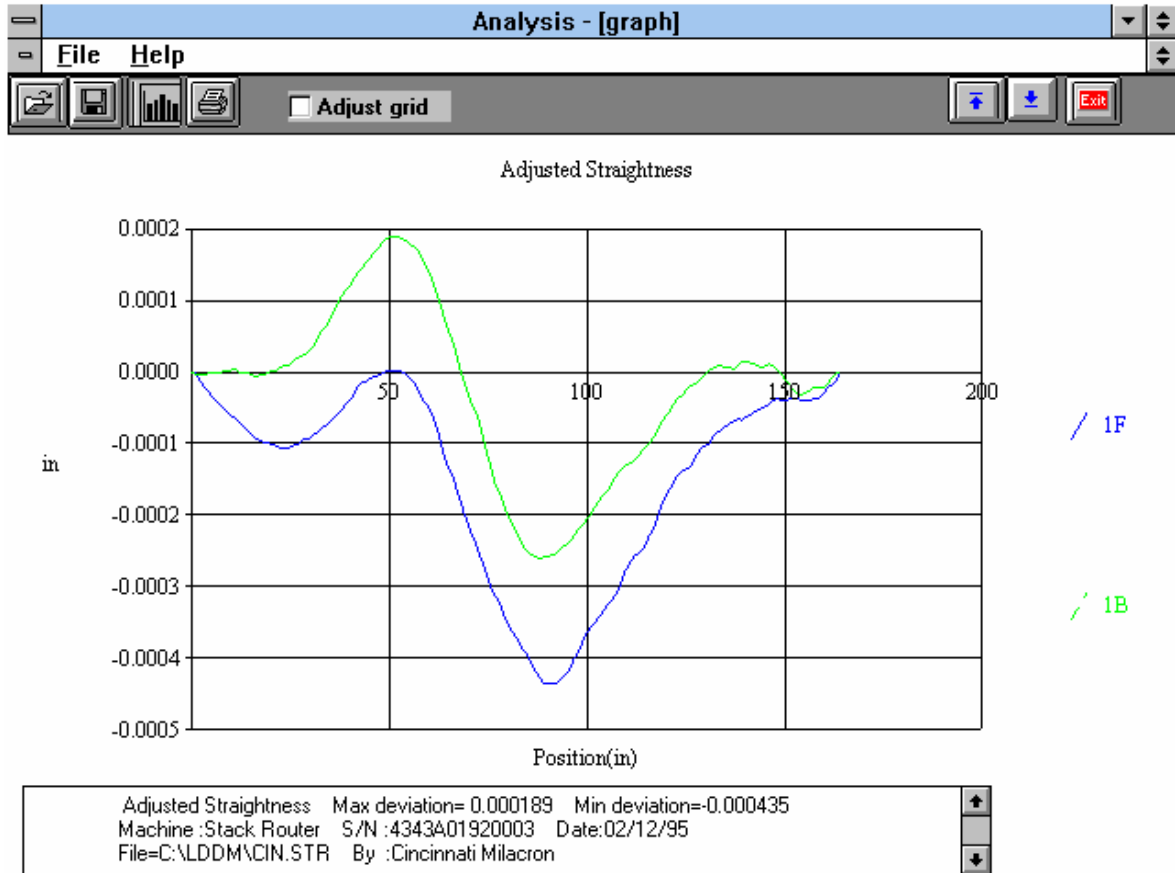


Fig. 5-5 Adjusted Straightness Measurement Data Plot

A typical straightness data plot is shown in Fig. 5-5.

## 5.5 Straightness Display

The straightness measurement here is very accurate and sensitive. However, for the alignment of a long guide rail. It is desirable to display the straightness for real-time adjustment of the rail. The straightness display is designed for this purpose. Click the straightness Display box in the main menu, the screen will show the straightness Display below:

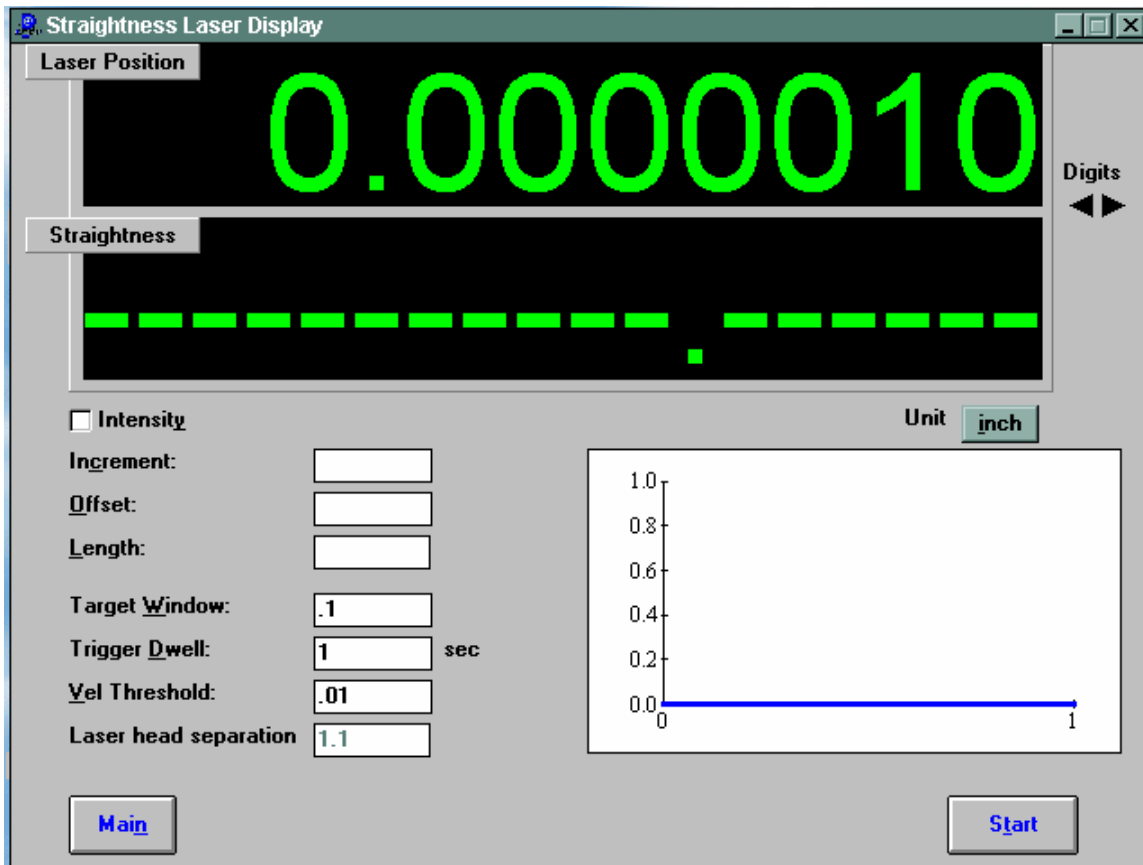


Fig. 5-6 Straightness Display Screen

The straightness displayed is calculated by integrate the measured angle times the increment and minus the off-set. Hence the straightness value displayed will be a constant between the increment.

**Increment** : Enter the increment value. Typical values are from 0.1 to 10 inches.

**Off-set** : Enter the end-point straightness value in the straightness measurement. For the first measurement, enter 0.000001. After the first measurement, enter the end-point value obtained from the display. A correct off-set value will set the end-point value to zero.

**Length** : This is the length of total travel Target Window. Trigger Dwell, Vel. Threshold and Laser head separation are the same as in previous sections. To start, align

the laser head and the dual-retroreflector properly and move the dual-retroreflector to the zero position then click the start box. Similar to the straightness measurement discussed before, move the dual-retroreflector to the next increment, the data will be taken automatically and display on the screen. The first line is the position and the second line is the measured straightness, as show below:

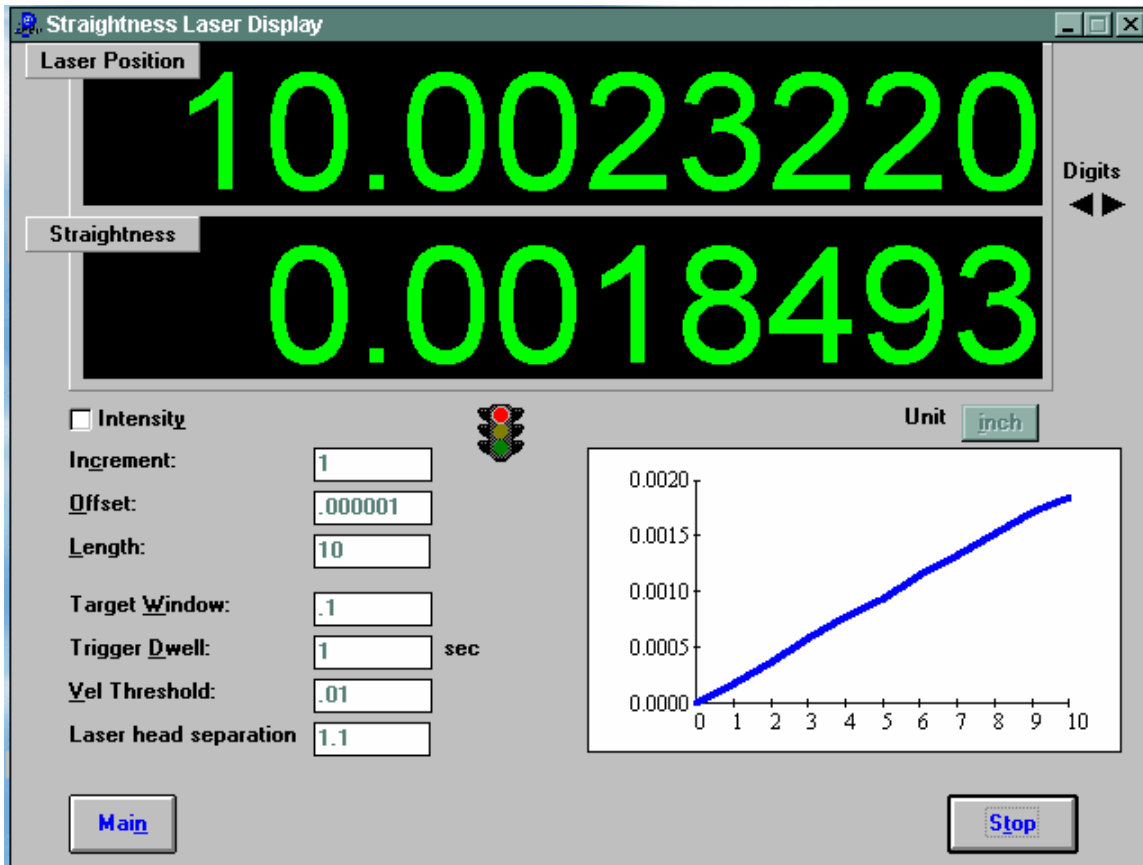


Fig. 5-7 Straightness Display Without Offset

You may move the dual-retroreflector back and forth, do a real-time adjustment on the rail, and display the straightness again.

Please note that the offset value may be changed after some real real-time adjustment on the rail. You may enter a new off-set value based on the end-point readings (add the end-point readings to the existing off-set value) .

After the rail is aligned, use the previous straightness measurement to collect straightness data and verify the straightness.

After clicking the **Flatness Measurement** Box on the Main Menu, you will be greeted by the Flatness Measurement Data Screen. If the LDDM is not in the correct port, a box with the port choice will appear asking you if the LDDM is connected to COM1 or COM2. Please enter the correct choice. If the LDDM is not connected, a dashed line will

appear in the Laser Position section of the window. Please check your connections and the LDDM reading on the display should appear.

## 6.0 Flatness Measurements

After clicking the **Flatness Measurement** Box on the Main Menu, you will be greeted by the Flatness Measurement Data Screen. If the LDDM is not connected to communication port, a message box will appear telling you that the LDDM interface not found. Please check your connections and the LDDM reading on the display should appear.

### 6.1 Flatness Measurement Main Display (Fig. 6-1)

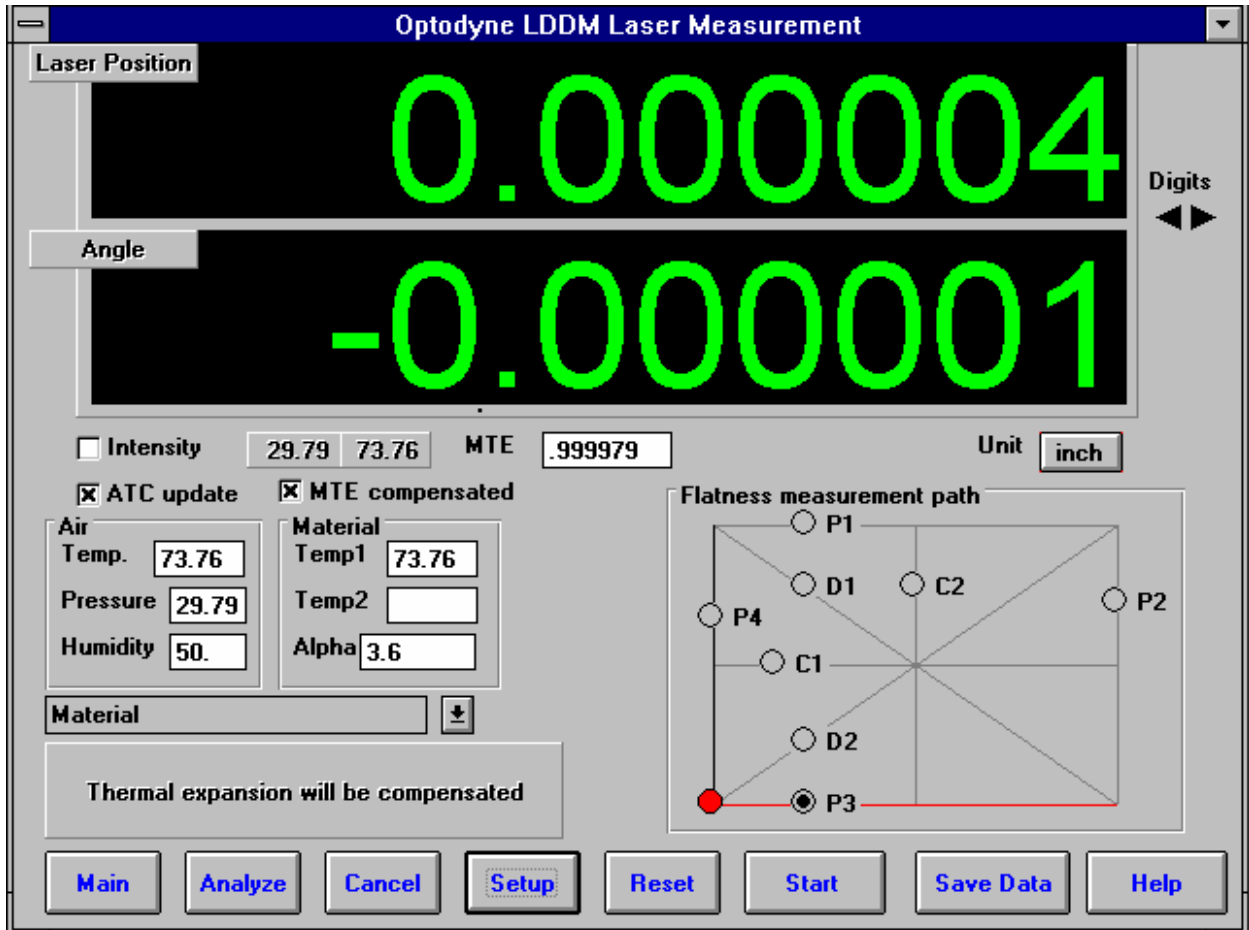


Fig. 6-1 Flatness Measurement Main Display

The display, in the straightness mode, shows the linear distance traveled on the top line, and the difference between LDDM #1 and LDDM #2 for the second line. If this second line value is divided by 1.1 (inches) or 27.94 (mm) then the value is in radians. When you look at the outgoing laser beam aperture positions on the front of the laser head, LDDM #1 is the one closer to the center of the laser head.

Choices on the Main Display are as follows:



**Intensity:** Align your system visually according to the User's Guide, then check your alignment by clicking on this box. A blue bar will appear in-between the Laser Position window and the Target window. This blue bar will range from between 0 and 100%. Please make sure that the intensity is at least 40% over your whole run. Press the intensity box again to return the system to its original state.

The two boxes next to the Intensity box show the Pressure and Temperature that the Processor Box is reading. If you have an ATC probe, these numbers will be continually changing. If you do not have an ATC probe, the values will be 68 degrees and 29.9 inHg. When the Intensity Box is clicked on, these values will disappear.

**ATC update:** The ATC update updates the air pressure, air temperature and material temperature readings from the processor box. The MTE value will be calculated from these updated values and Alpha material coefficient. A X mark will appear when the ATC value has been updated correctly for the next measurement.

**MTE compensated:** To show compensation for Material Thermal Expansion, please click the box to show the X mark. If the X-mark does not appear on the screen, the displacement value will show only environmentally compensated values.

**MTE:** The MTE value can be manually changed in this box.

**Unit:** This box, when clicked on, will allow the user to change between the inch and metric systems.

**Digits:** Clicking the **left arrow** will decrease the amount of digits shown (data will still be taken to 6 digits for inches, 5 for metric). Clicking the **right arrow** will increase the amount of digits shown (max 5 or 6).

**Air/Material Environmental, Alpha Boxes:** Values may be entered in the Air Temperature and Pressure boxes for those people who do not have an ATC probe. Humidity should be entered for all users of the LDDM system. The Material Temperatures are averaged together to get the MTE coefficient value. The material alpha can also be manually changed if the material list does not include the material of the machine being calibrated.

**Flatness measurement path Box:** This box shows which part of your flatness measurement that is being done, or is to be done next. To change directions of the measurement, please double-click the left mouse button on the circle next to the path you would like to measure. As you move the retroreflector along the path, the red dot will also move, showing the retroreflector position for this particular measurement.

For automatic measurements, a stoplight will appear. The green light indicates that the program is ready for the system to go to the next data point. The yellow light indicates that the retroreflector has dropped below the velocity threshold and is waiting for the set delay to complete. The red light indicates that the system is taking the data point.

**Material Box:** The material list and their corresponding alpha values are listed here. Click the mouse on the down arrow and a list of materials is shown. Please choose from the material list or enter your own value to the alpha box above.

The dialog box is just underneath the material box. This box tells you messages and describes the actions you are taking.

Buttons at the bottom of the screen:

**Main:** exits the linear measurement package and loads the main menu.

**Analyze:** exits the flatness measurement package and enters the analyze data package. For Flatness measurements, **do not** unload the module when prompted.

**Cancel:** Allows the cancellation of a measurement if it has gone out of alignment, or if something went wrong.

**Setup:** Opens the setup window, where measurement specifications may be edited or viewed.

**Reset:** Using this key allows for the reset of the LDDM. This key will also change the mode of the processor box to the current measurement type, i.e. if the processor is manually switched to a dual-beam mode while the program is in the linear measurement mode, the reset will return the processor to the linear measurement mode.

**Start Measurement:** This button starts the measurement defined in the setup window.

**Save Data:** This button will allow for the data storage of the last measurement taken.

The Laser Position window shows the current position of the retroreflector. This value always shows a value compensated for air temperature, pressure and relative humidity, but may or may not be compensated for MTE (if MTE compensated box is clicked on or off). The ATC or MTE compensation is NOT important for the flatness measurement.

The Angle window will show the angular value of the current position of the retroreflector. This value when divided by 1.1 inches or 27.94 mm, is the angle in radians.

## 6.2 Flatness Measurement Setup Screen (Fig. 6-2)

To input information: Please move the mouse pointer over the box on which you wish to change the information. The mouse pointer will turn in to a vertical bar. Two things may be done:

- 1) Block the text. Hold the mouse button down and move over the text completely. The text being blocked will become inverted in color (white on black). Type in the information to be entered. The original text will be replaced by the new information.
- 2) Click the mouse button while the vertical bar is over the box. Use the arrow keys and the delete key to erase the previous information. Then input the new information.
- 3) The P2 line of the graph always designates the "LABEL" side of the table. Please note this when setting up the measurement.

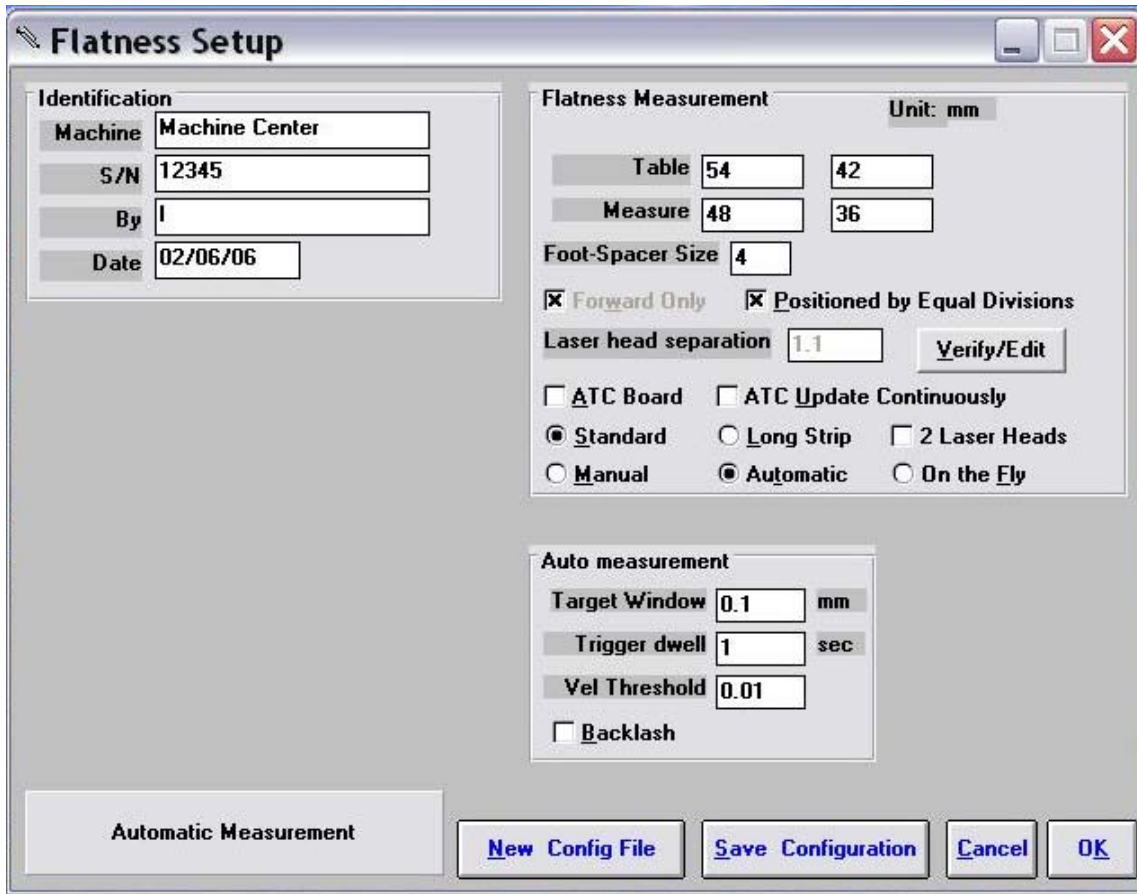


Fig. 6-2 Flatness measurement Setup Screen

#### Identification Box:

The identification of the machine, i.e. the machine type, serial number, the person doing the calibration, and the date, is entered here and is saved in the data file. The date is automatically entered using the computer system date.

#### Flatness Measurement Box:

**Table, Length/Width:** Enter the length and width of the table.

**Measure, Length/Width:** Enter the size of the surface which is to be measured.

**Foot Spacer Size:** Depending on which foot spacer is to be used, enter 2, 4 or 6 inches, or 50, 100, 150 mm.

**Positions by Equal Divided:** Make sure that this box is checked.

**Verify/Edit:** Click on this button to see the data acquisition setup. Make sure that your increments are correct. If there are increments to be changed to an irregular interval, you may edit the box.

**Forward Only:** All flatness measurements are automatically forward only.

**ATC Board: Do NOT** use the ATC Board when taking flatness measurements. Make sure that no X appears in the box. The ATC Board is not important to flatness data collection.

Please choose the type of measurement you wish to take:

**Standard :** The standard method is the Moody method or Union Jack method.

**Long Strip :** For a long surface plate, you may select the long strip method. Here instead of 2 diagonals and 2 centerlines, there are 5 parallel lines and only one diagonal. A total measurement of 8 segments is still the same.

**2 Laser Head:** for 2 laser heads (MCV-5000) click this.

**Manual:** The **Start Measurement** button will turn into a **Take** button after the measurement begins. At every collection point, this button will have to be pushed.

**Automatic:** The software will collect data every time the retroreflector comes within a "Target Window" and drops under a certain velocity. Automatic measurement is not recommended for Flatness Measurements.

**On-the-Fly:** The software will automatically take data as soon as it is sensed that the retroreflector is within the "Target Window" of the target position.

Auto Measurement Box:

**Target Window (automatic and on-the-fly):** For automatic and on-the-fly measurements, being within this value of the target position allows the software to take data. For on-the-fly measurements, the maximum speed is 10 times the target window.

**Vel Threshold (automatic only):** This is the threshold that the retroreflector must drop underneath so that a data point can be taken.

**New Config File:** You may load a previous configuration file if you have one for this particular machine.

**Save Configuration:** This updates the LDDM.3CF file so that the data seen on the screen will appear each time LDDM for Windows is run.

**Cancel:** Cancel the above changes and revert to the previous values.

**OK:** Settings are ok for this measurement. If you saved this setup as the default, it will come up first every time, otherwise the previous setup will re-appear next time the program is run.

### 6.3 Example of a Flatness Measurement

Flatness Measurement Main Display (See Fig. 6-1)

- 1) At the Main Menu, click the left mouse button on **Flatness**.
- 2) When the display screen appears, check your units, make sure that the units (inch/mm) are correct for your application.
- 3) Click the intensity box - an X and a blue bar under each measurement window will appear. Please align your system according to the User's Guide so that the blue bars are close to 100% over the complete path of measurement.
- 4) Go to the **setup** button and click the left mouse button.

Flatness Measurement Setup Screen (Fig. 6-2):

- 5) The setup screen will now appear, start with the upper left hand side of the setup window; fill in your **machine information**.
- 6) Setup your **table measurement specifications**. Input the actual table dimensions (Table), and the actual measured dimensions (Measure) for both length and width.
- 7) Choose your **foot spacer size**, 2, 4, or 6 inches.
- 8) Click on the **Verify/Edit** button to see if the diagonal travel is correct.
- 9) **Positions Equally Divided** should be clicked on at all times (due to the nature of the flatness measurement).
- 10) Make sure that the **ATC Board** option is turned **OFF**.

- 11) Choose the **type of measurement** (On-the-Fly is recommended and is the fastest).
- 12) For On-the-Fly measurements, the top speed of the retroreflector is 10x the window size you choose. If the window is 0.1 inch, the top speed of the measurement is 1 IPS.
- 13) Save your configuration by clicking on the appropriate button on the bottom of the screen. Type the name that you want to save it under and hit enter. The computer will automatically add the correct extension to the file name.
- 14) Click on **OK** to save.
- 15) If you want this setup to be the default file (the setup that appears every time you load the flatness program), click on **Yes**.
- 16) Press **OK** to return to the main screen.

Taking Data Points for an On-The-Fly Flatness Measurement (Fig. 6-3):

- 17) The measurement path (collection), by default follows the user's guide method on page 9-7.
- 18) You can change the order of measurement by clicking the left mouse button on the circle next to the run you wish to take. If you wish to change directions of your measurement path, double-click the circle of the path you want to change directions on.

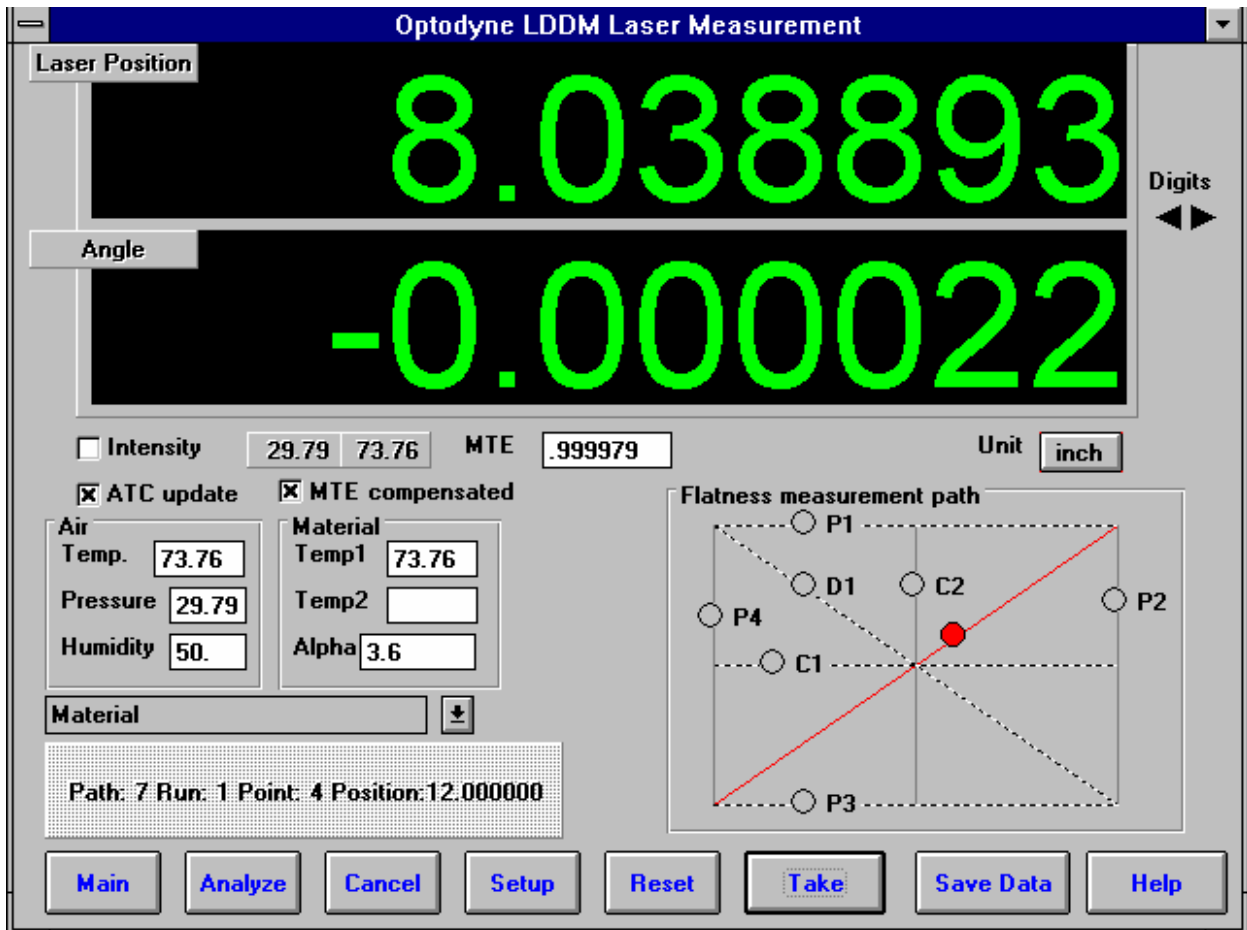


Fig. 6-3 On-The-Fly Flatness Measurement Data Collection

- 19) Press **Start** when in position and carefully pull the retroreflector across the surface.
- 21) If you move too fast or miss a point, you will hear a series of beeps, then move back until the beeps stop and continue with your measurement.
- 22) If you get the out of alignment message, find out what caused the message and fix it (be it alignment, human error, etc.). Move back to the previous position and click on the **OK** box. For automatic and on-the-Fly measurement, you will have to start that particular run over.
- 23) If you wish to redo a line, you may do so by clicking on the line you wish to redo. The resulting data will supersede the previous data.
- 24) After all of the lines have been taken, you may save the data by clicking on **OK**, when prompted, and typing in a file name. The .FLT extension will be automatically added to the filename.
- 25) You may also save the data after the run by pressing the **Save Data** key.

- 26) To analyze the data, click on the **Analyze Data** key, do not unload the module when prompted.
- 27) After viewing the table, you may want to immediately lap the surface that you are measuring. To be able to revise old data you must do the following:
- 28) Choose **Flatness** at the main menu.
- 29) Choose **Analysis** and DO NOT unload the module.
- 30) Go to **File** and **Load** the file with the data you wish to recheck.
- 31) Keep pressing the **up arrow** button (or hit the **ESC** key) until you return to the Flatness screen.
- 32) Click on **Setup** and make sure that the setup is the same. Hit **OK** after checking.
- 33) Choose the **line** which you wish to re-measure. Press **Start** and take your measurement.
- 34) After the line is taken, click on **Save Data** and save your measurement.
- 35) Go back to **Analysis** and check your data.



## 6.4 Flatness Data Analysis Menu (Fig. 6-4, 6-5, 6-6)

Position,in	P4	P3	P2	P1	C1	C2	D1
0.	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000
4.	-0.000006	-0.000025	-0.000059	-0.000011	-0.000057	0.000027	-0.000
8.	0.000071	-0.000015	0.000006	-0.000137	-0.000071	0.000043	-0.000
12.	0.000062	0.000051	0.000027	-0.000094	-0.000041	0.000028	-0.000
16.	0.000039	0.000076	0.000022	-0.000027	-0.000015	0.000036	-0.000
20.	0.000051	0.000076	0.000028	0.000034	-0.000011	-0.000104	-0.000
24.	0.000016	0.000029	0.000034	0.000035	-0.000036	-0.000077	-0.000
28.	-0.000001	-0.000004	0.000026	-0.000027	-0.000071	-0.000052	0.000
32.	0.000000	0.000014	0.000000	0.000000	-0.000020	0.000000	0.000
36.		-0.000004		0.000051	0.000032		0.000
40.		0.000000		0.000000	0.000000		0.000
44.							0.000
48.							0.000

Fig. 6-4 flatness Measurement Data Table

Under the **File Menu**, you can open a **new** data file, **save** a data file, set your **printer type**, set your **printer style**, or return to the **main menu**. When loading a file, choose the files with the extension of .FLT for flatness. You can only **print data** tables using the print function under this heading.

To view the Flatness table and graphs, first click on **Flatness** on the menu bar. This will convert the data shown on the table to Flatness. Then click on the **Adjusted Flatness** choice. This will convert the Flatness data into data that the Moody Method can handle. From here you may view the **Isometric (line) Plot**, or the **Numeric Plot**.

The following icons have the following function in Analysis:



Open a new data file.



Save a data file.



Graph a data file (After graphing, you may also change the scaling of the graph by checking X on adjust grid).



Print a data graph (for printing data tables, use the Print option under the “File” heading)



Moves to the previous screen.



Moves to the next screen.



Exits the program.

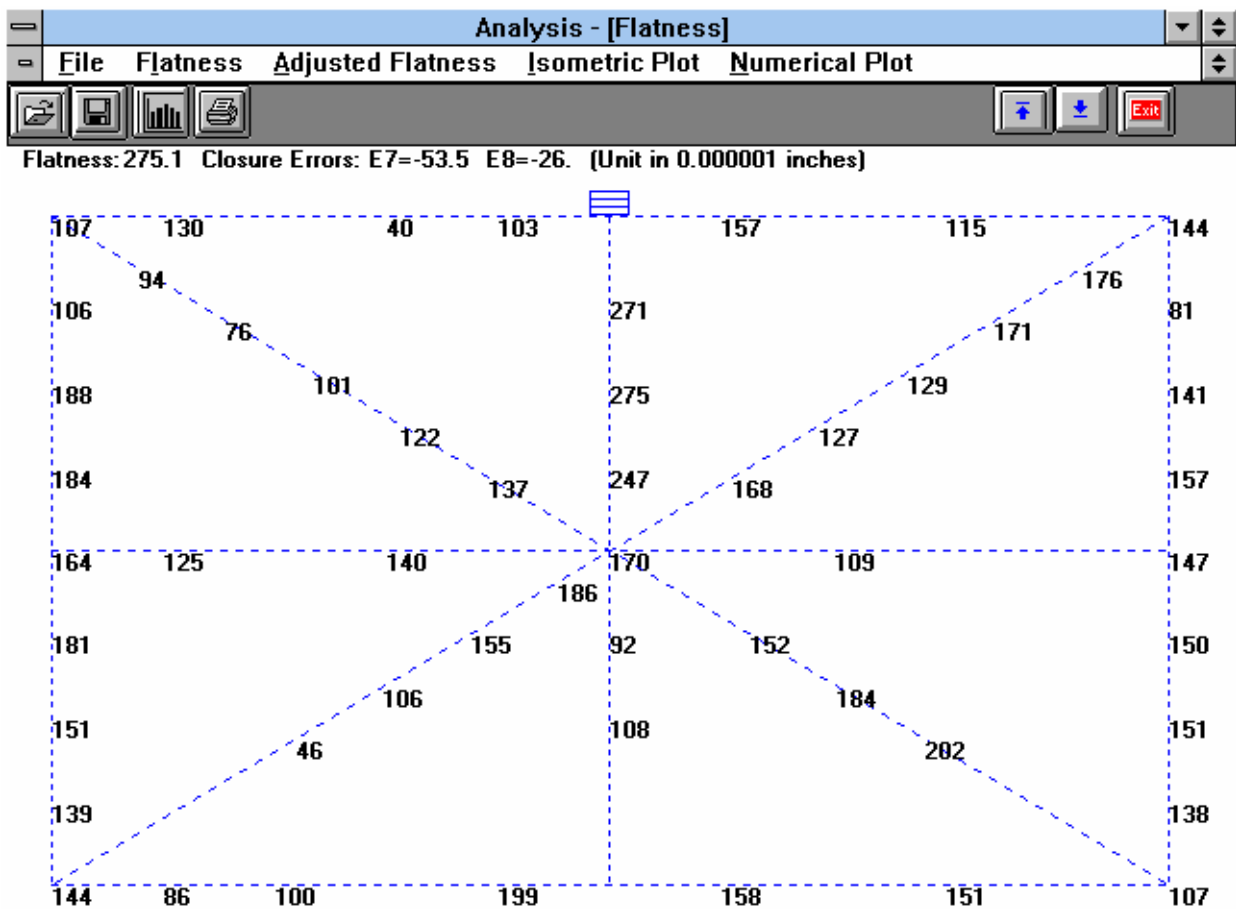


Fig. 6-5 Flatness Measurement Numerical Plot

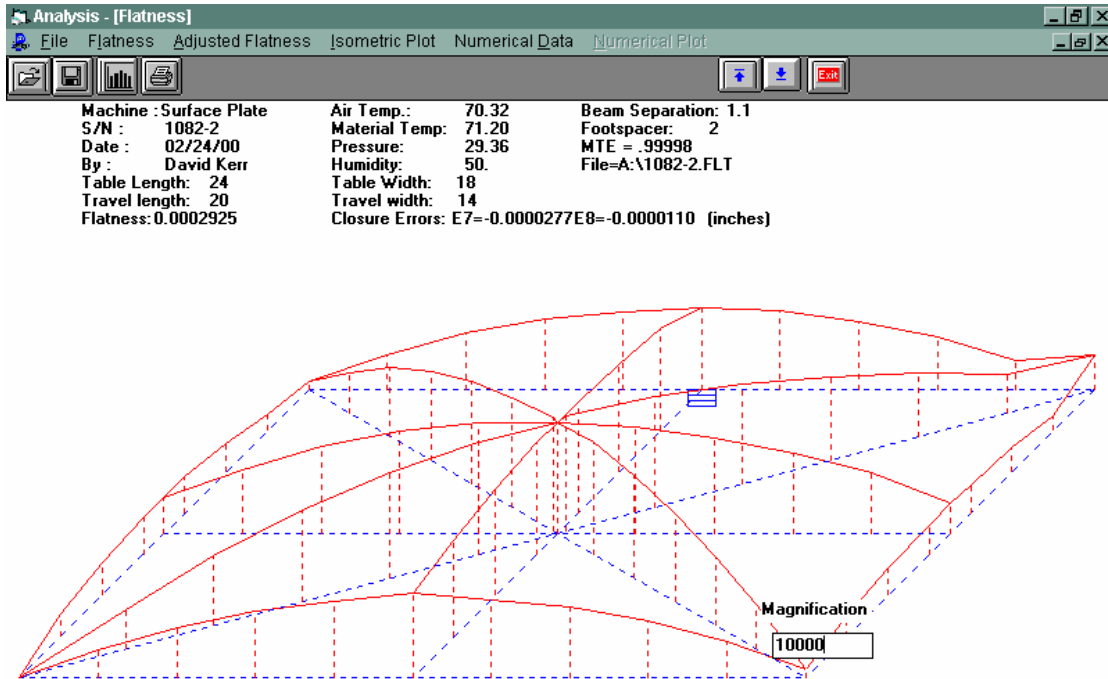


Fig. 6-6 Flatness Measurement Isometric Plot

Using the **Magnification** box in the lower right hand corner, you may increase or decrease the magnification of the graph. Enter a value and press **<Enter>**.

### 6.5 Revising Old Flatness Data Files

An excellent time saving feature in Flatness is the ability to revise old data files without having to reshoot a whole table. To revise an old data file, the following steps must be taken:

- 1) From the Main Menu, click on **Flatness**.
- 2) In the Flatness Main Display, click on **Analysis** but do NOT unload the program.
- 3) **Load** the file to revise (choose the flatness, .FLT, files)
- 4) Click on the **Up arrow** (or press the **ESC** key) until the Flatness Main screen reappears.
- 5) Align the laser, choose which line is to be re-shot, and click on **Start**.
- 6) After the data for that run is taken, press **Save Data** or repeat step 5 for another line.
- 7) The new data and graphs can now be viewed in **Analysis**.

## 7.0 Squareness Measurement

After clicking the **Squareness Measurement** Box on the Main Menu, you will be greeted by the Squareness Measurement Data Screen. If the LDDM is not connected to communication port, a message box will appear telling you that the LDDM interface not found. Please check your connections and the LDDM reading on the display should appear.

### 7.1 Squareness Measurement Main Display (Fig. 7-1)

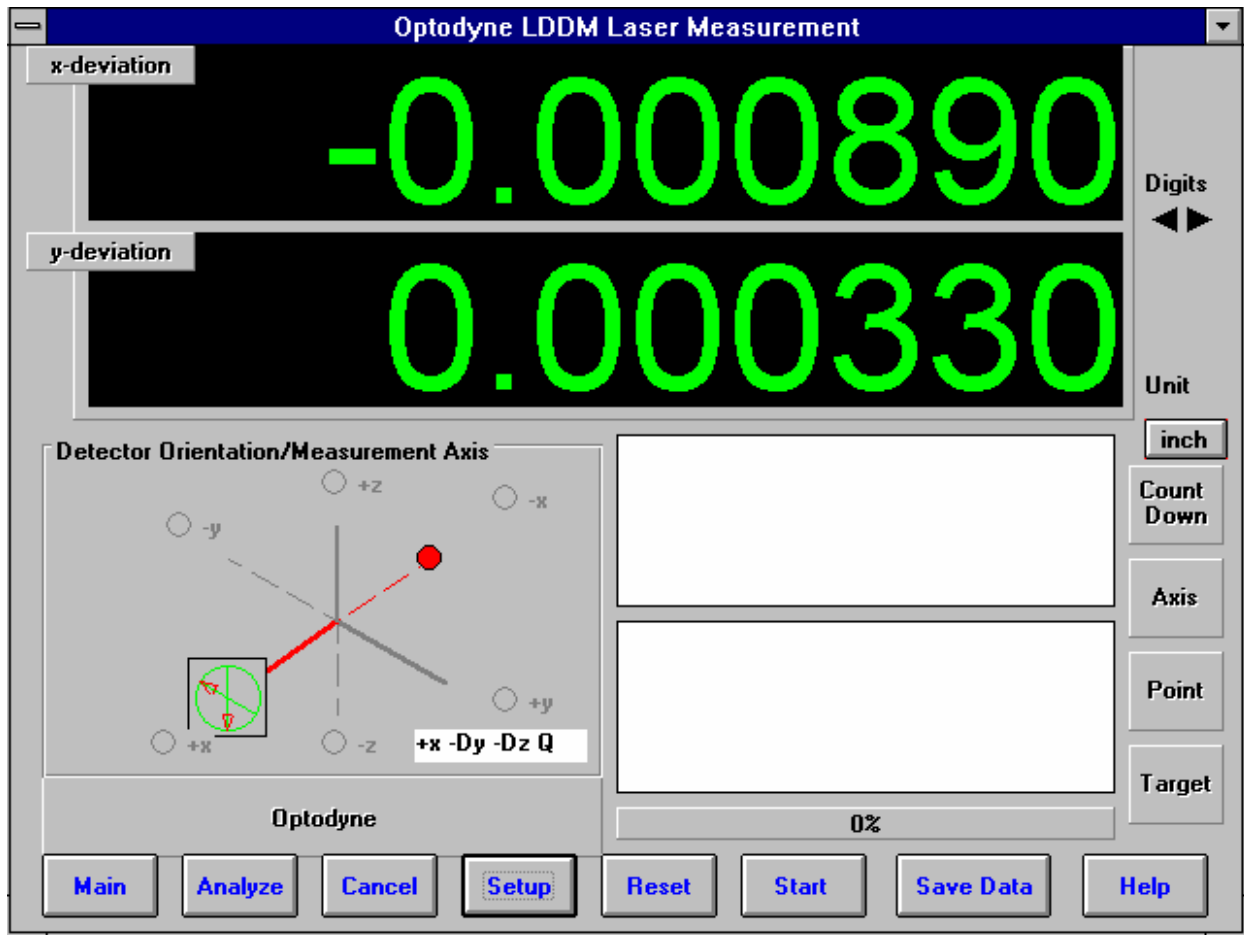


Fig. 7-1 Squareness Main display

The display, in the squareness mode, shows the deviation in inches or mm of the laser beam incident on the quad detector. The deviation in the quad detector's x and y axes are shown.

Choices on the Main Display are as follows:

Detector Orientation/Masurement Axis Box:

This box describes what axes your squareness measurement is currently taking, and if

modifications are necessary during the measurement (a setup was chosen poorly), then it can be corrected here.

The Red dot signifies the laser head/origin of the laser. The square with the two arrows designates the quad detector and its two inherent axes. The  $\pm x$ ,  $\pm y$ , and  $\pm z$  designate the machine axes.

The right hand side of the screen shows:

**Unit:** This box, when clicked on, will allow the user to change between the inch and metric systems.

**Digits:** Clicking the left arrow will decrease the amount of digits shown (data will still be taken to 6 digits). Clicking the right arrow will increase the amount of digits shown (max 6).

The **Countdown** box shows the number of points left to collect before an average value is calculated.

The **Axis** box shows what axis is being measured.

The **Point** box shows you what point is being measured.

The **Target** box shows the machine coordinate where the quad detector is supposed to be.

The two graphs on the right-center of the screen will show the data of the quad detector during a measurement. This will be updated after each data collection.

The measurement bar under the graphs shows what percentage of the total measurement has been completed.

The **Dialog** box is just underneath the Detector Orientation box. This box tells you messages and describes the actions you are taking.

Buttons at the bottom of the screen:

**Main:** exits the linear measurement package and loads the main menu.

**Analyze:** exits the flatness measurement package and enters the analyze data package. For Flatness measurements, **do not** unload the module when prompted.

**Cancel:** Allows the cancellation of the previous point or the whole measurement if something has gone wrong.

**Setup:** Opens the setup window, where measurement specifications may be edited or viewed.

**Start Measurement:** This button starts the measurement defined in the setup window.

**Save Data:** This button will allow for the data storage of the last measurement taken.

The Laser Position window shows the current position of the quad detector.

## 7.2 Squareness Measurement Setup Screen (Fig. 7-2, 7-3)

To input information: Please move the mouse pointer over the box in which you wish to change the information. The mouse pointer will turn in to a vertical bar. Two things may be done:

- 1) Block the text. Hold the mouse button down and move over the text completely. The text being blocked will become inverted in color (white on black). Type in the information to be entered. The original text will be replaced by the new information.
- 2) Click the mouse button while the vertical bar is over the box. Use the arrow keys and the delete key to erase the previous information. Then input the new information.

**Identification**

Machine: Machine Center  
 S/N: 12345  
 By: OPD  
 Date: 10/30/03

**Detector Orientation/Measurement Axis**

+y +Dx -Dz Q  
 Measurement 2  
 Quad detector move  
 Laser head move  
 Rotate Axis

**Linear Measurement** Unit: inch

Straightness  
 Squareness  
 Three Squareness

Minimum Number data averaging: 10  
 Error,  $\mu$ Rad: 90° Beam Bender: 2

Measurement	1. x-Axis	2. xy-Sqr
Direction	+x	+y
Quad Orientation	-Dy -Dz Q	+Dx -Dz Q
Start Position	0	0
End Position	10	8
No Points	6	3
Pt #1	0.0000000	0.0000000
Pt #2	2.0000000	4.0000000
Pt #3	4.0000000	8.0000000
Pt #4	6.0000000	
Pt #5	8.0000000	
Pt #6	10.0000000	

Automatic Interval: 10 Number of Runs: 3  Positions Equally Divided  Forward Only Verify/Edit

View or Edit Positions to be measured

New Config File Save Configuration Cancel OK

Fig. 7-2 Squareness Measurement Setup Screen (Leg 1)

Identification Box:

The identification of the machine, i.e. the machine type, serial number, the person doing the calibration, and the date, is entered here and is saved in the data file. The date is automatically entered using the computer system date.

Squareness Measurement Box:

Choose which type of measurement you would like to take: Straightness, Squareness or Three Squareness.

**Minimum Number Data Averaging:** Choose the number of data points to be collected and averaged together.

**Automatic Data Collection:** Click this button for automatic data collection based on a time interval. Select a time interval from 1 to 60 seconds.

**Optical Square Error:** If the error of your optical square (LD-16) is known, enter it here in microradians. If your error is specified in arcseconds, multiply the value by 4.8 and enter it here. Enter 0 if you do not have your optical square calibrated.

If you have chosen **Three Squareness**, you will be asked to enter your **second optical square** value.

Detector Orientation/Measurement Axis Box:

This is critical for getting correct squareness results. The x, y, and z axes seen on the graph indicate the MACHINE axes. The box with the two arrows indicates the QUAD DETECTOR and its axes. The red dot indicates the LASER HEAD.

**Rotate Axis:** The default coordinate is z-axis in the vertical direction. For machine with y-axis in the vertical direction, click the “Rotate Axis” once. For machine with x-axis in the vertical direction, click the “Rotate Axis” twice.

**Measurement 1:** This button is to be pressed after setting up the values for the first leg of the measurement. For straightness measurements, there is only 1 leg to be measured. For squareness measurements, 2 legs are required. For three-squareness measurements, 4 legs must be measured.

**Quad detector/Laser head move:** For this leg, choose which is to be moving. You may NOT move or tilt the laser head after the first leg, the reference line would be lost.

Setup the graph according to the way the laser is setup on the machine. Rotate the quad detector arrows so they correspond to the axes of the machine.

**Measurement box:** The Direction and Quad Orientation boxes are automatically filled in when the graph axes are chosen. Enter your MACHINE Start/End coordinate, plus the number of points (including the start and end points).

**Verify/Edit:** Before pressing the Measurement button in the Detector Orientation box, press verify view to see if the machine coordinates selected are correct.

**Number of Runs:** Enter the number of runs, up to 7 runs.



**Positions equally divided:** If the point values in the measurement box are okay, put an X in the box here. If you would like to change the stop coordinates to what you want, do so and click the box until the X disappears.

**Forward only:** For bi-direction runs, unclick this button.

When you are done setting up the first leg, click the **Measurement** button and set up the next leg (if applicable) and repeat the previous steps. Please note the following change:

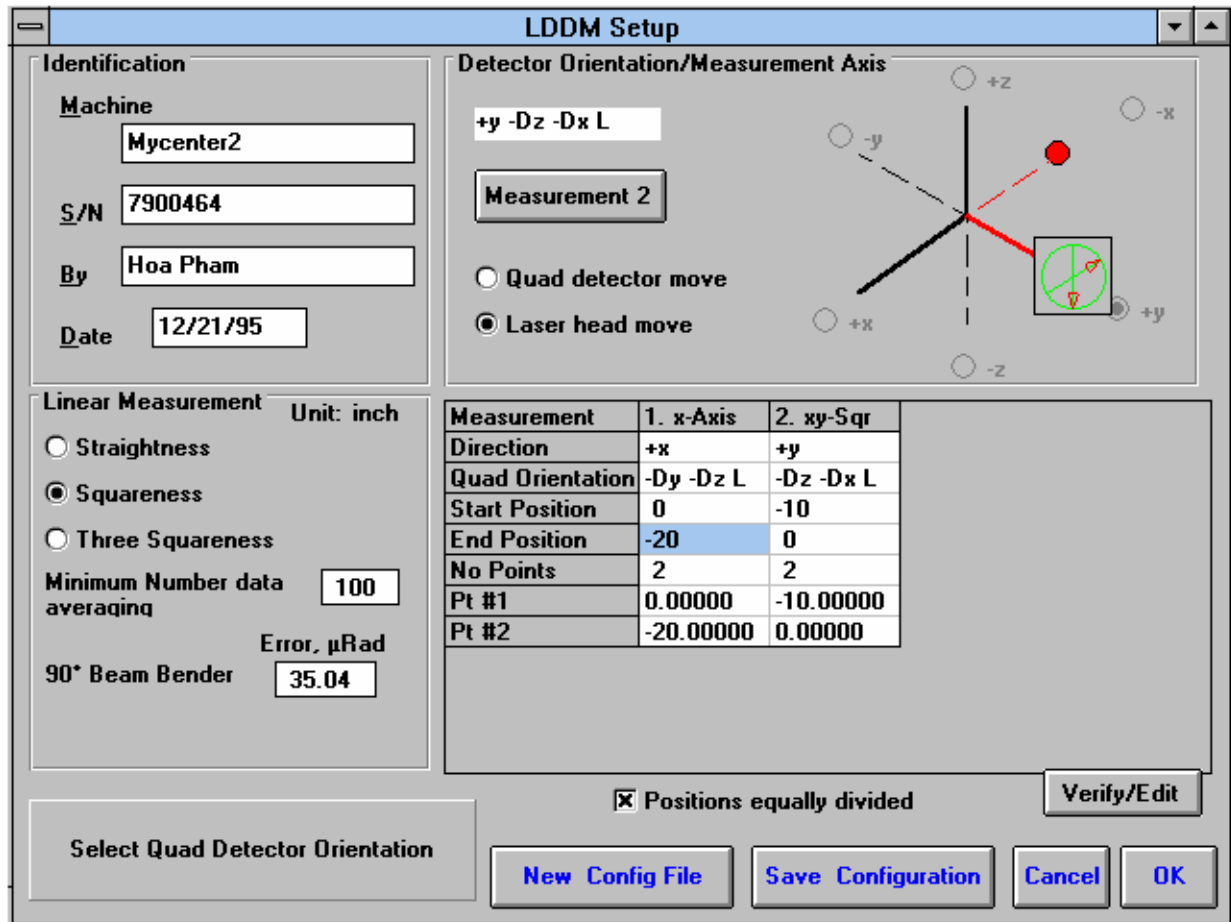


Fig. 7-3 Squareness Measurement Setup Screen (Leg 2)

For the second leg, the graph in the Detector Orientation box will bend 90 degrees. Make sure that it is set up correctly.

**New Configuration:** You may load a previous configuration file if you have one for this particular machine.

**Save Configuration:** This updates the LDDM.3CF file so that the data seen on the screen will appear each time LDDM for Windows is run.

**Cancel:** Cancel the above changes and revert to the previous values.

**OK:** Settings are ok for this measurement. If you saved this setup as the default, it will come up first every time, otherwise the previous setup will re-appear next time the program is run.

### 7.3 Example of a Squareness Measurement

- 1) At the main menu, click the left mouse button on **Squareness**.

Squareness Measurement Main Display (Fig. 7-1)

- 2) Check your units (**inch/mm**), change them by clicking on the button.
- 3) Go to the setup screen (Click on **Setup** at the bottom of the screen)
- 4) Enter your **machine information** and ID.
- 5) Enter the type of measurement, **Straightness**, **Squareness** (1 optical square), or **Three-Squareness** (2 optical squares).
- 6) Enter the **number of data points** you would like to average over. (10 data points/second)  
The more noisy an environment, the longer you will want to average the data (around 1 minute, 600 data points at maximum)
- 7) Enter the **known errors** (in microradians, 1 microradian = 4.8 arcseconds) of the optical squares or 0 if not known.
- 8) The Setup Graph: Enter the first axis with the ball being the position of the laser head and the square being the position of the quad detector.  
Note: It is important to know which direction your beam is pointing.
- 9) Determine which piece is fixed, the **quad detector** or the **laser head**.
- 10) Rotate the quad detector icon so that the arrows are pointed in the correct MACHINE axes.  
To rotate, click the left mouse button on the **quad detector square** icon.
- 11) Edit the **measurement setup**, enter the start/end MACHINE coordinates and the number of points.
- 12) Press **View/Edit** to check your increments.
- 13) If you would manually like to change a point, change the values in the boxes, and click the **Positions Equally Divided** box to off.
- 14) After completing the first axis, press the **Measurement 1** button.

Squareness Measurement Setup Screen (Fig. 7-2, 7-3)

- 15) Setup your system in the second axis. Repeat steps 10-14. Repeat up to 3 times (if you have chosen 3 squareness).

16) After you are finished setting up the measurement, a setup completed message will appear. Press **Save Configuration** and enter a filename. A message will ask if you want this file to be the default file. If you answer **Yes**, this setup will become the default configuration.

17) Press **OK** to exit the setup screen. You are now ready to take measurements.

Taking DataPoint for a Squareness Measurement (Fig. 7-4)

18) Align the quad detector according to your setup and the procedure in the User's Guide. Last minute changes may be made in the bottom left hand graph of the measurements.

19) Press **Start**. Move to each point along the first axis and press the **Take** button. A countdown of data points being averaged is shown. When you are done with your first axis, the Take button will change into **Start Axis 2**.

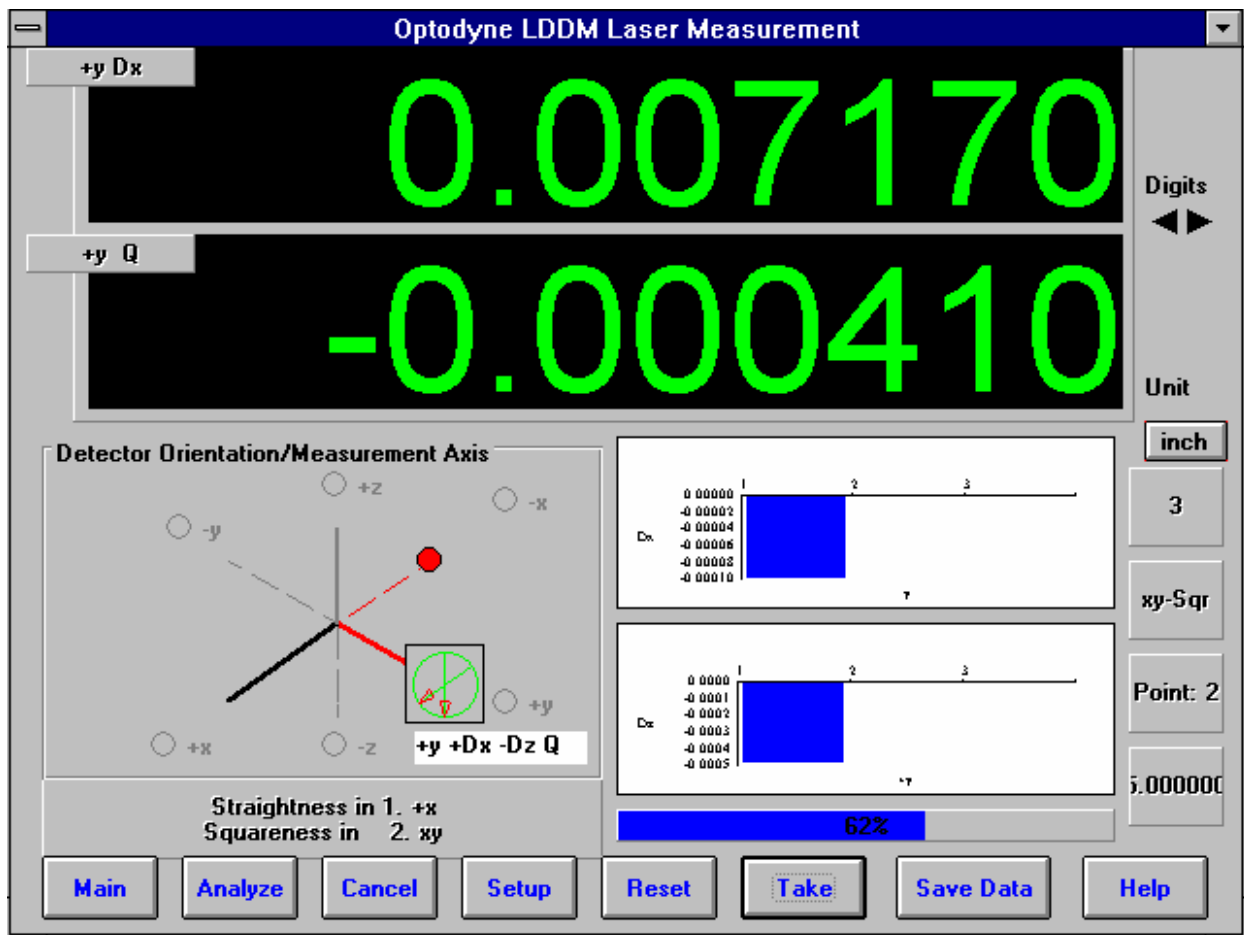


Fig. 7-4 Manual Squareness Data Collection

20) Setup your second axis and press the **Start Axis 2** button, repeat 19.

- 21) After finishing all of your data points, a save file message will appear. Press **Yes** and type in your **filename** to save your data (the extension of .SQR is automatically added).
- 22) Check your results by clicking on the **Analysis** button and opening your file for squareness.
- 23) The squareness reading you will get is + for greater than 90 degrees, - for less than 90 degrees, and will ALWAYS represent the angle in the +XYZ planes (e.g. +XY, +YZ, +ZX).

## 7.4 Squareness Data Analysis (Fig. 7-5, 7-6)

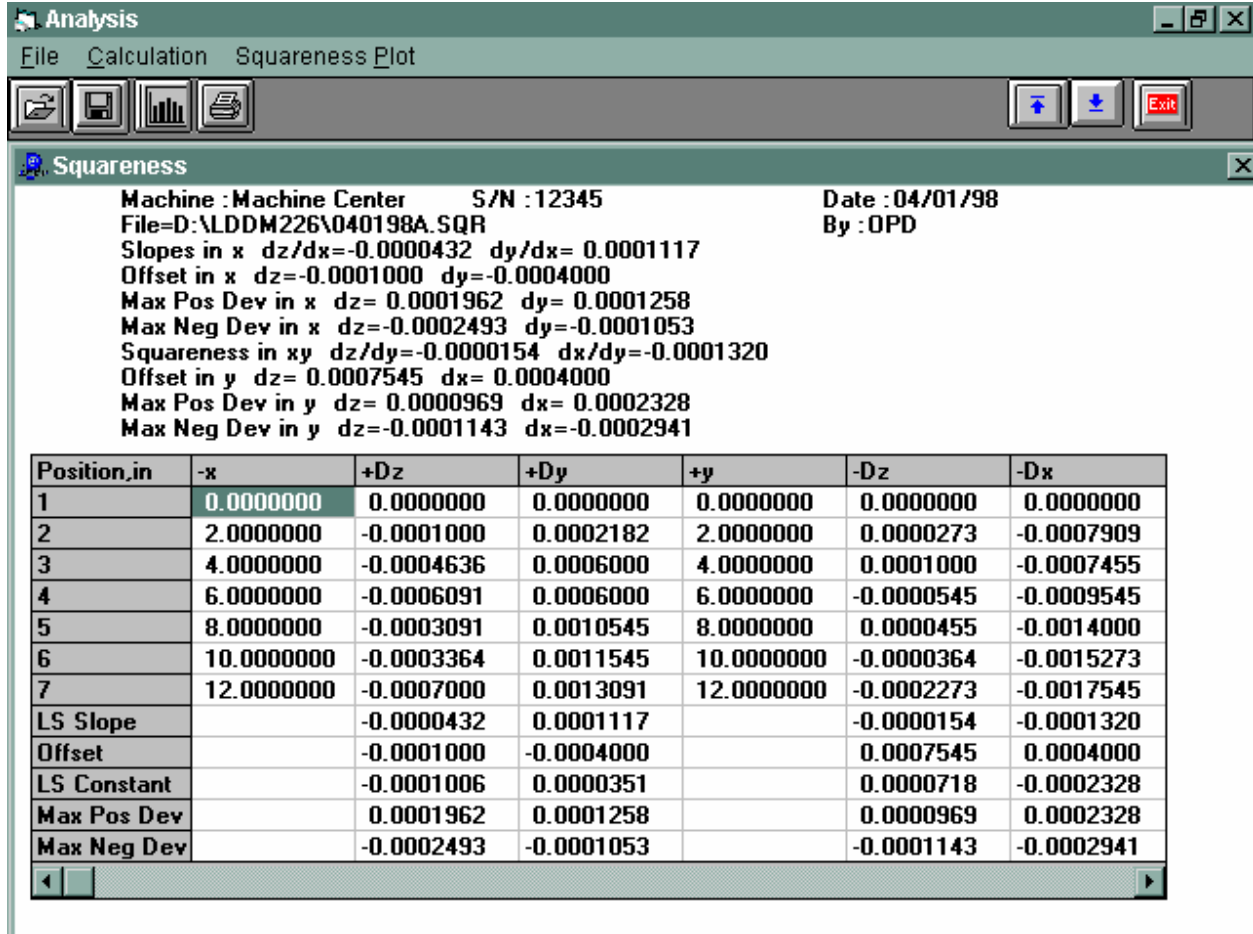


Fig. 7-5 Squareness Measurement Data Table

Under the **File Menu**, you can open a **new** data file, **save** a data file, set your **printer type**, set your **printer style**, or return to the **main menu**. When loading a file, choose the files with the extension of .SQR for squareness. You can only **print data** tables using the print function under this heading..

To view the Squareness data and graphs, first click on **Calculation** on the menu bar. This will convert the data points shown on the table to the Least Square Fit lines, their intercepts and their slopes.

These lines can be seen by clicking the **Bar Graph** choice on the second bar.

The followings are the definitions in the straightness data table, squareness data table and plots.

**Off-set** : this is the initial position of the quad-detector from the laser beam center.

**LS slope and LS constant** : this is the least square fitted straight line LS slope is the slope and

LS constant is the constant of the fitted straight line ( $y = \text{LS constant}$  when  $x = 0$ ).

**Max Pos Dev and Max Neg Dev. :** this is the maximum distance from the least square fitted straight line in the positive direction and negative direction, respectively. Usually, when these values are too large, you may need to measure the squareness again.

**Squareness Plot:** This will show the angle between the POSITIVE X, Y and Z axes of your machine (depending on which axes were measured). Note: This angle MAY or MAY NOT be the one you measured, but the angle has been calculated out to the machine's positive axes.

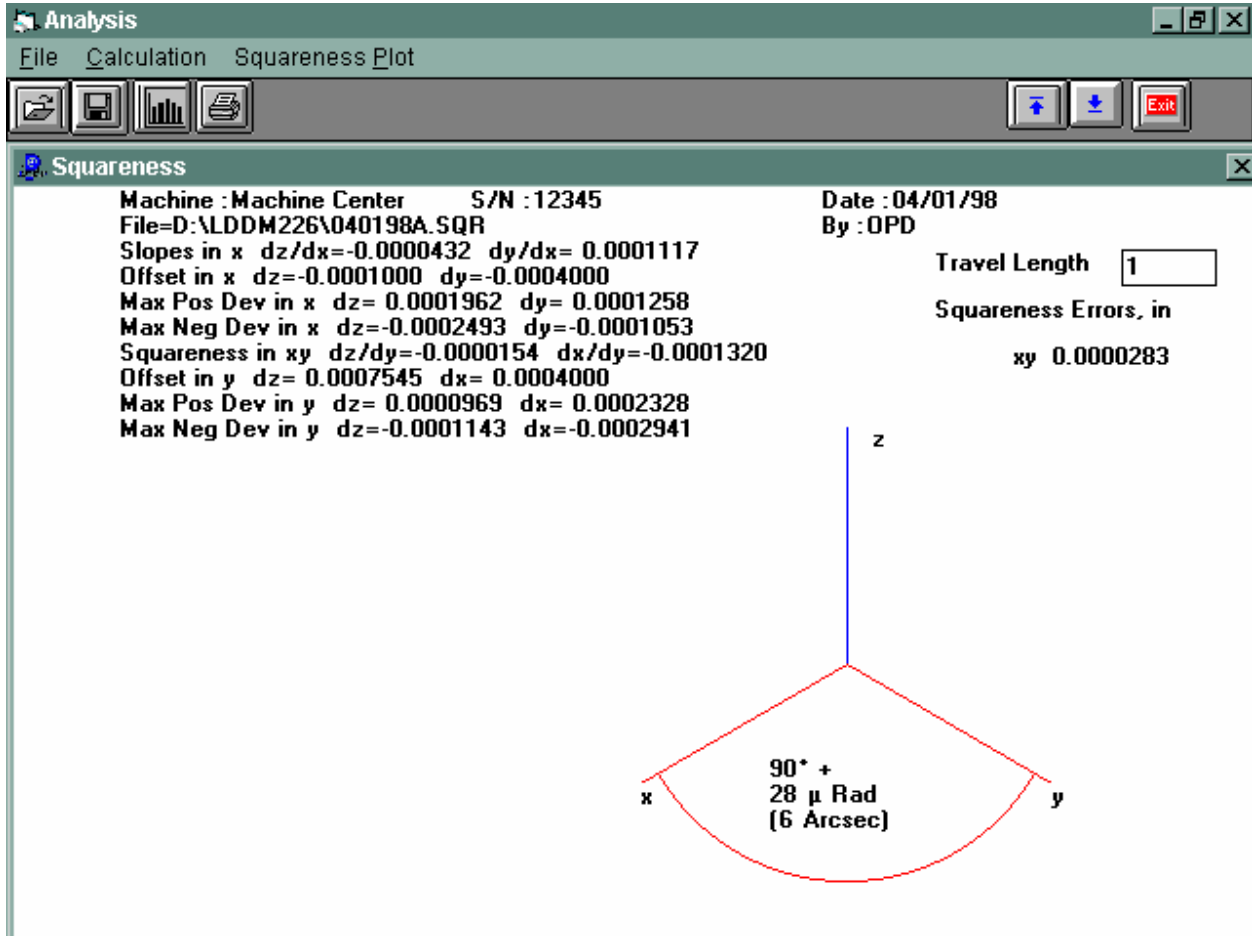


Fig. 7-6 Squareness Measurement Data Plot

## 7.5 Adjusted Straightness and Averaged Straightness

The squareness data consists of two straightness measurement. Click on the **Adjusted Straightness**. The table will show the adjusted straightness values. Click on the graph to display the two plots shown in Fig 7-7. Here both end points are zero.

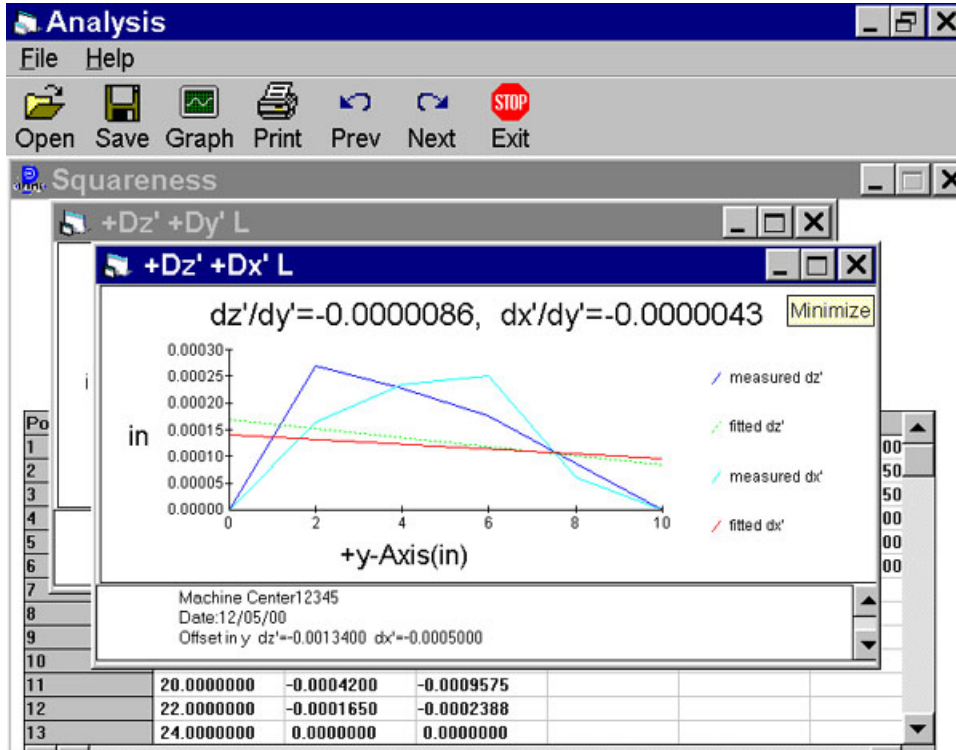


Fig. 7-7 A Plot of Adjusted Vertical and Horizontal Straightness. The Straight Line is the Least Square Fit.



The least square fitted line is a straight line with off-set and slope. Click on the **Averaged Straightness**, the table will show the averaged straightness values. Click on the graph to display the two averaged straightness plots shown in Fig. 7-8. Here the least square fitted line is rotated to be zero off-set and zero slope.

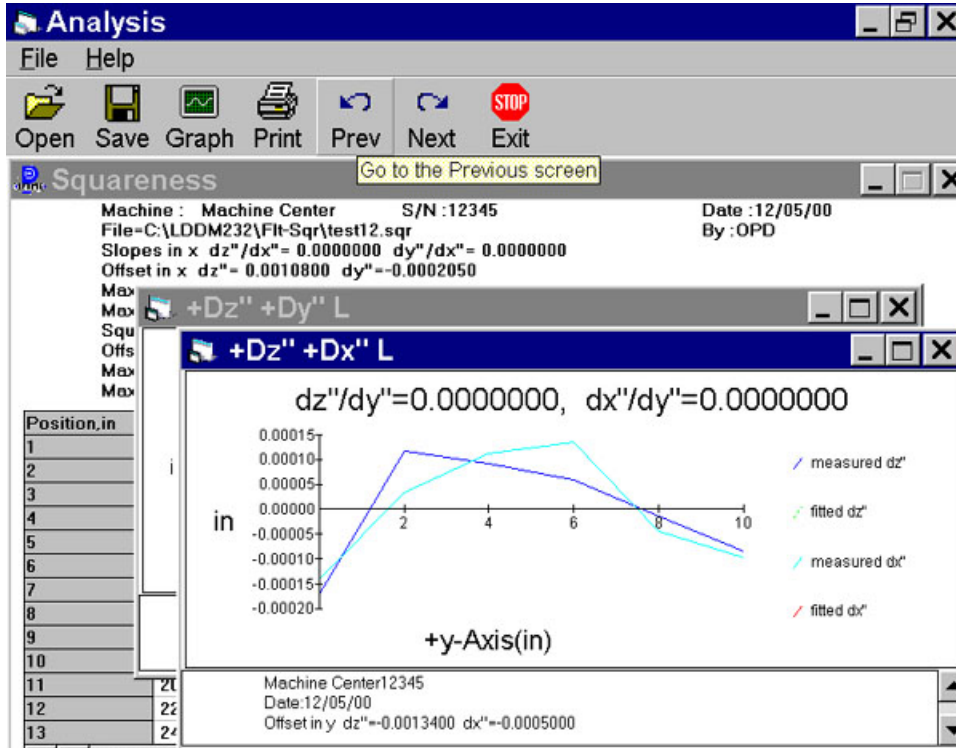


Fig. 7-8 A plot of Averaged Vertical and Horizontal Straightness. Here the Least Square Fit Line is at Zero and Parallel to the Axis of Travel.

The following icons have the following function in Analysis:



Open a new data file.



Save a data file.



Graph a data file (After graphing, you may also change the scaling of the graph by checking X on adjust grid).



Print a data graph (for printing data tables, use the Print option under the “File” heading)



Moves to the previous screen.



Moves to the next screen.



Exits the program.

## 8.0 Rotary Table Measurements

The rotary measurement setup is similar to the Straight / Angular measurement, except the starting position is always zero. The least increment is 1 degree with an increment of 1 degree up to 10 degree. Briefly, a dual-retroreflector is placed on top of a small rotary table supplied by Optodyne, which is in turn mounted on the test device, a rotary table or stage. The test device is programmed to move in incremental steps of 1 to 10 degrees. At the end of each step, the data will be recorded. Then rotate the small rotary table in the opposite direction to prevent laser beam break. At the end of the rotation the residual value will be recorded. Hence the rotational angle of the test device and the rotational angle (in the opposite direction) of the small rotary table are all recorded. The software will calculate the difference (error) data from both the forward and reverse angular measurements and will provide full data storage, analysis and plots. For more detailed setup, see user's guide section 12.

### 8.1 Rotary Table Measurement Main Display ( Fig. 8-1)

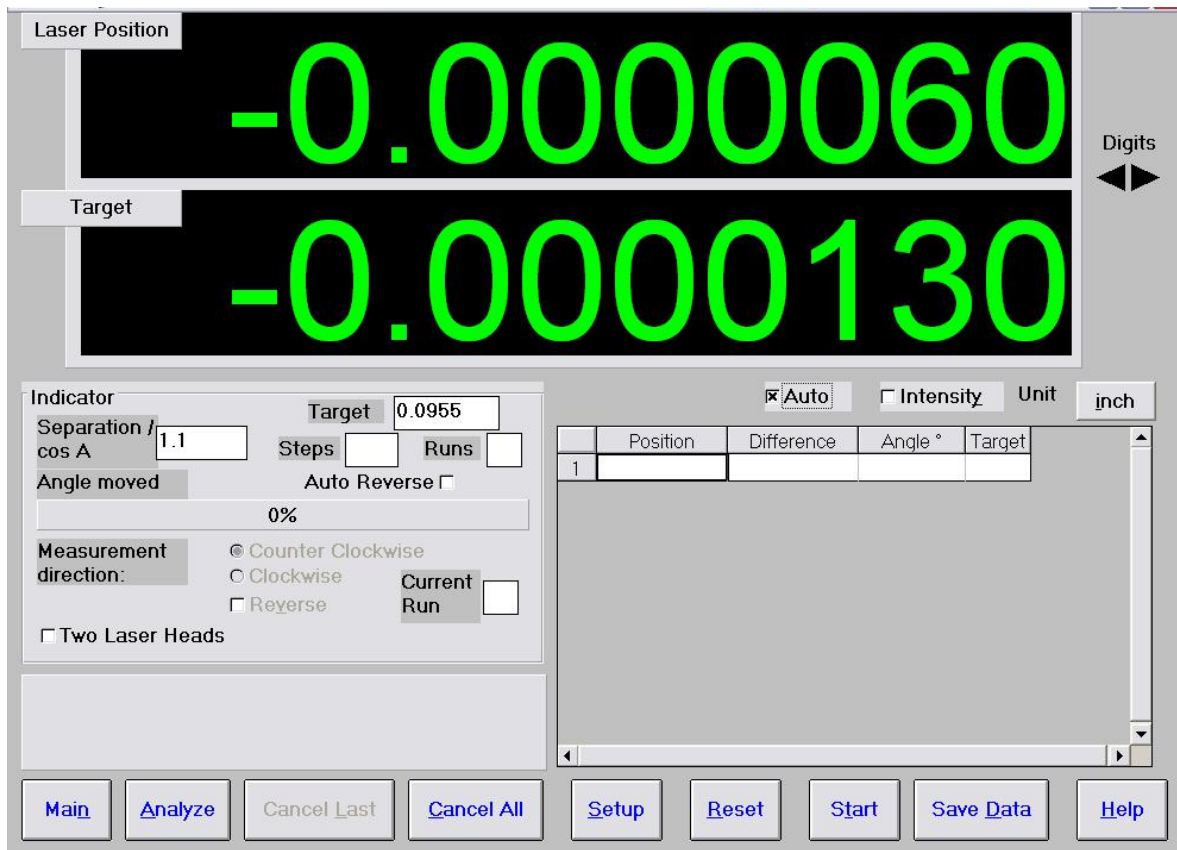


Fig. 8-1 Rotary Table Measurement Main Display

The display shows the linear distance traveled on the top line, and the difference between LDDM #1 and LDDM #2 for the second line. If the second line value is twice of the top line value, the center of rotation is exactly between the centers of the two retroreflector. (See user's guide section 12.5.4 for alignment procedure).

Choices on the Main Display are

**Separation :** This is the separation of the dual-retroreflector. Typical value is 1.105 in or 28 mm. More accurate value could be obtained by calibration.

**Steps, Runs and Auto Reverse:** These are for motorized turn table. For example, 3 bidirectional runs of 10 degrees increment, set steps=36, runs=3 and click on Auto Reverse. Maximum number of runs is 9. The saved data file is for a single run. For 5 runs, the data will be saved in 5 data files with same name, but with the run number added before the extension .rot.

**Angle moved :** This box show the angular movement of the rotary table. 50% is about 10 degree and 100% is about 20 degree. When the angle moved is more than 10 degree, there is a message asking the operator to move the retroreflector back to zero. However, as long as the laser intensity is okey, you can continue taking data.

**Measurement direction :** If you want counter clockwise rotation to be positive, click counter clockwise. Otherwise click clockwise. For bi-directional measurement, after you reached 360 degree and taken the data, click the "Reverse" button. Move the dual-retroreflector (small table) back to zero and move the stopper to the other side. Take the residual reading then continue in the reverse direction.

**Two Laser Heads:** Click this button, if two laser heads are used.

**Auto :** In the automatic data collection, click this to change to manual data collection. Click again to change back to automatic data collection. For automatic data collection, the return of the motorized turn-table is triggered after the data is collected. To setup the Auto mode, use the PC trigger cable to connect the motorized turn-table controller ( Port marked Discrete I/O ) to the LDDM Processor ( Port marked RS-232 ). Also, select program 31 for 10 degrees CW, Program 32 for 10 degrees CCW, program 33 for 5 degrees CW and program 34 for 5 degrees CCW.

## 8.2 Rotary Measurement Setup Screen

Click on the setup box, the screen will show the setup menu.

The screenshot shows a software window titled "Rotary Table Setup". It is divided into several sections:

- Identification:** A group box containing four text input fields: "Machine" (Machine Center), "S/N" (12345), "By" (OPD), and "Date" (04/02/98).
- Rotary Table Measurement:** A group box containing a "Laser head separation" field with the value "1.105" and the unit "inch". Below it are two radio buttons: "Manual" (unselected) and "Automatic" (selected).
- Auto measurement:** A group box containing two text input fields: "Trigger dwell" with the value "1" and the unit "sec", and "Vel Threshold" with the value ".01".
- Buttons:** A row of five buttons at the bottom: "Automatic Measurement", "New Config File", "Save Configuration", "Cancel", and "OK".

Fig. 8-2 Rotary Measurement Setup Screen

**Identification:** these are information for your own identifications.

**Laser head separation :** This is the same box as show in the previous screen. You may enter a more accurate value after the calibration.

**Manual :** The “start” button will turn into a “take” button after the measurement begins. At every collection point, this button will have to be clicked.

**Automatic :** The software will collect data every time the dual-retroreflector moved and stopped.

**Trigger dwell :** For automatic measurements, the settling time of the machine is entered here. Choose a value of at least 2 seconds less than the programmed machine dwell time.

**Vel threshold :** For automatic measurement, this is the threshold that the dual-retroreflector must drop underneath, so that a data point can be taken.

The total travel is set to 360 degree. For measurement less than 360 degree, a more accurate separate value should be used. The increment can be varied from 1 degree up to 10 degree. It has to be an integer of degree.

**New Configuration :** You may load previous configuration file if you have one for this particular machine.

**Save Configuration :** This updates the configuration file so that the data seen on the screen will appear each time LDDM for Windows is run.

### **8.3 Example of a Rotary Table Measurement**

Before starting, please make sure all the hardware and software is installed properly.

- 1, Double click on Optodyne logo to get the main menu.
- 2, Click on rotary calibration, a screen with two LDDM readings will show up.
- 3, Click on “set up” to set up automatic data collection or manual data collection.
- 4, ‘Dwell time’ is the time delay between stage stopped and data collection. It may be zero or up to a few seconds.  
  
“Velocity threshold” is the maximum vibration motion of the stage. Typically set to 0.001 to 0.00001. For noisy environment use large number.
- 5, Set the beam separation value to ----- (default 1.105).
- 6, For automatic data collection, click reset, then click start. The initial position will be recorded.
- 7, Move the stage to be calibrated to the first position (at least 1 degree, no more than 10 degree) then stop. The data will automatically be recorded after the dwell time.
- 8, Move the second stage in the opposite direction to zero. The data will automatically be recorded.
- 9, Continue steps 7 and 8 until reading 360 degrees.
- 10, Select “save data” to save data file with extension .ROT .
- 11, To analyze data, click on “Analyze” in the bottom or in the main menu.

- 12, Open the data file.
- 13, Click on “data selection” and select “angle”.
- 14, click on down arrow to get to the end of data file, or at 360 degrees. Double click and type 360. (For data file less than 360 degrees, double click the last target reading and type the actual angle in degrees). Move the cursor to target readings less than 360 degree and click again. The data file will move to the beginning and the “calibration” button will stand out.
- 15, Click on the “calibration” button. New data files will be calculated, and the new beam separation number will be calculated. (Record this number and enter in Step 5). The graph on the right hand side will be replotted.
- 16, Please note that data may be collected at 1 degree increments, 2 degree increments, up to 10 degree increments automatically. After 10 degrees the second stage must rotate in the opposite direction to zero and stop. The zero position data will be recorded automatically.
- 17, For hands off operation, the second rotary table with the dual-retroreflector needs a control signal either from the rotary table to be calibrated, or from a signal generator. Please make sure the time between movements is much large than the dwell time set in the data collection software.

## 8.4 Rotary Data Analysis Menu

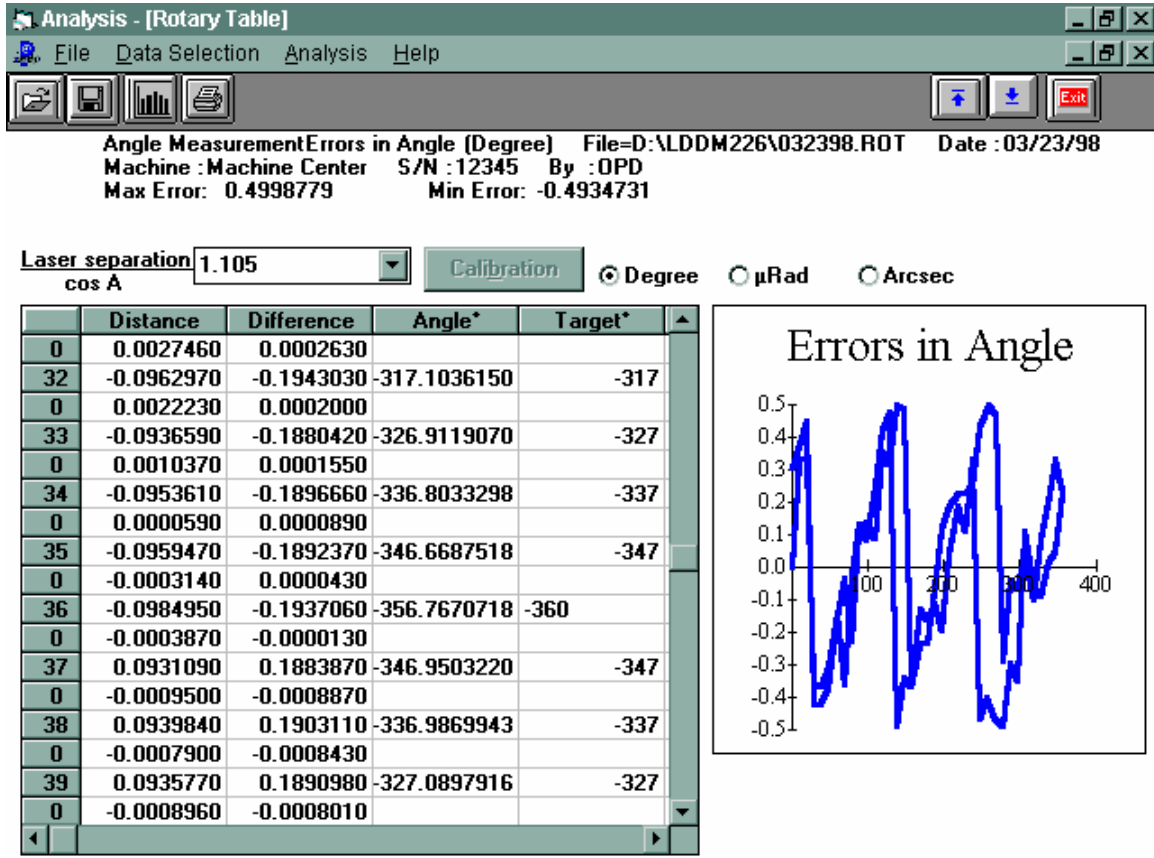


Fig. 8-3 Rotary Data Analysis Table

Under the “File Menu”, you can open a new data file, save a data file, set your printer type, set your printer style, or return to the “Main Menu”. When loading a file, choose the files with the extension of .ROT for rotary data. You can only print data tables using the print function under this heading.

To analyze data, go to the target readings and select the reading nearest to the 360 degrees. Double click and type 360. (For data file less than 360 degrees, double click the last target reading and type actual angle in degrees). Move the cursor to target readings less than 360 degree and click again. The calibration box will stand out. Click on the calibration, new data files will be calculated, and the new beam separation value will be calculated. (Record this value and enter the value in the beam separation box in the setup menu). The graph on the right-hand-side will be replotted as shown in Fig. 8-4 .



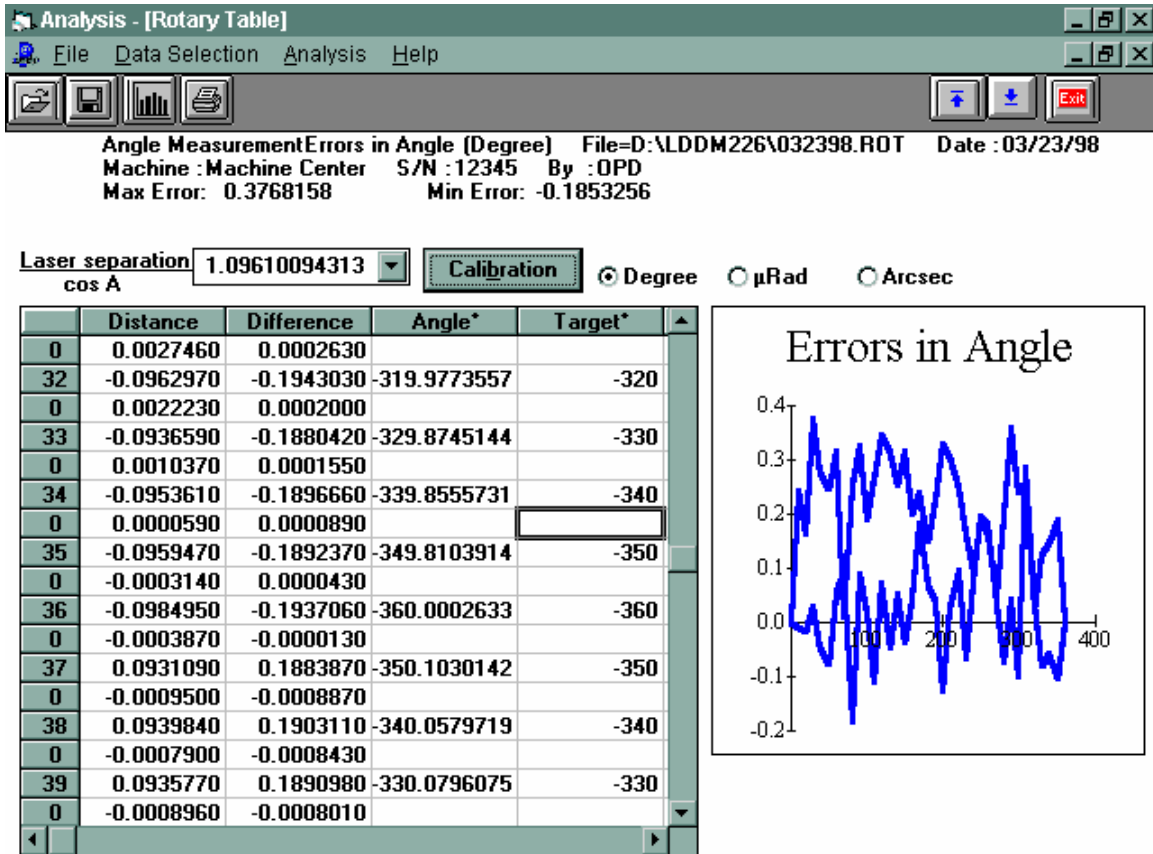


Fig. 8-4 Rotary Data Analysis Show Error Table

To print error table or error plot, move the cursor to “Analysis” and click on “error”. The error table is shown below:

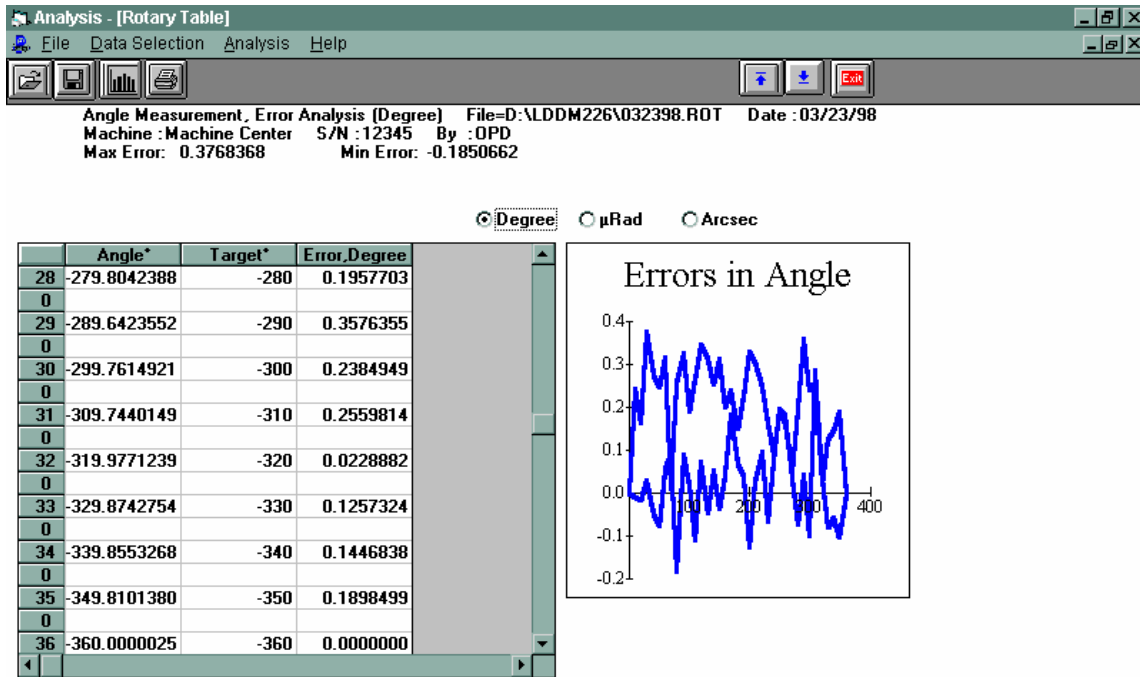


Fig. 8-5 Rotary Data Analysis Show Error table

To get a line plot, click on the graph icon. To print the graph, click on the printer icon. An error plot is shown in Fig. 8-6 .

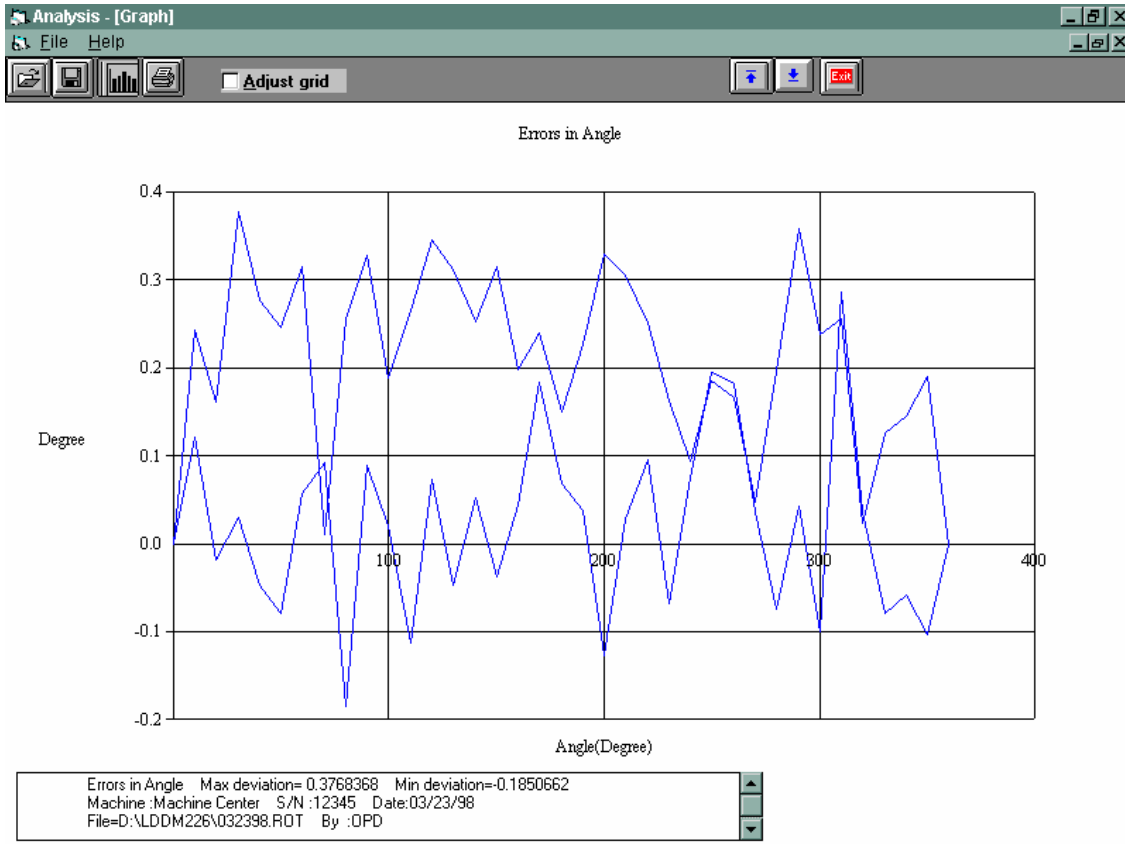


Fig. 8-6 Rotary Measurement Error Plot in Degree

## 9.0 Circular test (Laser/Ballbar)

### 9.1 General Description

For general description, windows, installation and starting LDDM program, see section 7.6.

### 9.2 2D Time Base Data Collection

The 2D time base collects data through a special PCMCIA card. The maximum data rate is 10,000 data/sec, and the maximum number of data point is 24,000 points/record. Click on the “2D time base” button in the main menu to get the data collection screen as shown in Fig.8-6. For two PCMCIA cards, the available address are: 350,110, 220,100 and 300.

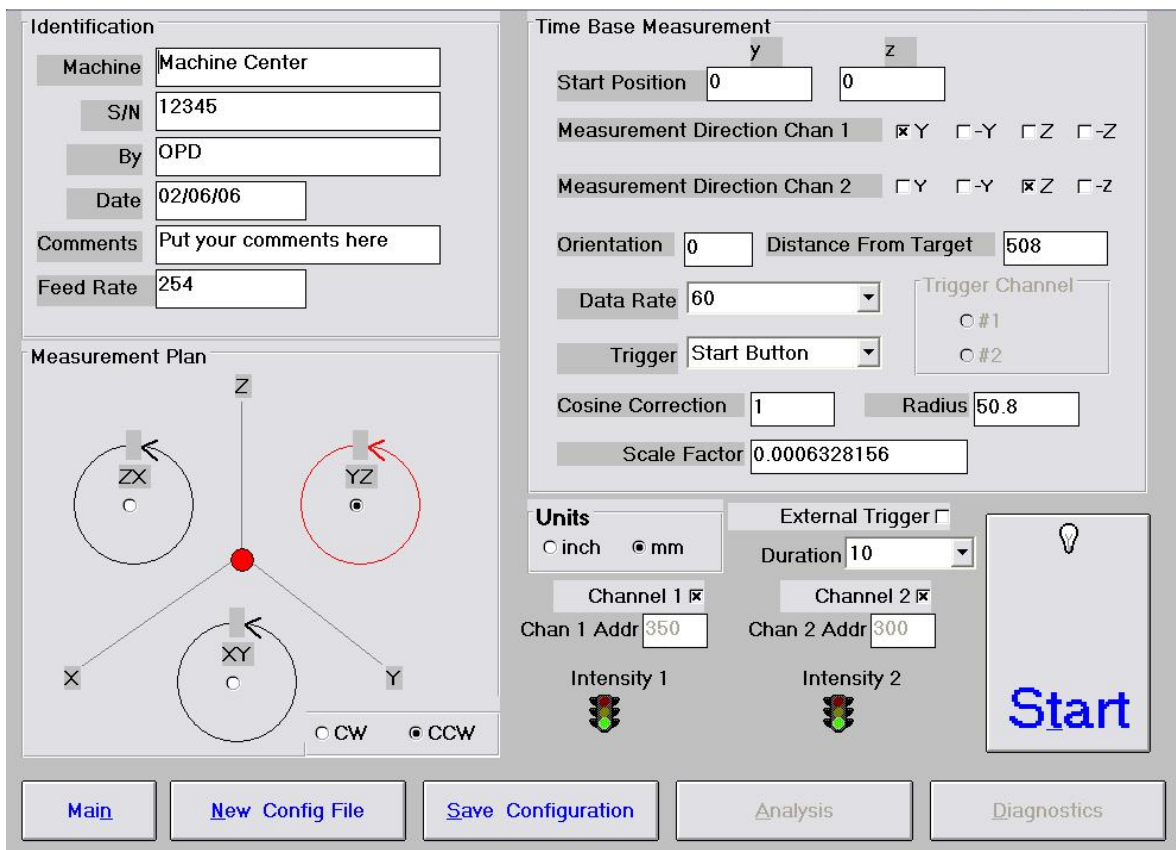


FIG. 9-1 2D TIME BASE DATA COLLECTION SCREEN

Choices on the data collection screen are as follows:

**Identification:** Input the machine type, serial number, operator, date, your comments or remarks and feed rate in/min or mm/min.

and direction of the circular path, either cw or ccw.

**Time base measurement:** Enter start position, measurement Direction ( -x means the laser beam is pointing in the -x direction), and distance from the target. Click positive axis direction when the laser beam is pointing in the positive axis direction. The orientation is the angle between the measurement direction and the first-axis direction. The data rate is determined by the selected feed rate and radius (see section 8.5.3). Trigger mode is “start button” only. The displacement or velocity trigger will be added later. Click the External trigger if you have the external trigger option. The external trigger is used for external clock or external synchronized events, such as nonstop leadscrew calibration. Cosine correction is 1 for normal operation. It is  $2\cos(\text{angle})$  for double pass and the angle is the angle between outgoing and return beams. The radius is the radius of the programmed circular path. The scale factor is 0.000024914 in or 0.000632816 mm. Click “in” for inch unit and “mm” for metric unit. Click both channels for 2 channel data collection.

**Data Rate:** Select a data rate up to 10,000 Hz.

**Duration:** Select a duration. The maximum duration is limited by the maximum size of the record, 24,000 data/record.

**External trigger:** For external trigger, click on “External Trigger” box. A special cable with external trigger connector is needed. The trigger pulses should be TTL standard, the pulse width larger than 30  $\mu\text{sec}$ , and the rep rate less than 3000 Hz. For 2 channels, connect the trigger pulses to channel #1 and both channels will collect data synchronized with the trigger pulse. The data age is a few microseconds.

**Intensity:** The green light indicates the laser is aligned properly and the red light indicates the alignment is off. Block the laser beam to check whether the PCMCIA Card is installed properly.

**Start/stop:** Click “start” to start the data collection and “stop” to stop the data collection. After stop, enter the filename to save the data collected. The extension .2dr will be added automatically. After select a data rate, select a duration. If you want to stop data collection before the selected time duration, click “stop” to stop data collection.

### 9.3 Data Analysis

To analyze data, go to the main menu first then click on the “analysis”. Click on “file” to open a file with extension .2dr. The file usually is very large, please wait a while for the file to be ready. After the .2dr data shown on the screen, click on “data selection” and “displacement 1”.

The displacement values will be calculated and displayed as shown in Fig 9-2.

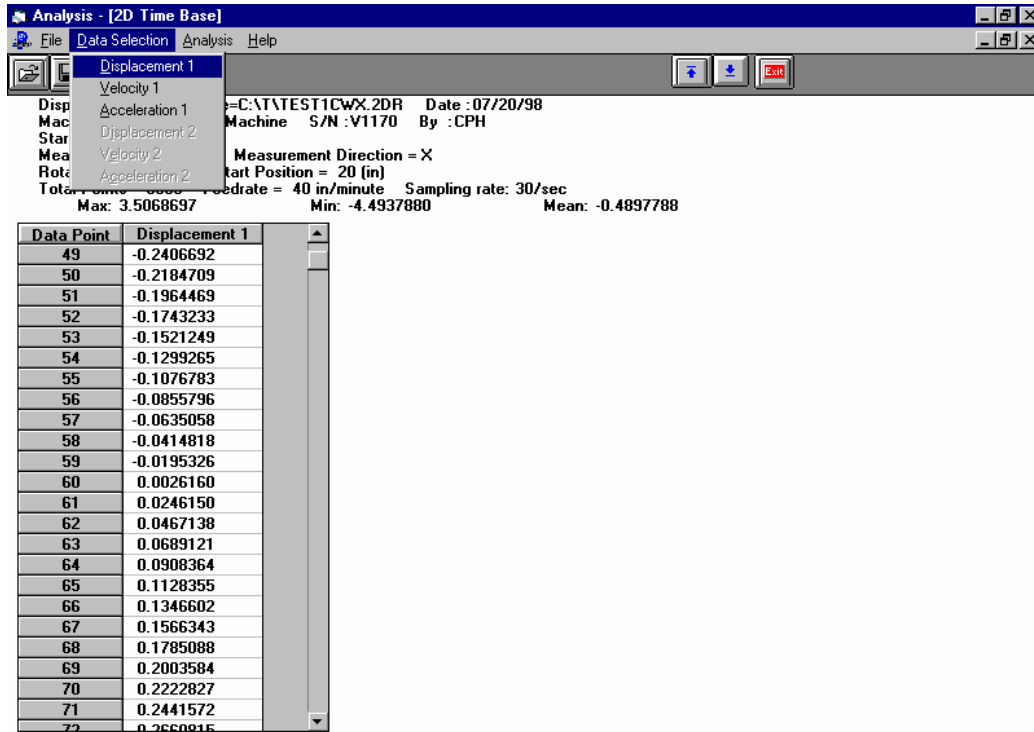


FIG.9-2 THE ANALYSIS SCREEN WITH DISPLACEMENT DATA

After the displacement values are displayed, click on the “graph” to plot the displacement. A typical plot of the displacement is shown in Fig 9-3

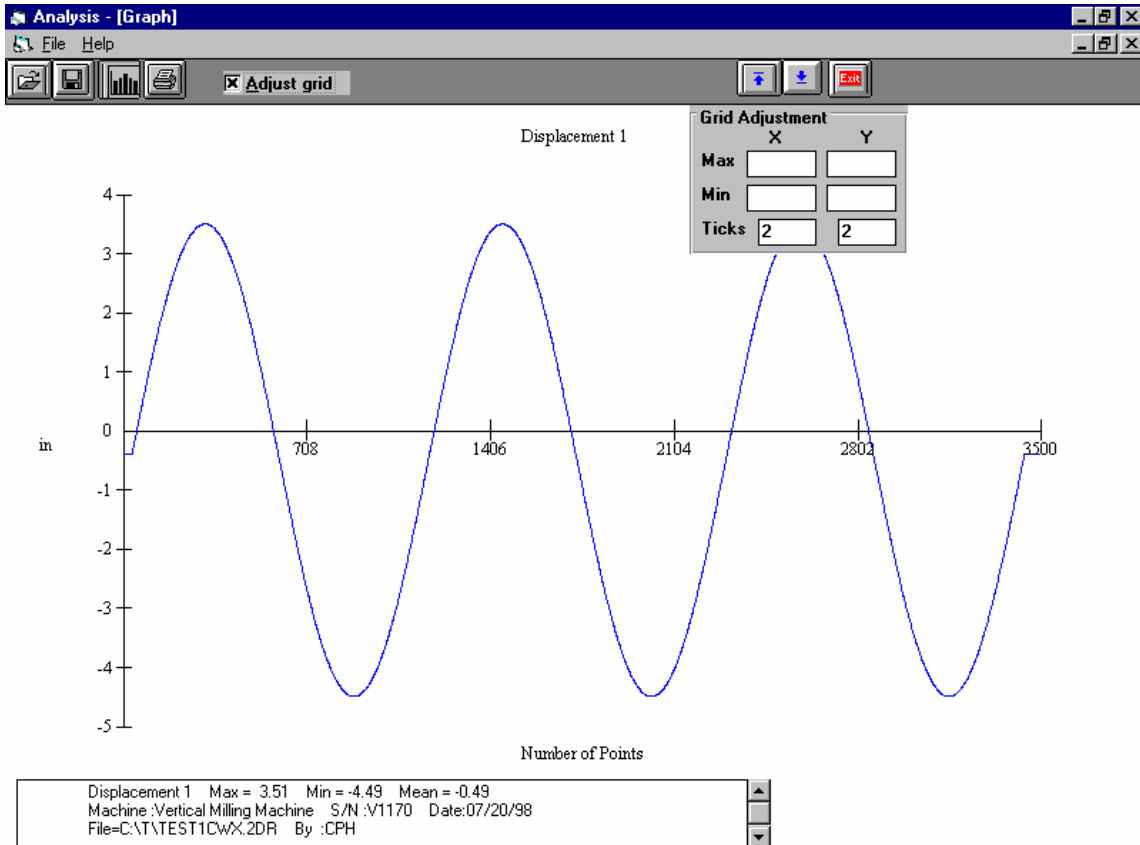


FIG. 9-3 A Typical Plot on Displacement Data

To generate a data file for polar plot, click on “file” and “save”. Select 2dd in the popup screen. Another popup screen asking the starting point and ending point of the data file. The starting point should be before the first maximum and the ending point should be at least 2 and  $\frac{1}{4}$  cycles after the first maximum. If not enough data, a popup screen will indicate so. Enter a filename to save the data file. The extension .2dd will be added automatically. A popup screen will show the actual starting point, number of points per cycle, ending point, and the data file is for one or two cycles. After click on “Yes”, another screen will popup for the change of number of points per cycle. You may enter an integer either larger or smaller than the default value. Please make sure that all 4 2dd files have the same number of points per cycle. We believe, 360 points per cycle is adequate. Of course, more points provide more resolution, but it also need more storage space and larger processing time. The default value is the existing number of points per cycle. If there is no change, press “enter” or click on “ok”, then another screen popup to change the shift. You may enter any shift value between  $-10$  to  $+10$ . The default shift is zero.

For some machine, the feed rate can not be controlled exactly, hence the number of points per cycle varies. It is more desirable to keep the number of points per cycle the same for all 4 files. Please note that to generate a complete circular path, 2 data files, one in the x-direction and the other in the y-direction (for xy-plan) are needed. The number

of points in these two data files should be the same. If one data file is 2 cycles and the other is 1 cycle, only one cycle of the data will be processed.

## 9.4 Circular Path

To generate a circular path, first to process all raw data files (.2dr) to generate the data files (.2dd).

Click on “analysis”, “circular”, “polar plot” and “ISO 230”, a screen will popup. The file cannot be entered by type the filename. Click on the right-hand-side to enter the files. The first line is cw, x-direction, the second line is cw, y-direction, the third line is ccw, x-direction and the fourth line is ccw, y-direction. For a complete circular path, 2 data files in the same cw or ccw rotation are needed. For both cw and ccw circular path, enter all 4 files. For most machine, click on “ok”. “sync” is for machines without velocity control. Please wait for the data files to be displayed on the screen. Click on “graph” to plot the circular path in polar plot as shown in Fig. 9-4.

Before the polar plot, a screen will popup and ask for the values of S1, S2, S3, S4, Rcw, Rccw, sc and scc. These shifts and rotations are used when the measurement directions are not perpendicular to each other or the measurement directions are not along any axis direction.

For the measurement of servo mismatch or squareness errors, it is desirable to measure in the directions 45 degree from the axis. Hence, in the polar plot enter Rcw and Rccw equal to 45 degree or – 45 degree.

Positive S shifts in the ccw direction and negative S shifts in the cw direction. S is the number of points to be shifted. It is zero or an integer. S1, S2, S3, and S4 are the shifts in cwx, cwy, ccwx and ccwy respectively. Positive R rotates in the ccw direction and negative R rotates in the cw direction. The maximum angle of rotation is +/- 180 degree. Rcw and Rccw are rotational angles for cw measurements and ccw measurements respectively. Sc and scc are shifts between cw and ccw rotations respectively.



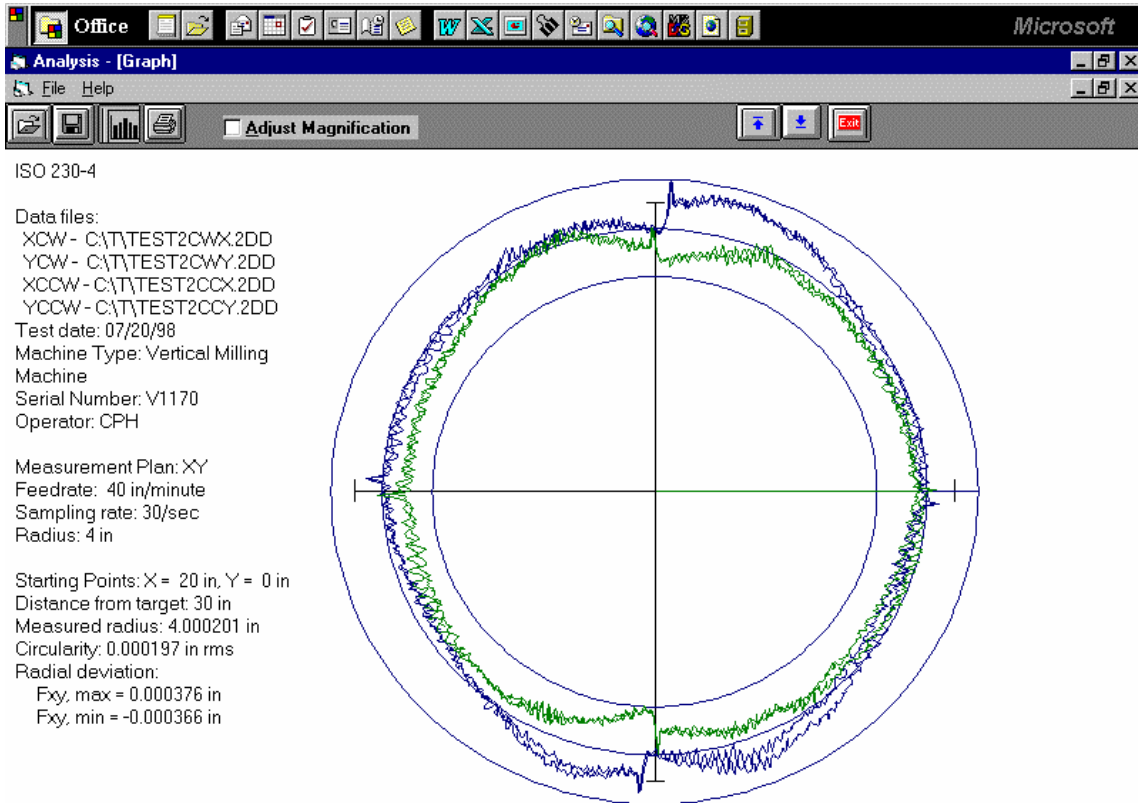


FIG. 9-4 A TYPICAL POLAR PLOT OF THE CIRCULAR PATH

There are 3 circles on the plot. The radius of the middle circle is the measured radius. The radius of the largest circle is the measured radius plus the  $F_{xy,max}$  and the radius of the smallest circle is the measured radius minus the  $F_{xy,min}$ . Or the distance between the largest circle and smallest circle is equal to  $F_{xy,max} - F_{xy,min}$ . Click on the “adjust magnification” to change the magnification of the plot. The circularity is the rms value of the deviations from the measured radius.

To view more details such as vibration frequency, backlash values, reverse spikes, etc., click on “analysis”, “circular”, “polar plot”, “linear plot”, and “one of the 4 files”, then click on the “graph” button. A popup screen will let you input the starting point and the ending point of the plot. A typical linear plot is shown in Fig 9-5.

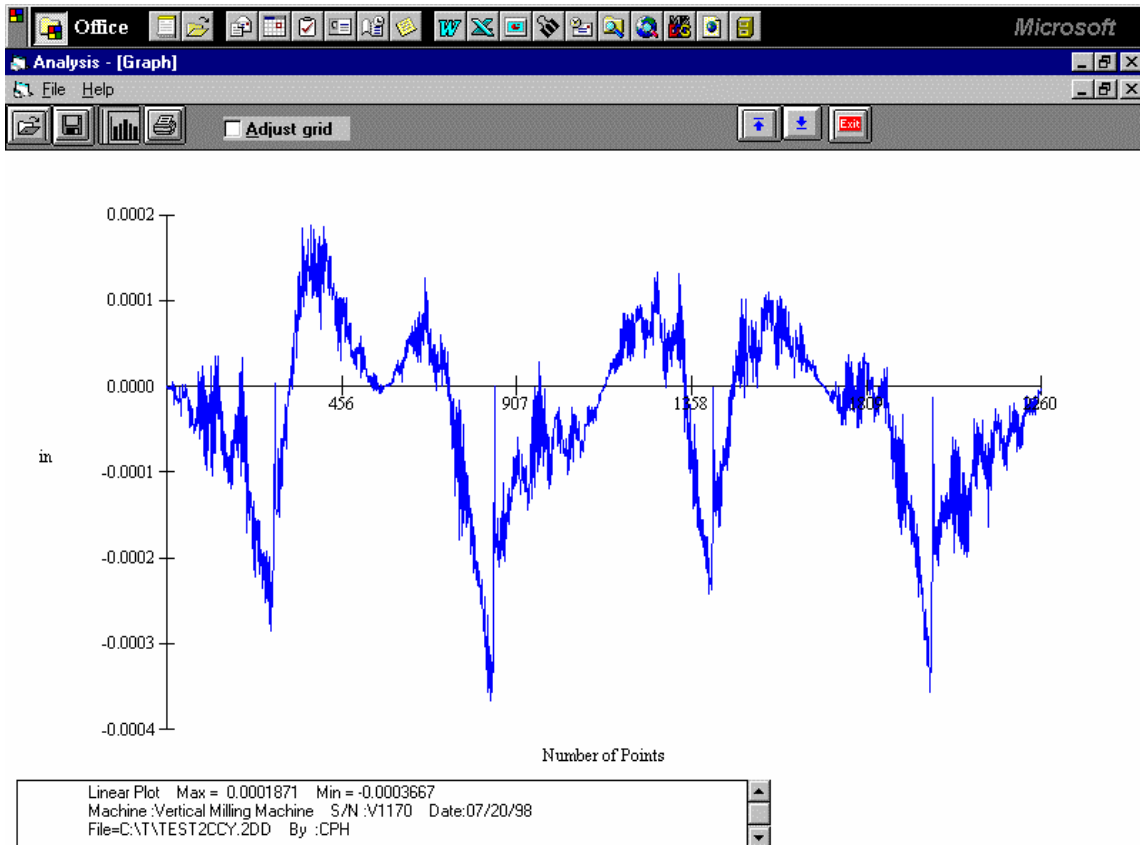


FIG. 9-5 A Typical Linear Plot of the Circuit Path

You may view more details in a region by enter the starting point and the ending point near the region of interests. You may also adjust the grid to change the vertical scale. Click on “Save” and select “xyfile”, then enter a file name in the popup screen, 4 files with extensions xcw, ycw, xcc, ycc will be generated. For multiple runs with the same setup, up to 3 runs can be entered and plotted in the same graph.

### 9.5 Output Data File for “Polarcheck” or “Polaranalyser” Software

To use a commercial analysis or diagnostic software, such as Polarcheck\* or Polaranalyser, a compatible data file can be generated. In the previous section, before click on “graph” to plot the circular path in polar plot as shown in Fig.8.8, click on the “file”, then “save”, a screen will popup. Enter a filename and a file will be generated with extension .rtb.

This data file is similar to a telescoping ball-bar data file. The first 24 line header is machine information and parameters. Run count is how many 360 degree cycles. Max Targets is the number of points in 1 run or a 360-degree cycle. Direction -1 is cw and +1 is ccw. The best R is the actual measured radius. Since there is no center offset, hence the best X and Y are all zero. The first column is the point number and the second column is the deviation in the radial direction. EOF is end of file.

- \* For more information, check the Polarcheck Analyser Web Site:  
<http://kiila.me.tut.fi/projects/dbbbros.htm> or e-mail [jouni.holsa@qplus.fi](mailto:jouni.holsa@qplus.fi)

A typical polar plot similar to Fig.9-4, but using the .rtb data file and the Polarcheck software, is shown in Fig.9-6.

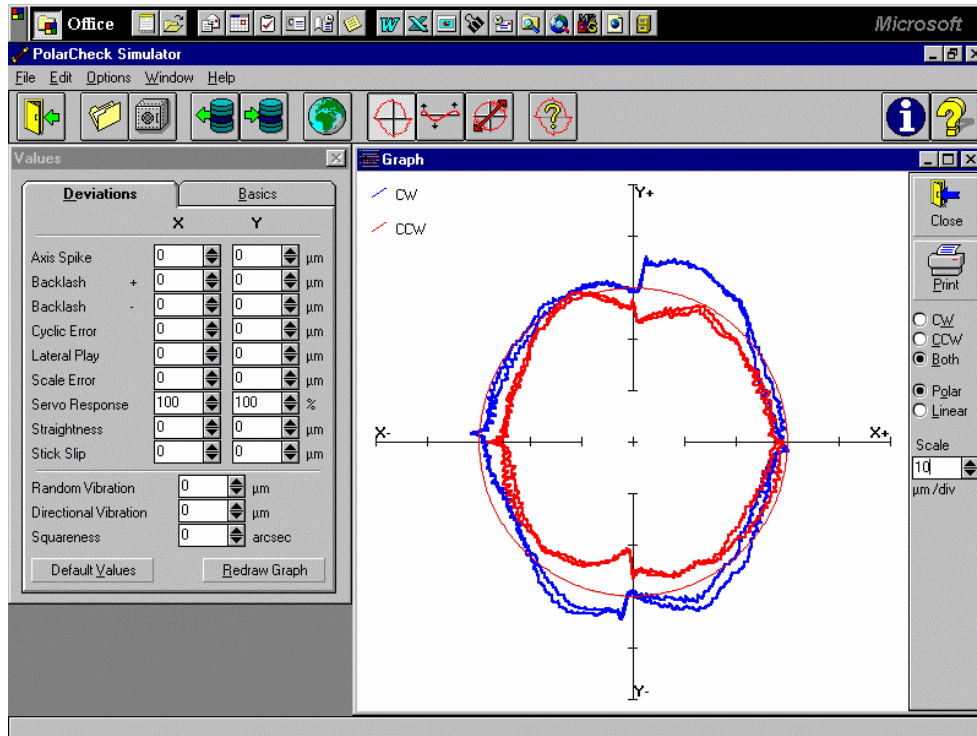


Fig. 9-6 A TYPICAL POLAR PLOT USING POLARCHECK

## 9.6 “rtb” Button to Generate Output File Directly

To generate an output file directly from 2dr files, click on the “rtb” button. A screen will popup and allow you to enter 4 2dr files. You may click on “ok” or “sync”. For most machines, click on “ok”. “sync” is for machines without velocity control. Enter the filename to save the output data file. To verify the output data, click on “graph” to view the polar plot. In case of error, use the procedure in the previous section.

## 9.7 Velocity, Acceleration and Other Measurements

As shown in section 9.3, the displacement values can be displayed or plotted. Click on the “velocity 1”, the velocity values are calculated and displayed. Click on the “graph” to plot the velocity profile. Similarly, the acceleration values can be calculated by click on the “Acceleration 1” button. To remove a spike or spikes, click on the “R-spike” button, and specify the starting point and the ending point, the spike or spikes between

the starting and ending point, will be removed and the displacement values recalculated. Please note that, remove the spikes may distort the circular path.

The 2D time base data collection can collect data up to 1000 Hz. It can also be used for many other applications, such as small increment displacement test, etc.

## 9.8 Feedforward and Velocity Feedback

For some controllers without the feedforward function or the feedforward function is not turned on, there is a notch on the velocity profile as shown in Fig. 9-7. These velocity notches may cause non-uniform cutting and effect the surface finish of the part.

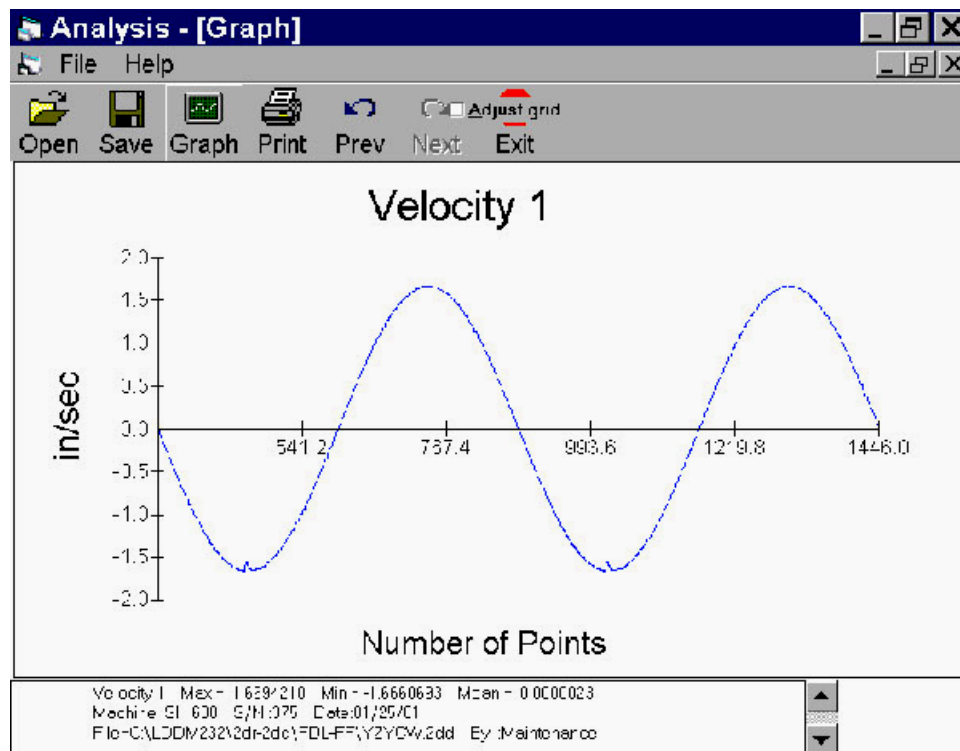


Fig. 9-7 A Plot of Velocity Profile without Feedforward. There are Notches near the Maximum Velocity in the Negative Direction.

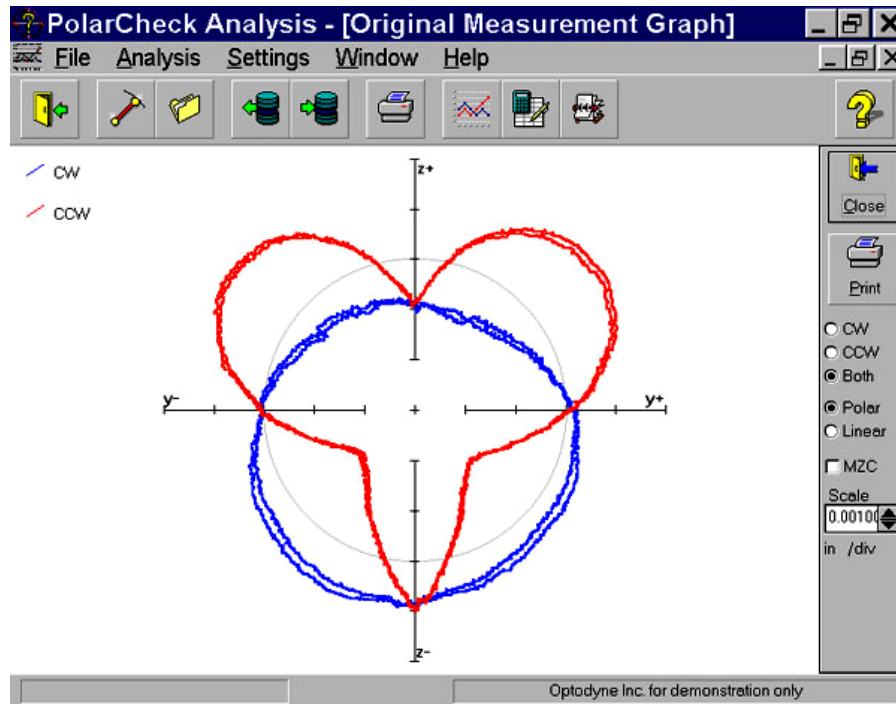


Fig. 9-8 A Polar Plot of the Circular Contouring Error without Feedforward

The large non-roundness shown in Fig. 9-8 is caused by the velocity notches. Once the feedforward function is turned-on, the velocity notches in Fig. 9-6 are removed and the polar plot shown in Fig. 9-9. The non-roundness is reduced considerably.

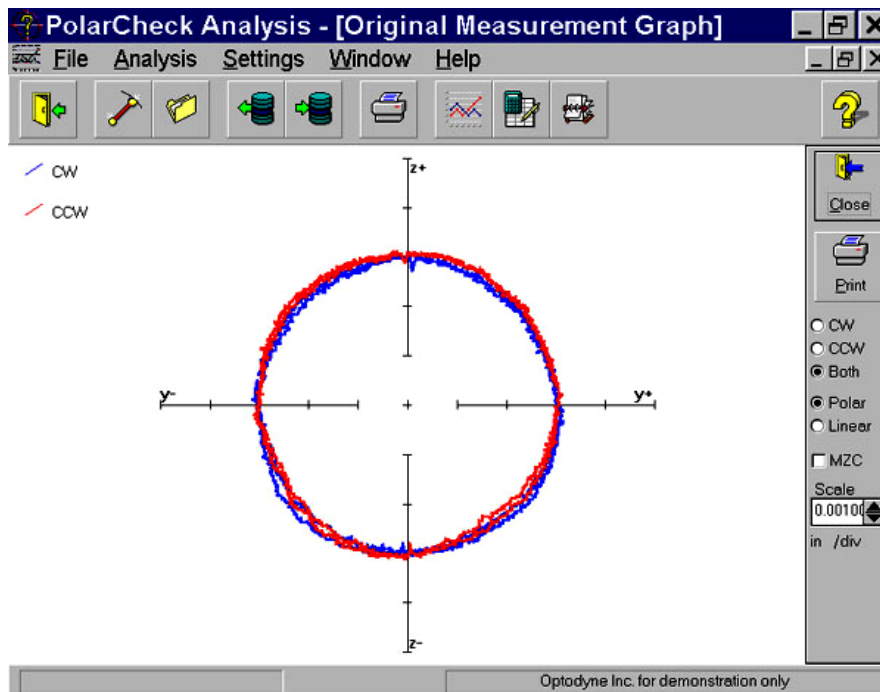


Fig. 9-9 A Polar Plot of the Circular Contouring Error with Feedforward

For some controllers, there is no velocity control, the velocity profile looks like triangular shape (see Fig. 9-10) instead of the sinusoidal shape. The polar plot, (see Fig. 9-11) shown large loop and the non-roundness is excessive large. This is because in the data processing,

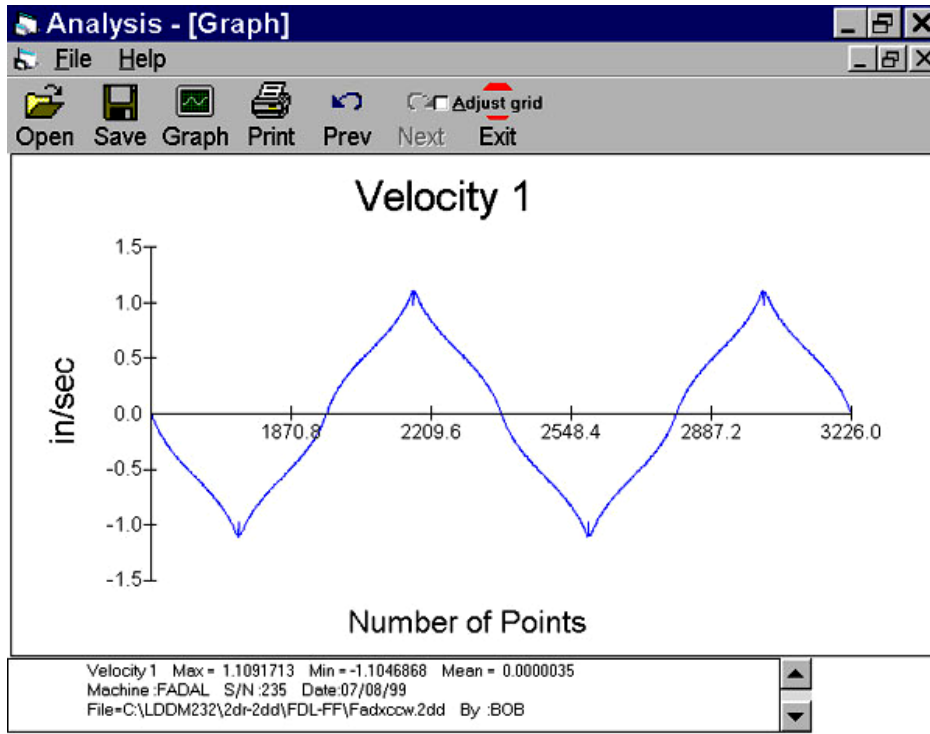


Fig. 9-10 A Plot of Velocity Profile without Velocity Feedback

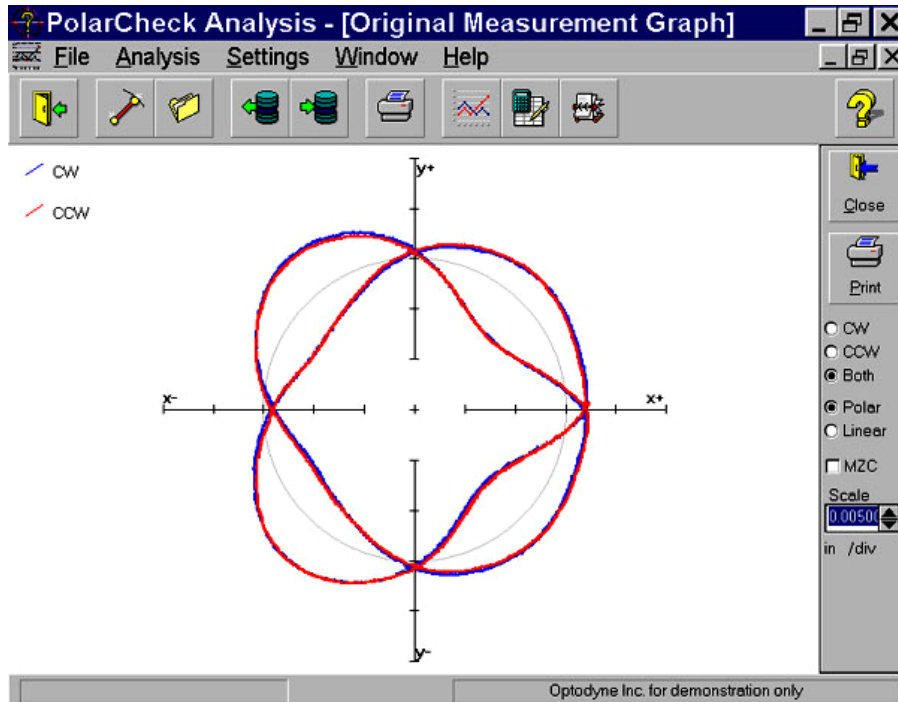


Fig. 9-11 A Polar Plot of the Circular Contouring Error without the Synchronized Data Processing

it is assumed that the velocity is uniform or sinusoidal. To fix this problem, a “sync” button is added in the “select Axis Data files” screen. The non-roundness is reduced as shown in Fig. 9-12.

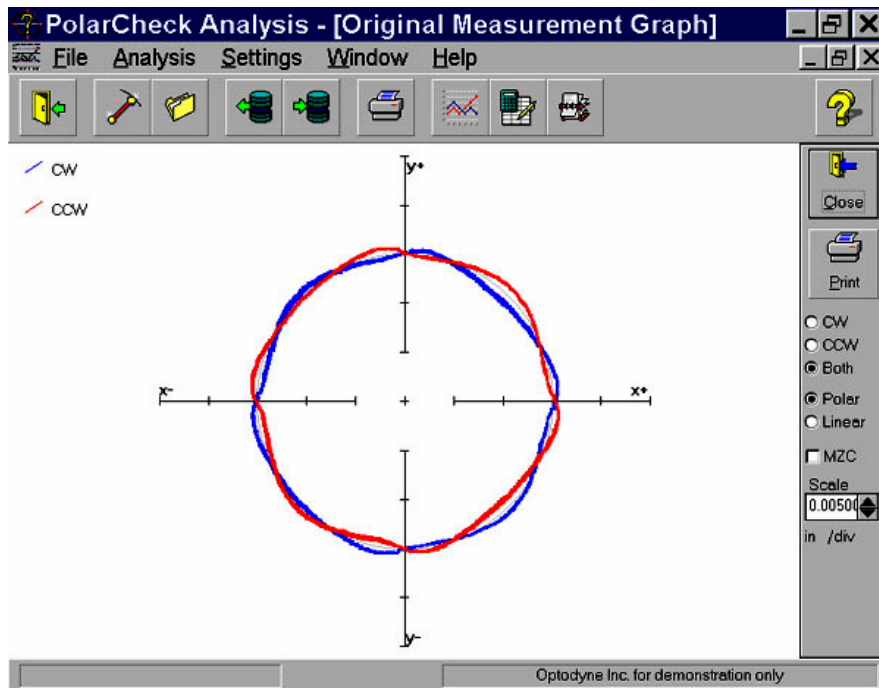


Fig. 9-12 A Polar Plot of the Circular Contouring Error with the Synchronized Data Processing



**OPTODYNE, INC.**  
**1180 Mahalo Place**  
**Compton, CA 90220**  
**310-635-7481**

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