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Ballbar technology maximises efficiency and minimises scrap in quartz processing

Introduction

Quartz sand (or quartz) is everywhere in our daily lives. Although the mineral resembles ordinary glass in its appearance, it displays distinct properties as a result of its high concentration of pure silica dioxide. With a high softening point of up to 1700 °C, quartz displays excellent resistance to heat and chemical corrosion. "Glass" substrates made of quartz also have an exceptionally low coefficient of thermal expansion, allowing them to remain stable even in environments with frequent temperature changes.

These unique advantages have made quartz the most critical material for the manufacture of wafers and other semiconductors that power everything from mobile phones to heavy-duty industrial machines.

A typical example is the quartz furnace tube, a heating device that prevents contamination of metals generated during the high-temperature process of producing wafers. Its first, outer tube isolates the furnace body from the heater filament, while the secondary inner tube provides a layer of protection for the wafer placed within. Quartz-based semiconductor carriers and components are therefore the most essential consumables in semiconductor manufacturing.

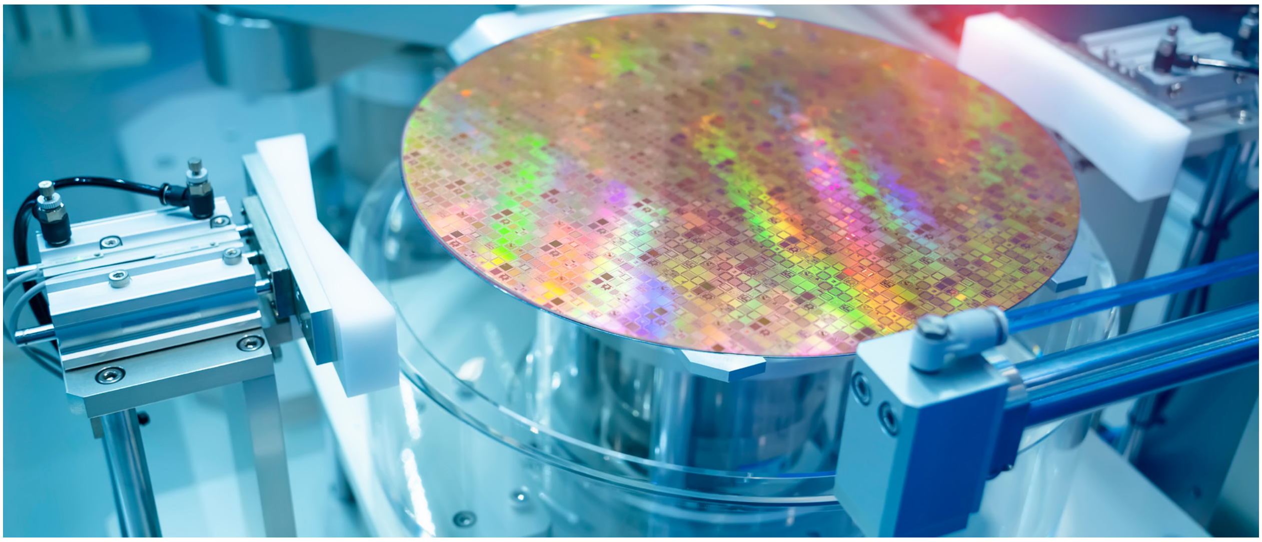
Industry challenges

Quartz-based semiconductor carriers and components come in a wide variety of shapes, such as furnace tubes, quartz boats, babel quartz, quartz rings, and quartz tanks. With a frequent replacement cycle for these carriers ranging from 3 months to 1 year, manufacturers constantly face the challenge of optimising their equipment by reducing scrap wastage of quartz parts.

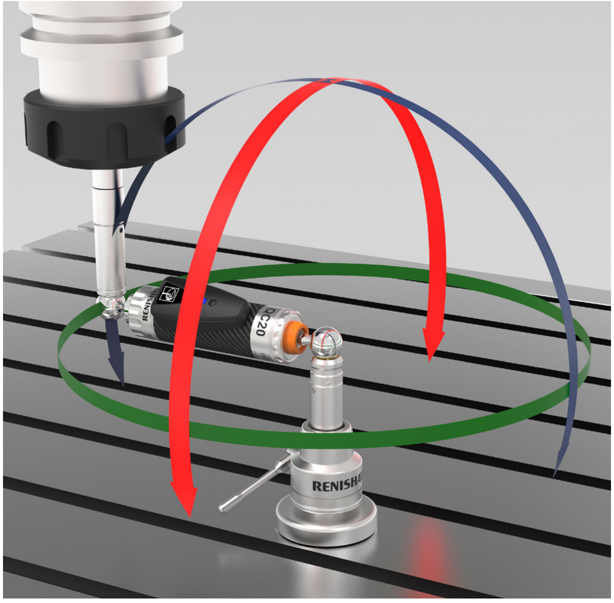
In addition, emerging industry demands for thinner wafers make the maintenance and replacement of these specialised quartz parts more time-consuming and expensive. For instance, to meet customer needs for transparency on carrier surfaces, manufacturers employ complex processing equipment such as machine tools, and laser and waterjet cutting machines.

In the past, equipment breakdowns were solved manually by highly experienced and skilled technicians from suppliers who could manually weld the various components together with simple tools e.g. dial gauge, measuring tapes, and artefacts. However, waiting for replacement parts for the newer, more specialised components and carriers can lead to an increase of unproductive downtime and unnecessary scrap rates.

Since the raw material of quartz is expensive to process and costly to maintain, manufacturers constantly face the challenge of how to effectively reduce the scrap rate during the production of substrates. With a proven scrap reduction rate of 5%, the Renishaw QC20 ballbar allows users to benchmark and track the condition of their machines, and to quickly diagnose problems that may require maintenance.


Semiconductor wafer

How a ballbar works



A high-precision, telescope linear sensor, the ballbar automatically diagnoses and analyses errors in machine positioning performance.

- The ballbar consists of a precision ball fixed at each end, mounted on two precision magnetic mounts. During operation, one magnetic mount is attached to the machine's motion platform, while the other is mounted on the main spindle of the machine.
- As the machine travels a predefined circular path, the QC20 ballbar tracks variations in the radius. (If the machine's positioning performance is in perfect condition, it will produce an error plot that matches the commanded motion path.) This enables precise and immediate diagnosis of machine errors by tracking variations between the error plot and a perfect circle.
- Tests are typically performed in three separate planes as shown in the image above. Where it is not possible to complete a full 360 degree test, a 220 degree partial arc test can be used.
- By using the Ballbar 20 software, customers can automatically diagnose up to nineteen specific machine position errors, including backlash, perpendicularity, straightness, centre misalignment and more. Users can analyse and apply the data from these reports with ease, thanks to intuitive graphs that are in accordance with various international standards (such as GB 17421-4, ISO 230-4, ASME B5.54).
- The software also provides a detailed ranking of the impact of each error on the machine tool, enabling maintenance personnel to perform targeted maintenance on machine issues. With the ability to accurately identify error sources, manufacturers no longer need to rely on time-consuming and tedious experimental assessment of error sources.

Reduce scrap rate with the QC20 ballbar

A lack of understanding about the performance efficiency of each piece of equipment can lead to manufacturers inadvertently mismatching resources: lower precision equipment might be utilised for tasks that require higher quality capabilities, and urgent orders might be allocated to less efficient equipment.

The Renishaw QC20 ballbar helps customers eliminate this costly guesswork through accurate diagnosis of their machines' production capacity. Using the generated reports on overall performance efficiency, manufacturers can categorise machines into different precision levels, and allocate work to the appropriate equipment upon receiving orders.

The QC20 ballbar also enables supervisors to accurately estimate production time, which is crucial for optimising production plans and organising customer orders within short timeframes. Since the performance test reports comply with international standards, manufacturers can reduce delivery delays and secure customer confidence with a proven track record of machine efficiency and consistent productivity.

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Lowering non-conforming rate

One quartz carrier and component manufacturer used the QC20 system to address a major challenge: a high scrap rate of 5% in their workpiece processing.

With the QC20 ballbar, the manufacturer identified the causes of the machine errors, verified the accuracy of the machine process, and decreased the overall scrap cost.

In addition, the manufacturer made use of the Renishaw QC20 cost benefits calculator to estimate the costs saved by using ballbar technology. By using the QC20 ballbar for preventative maintenance, the manufacturer is able to save USD 96,000 per year in additional costs.

QC20 ballbar cost justification calculator (Reduction in scrapped components)				
1	Number of CNC machines in use		20	
2	Loaded machining time rate	USD	28	/ per hour
3	Average cost of machined part including prior value added activities	USD	1.3	
4	Parts made per hour per machine		10	/ per hour
5	Total machining hours per day		8	hour(s)
6	Number of working days per year		300	day(s)
7	Estimated percentage of scrapped components caused by machine errors		5	%
This cost can be eliminated if all machines are certified by the QC20 ballbar on a regular basis. The calculation above does not consider any additional costs incurred by reworking out of tolerance components, which can often exceed scrap value. Therefore, annual savings are likely to be higher than stated.				
	Saving made by QC20 ballbar testing	USD	96,000	per year

Calculation :

[(❶ ______ x ❺ ______ hour(s)) x ❻ ___ [(❹ ______ x ❸ USD______ + ❷ USD______ / per hour) x ❼ ______%] /100

Annual saving made by ballbar testing = USD

Click on the link to access the Renishaw QC20 cost benefits calculator to estimate how much a ballbar can save in production costs.

Reducing machine downtime

Another manufacturer adopted the QC20 ballbar to address the issue of significant machine downtime, facing an estimated 24 instances per year, per machine. This translated into an average annual downtime of 24 hours per machine.

Using the Renishaw QC20 cost benefits calculator, the incurred costs of this idle time became clear: approximately USD 311,040 spent on machine downtime alone.

The QC20 ballbar helps to avert such losses thanks to its regular and accurate diagnoses of machines' status, providing early warning for potential failures. In some cases, customers save 70% of costs (equivalent to USD 217,728) after adopting ballbar technology.

QC20 ballbar cost justification calculator (Reduction in machine downtime)				
1	Number of CNC machines in use		20	
2	Loaded machining time rate	USD	28	/per hour
3	Average number of crashes / breakdowns per machine per month		2	
4	Average downtime per machine per breakdown		24	hour(s)
5	Average annual cost of production downtime caused by CNC machine faults	USD	311,040	per year
By very rapidly diagnosing the source of machine error, the QC20 ballbar reduces problem solving time by at least 70%.				
	Saving made by ballbar testing	USD	217,728	per year

QC20 ballbar test report: comprehensive and actionable data

QC20 ballbar generates a series of comprehensive test reports to effectively address machine downtime by identifying and diagnosing the most significant error data for each machine.

Figure 1

Each error is ranked according to its significance to overall machine performance alongside the error value. The diagnosis report shows how one machine displayed backlash errors in the X and Y directions accounting for 29% and 23% of the error. Other errors include scale mismatch, perpendicularity, and reverse spike Y.

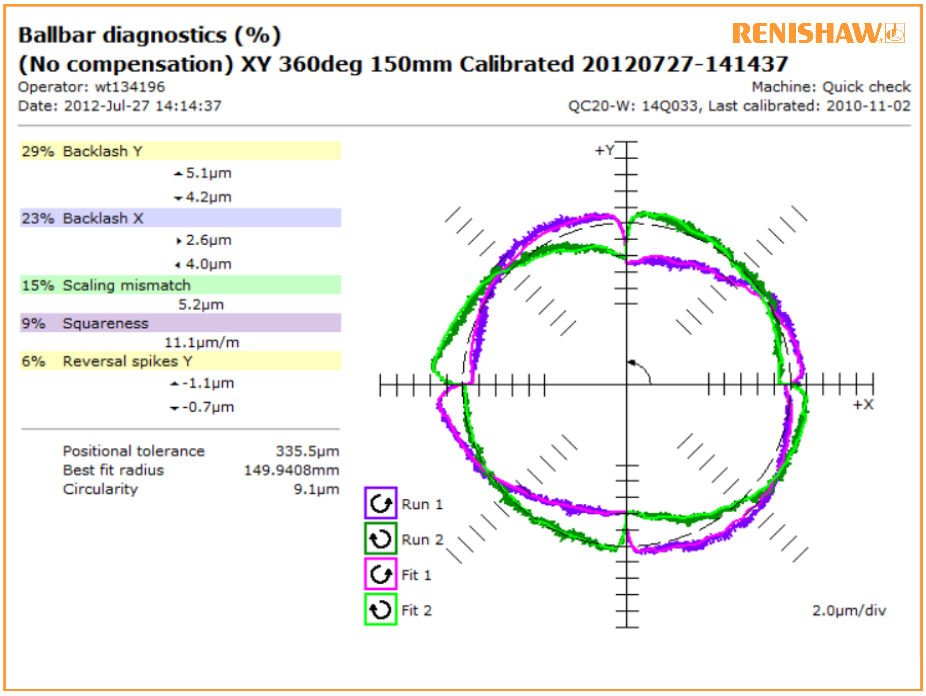

Figure 1

Figure 2

The “Values” page of the diagnosis report provides further information on the main and secondary error data values, including their impact on overall machine accuracy.

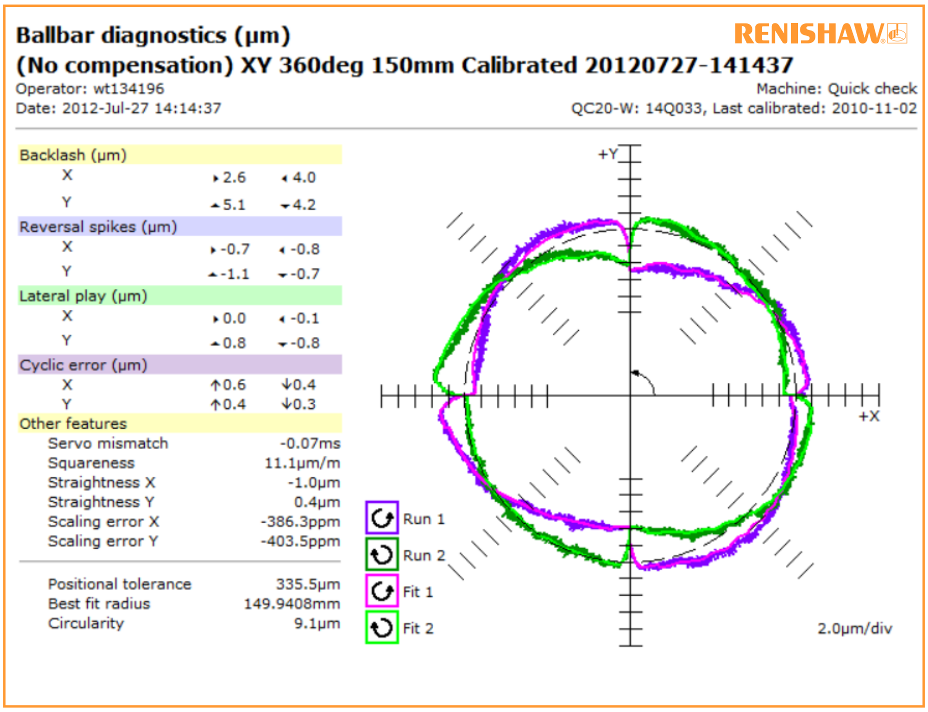

Figure 2

Figure 3

Based on the diagnosis report, the customer performed parameter compensation on the controller.
Figure 3 is the new diagnosis report immediately showing the results of the machine fixes/corrections.

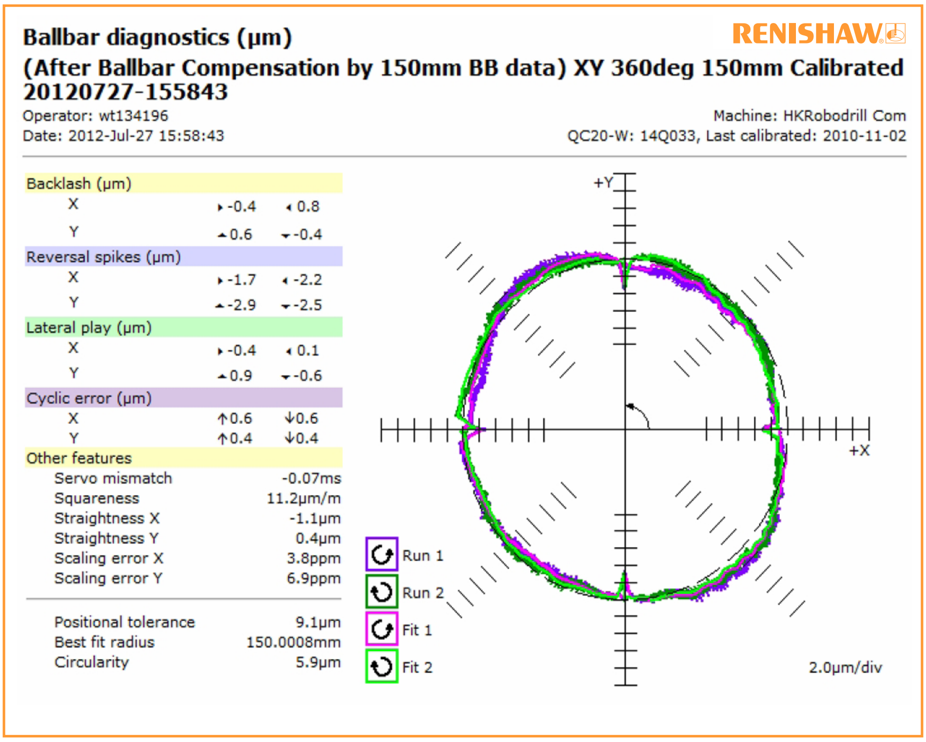

Figure 3

Figure 4

This data is a comparison of the test data obtained from the machine using the QC20 ballbar before and after compensation. The data shows a noticeable improvement in the relevant errors and the roundness of the graph is improved compared to before compensation. The paths in both the clockwise and counter-clockwise directions are also more closely aligned.

		Before compensation		After compensation	
Backlash（µm）	X	2.6	4.0	-0.4	0.8
	Y	5.1	4.2	0.6	-0.4
Reversal spikes（µm）	X	-0.7	-0.8	-1.7	-2.2
	Y	-1.1	-0.7	-2.9	-2.5
Lateral play（µm）	X	0.0	-0.1	-0.4	0.1
	Y	0.8	-0.8	0.9	-0.6
Cyclic error（µm）	X	0.6	0.4	0.6	0.6
	Y	0.4	0.3	0.4	0.4

		Before compensation	After compensation
Scaling mismatch		-0.07 ms	-0.07 ms
Squareness		11.1 µm/m	11.2 µm/m
Straightness	X	-1.0 µm	-1.1 µm
	Y	0.4 µm	0.4 µm
Scaling error	X	-386.3 ppm	3.8 ppm
	Y	-403.5 ppm	6.9 ppm
Positional tolerance		335.5 µm	9.1 µm
Best fit radius		149.9408 mm	150.0008 mm
Circularity		9.1 µm	5.9 µm

Figure 4

Figure 5

The data captured by the Ballbar 20 software can be displayed and analysed according to various international standards, such as ISO 230-4, ANSI B5.54, and it can also be utilised using the comprehensive Renishaw analysis format.

By clicking on the error sources in the report, the software's built-in relevant explanations and suggested actions pages will open automatically, allowing users to understand the causes of the errors and providing corrective suggestions to improve machine performance.

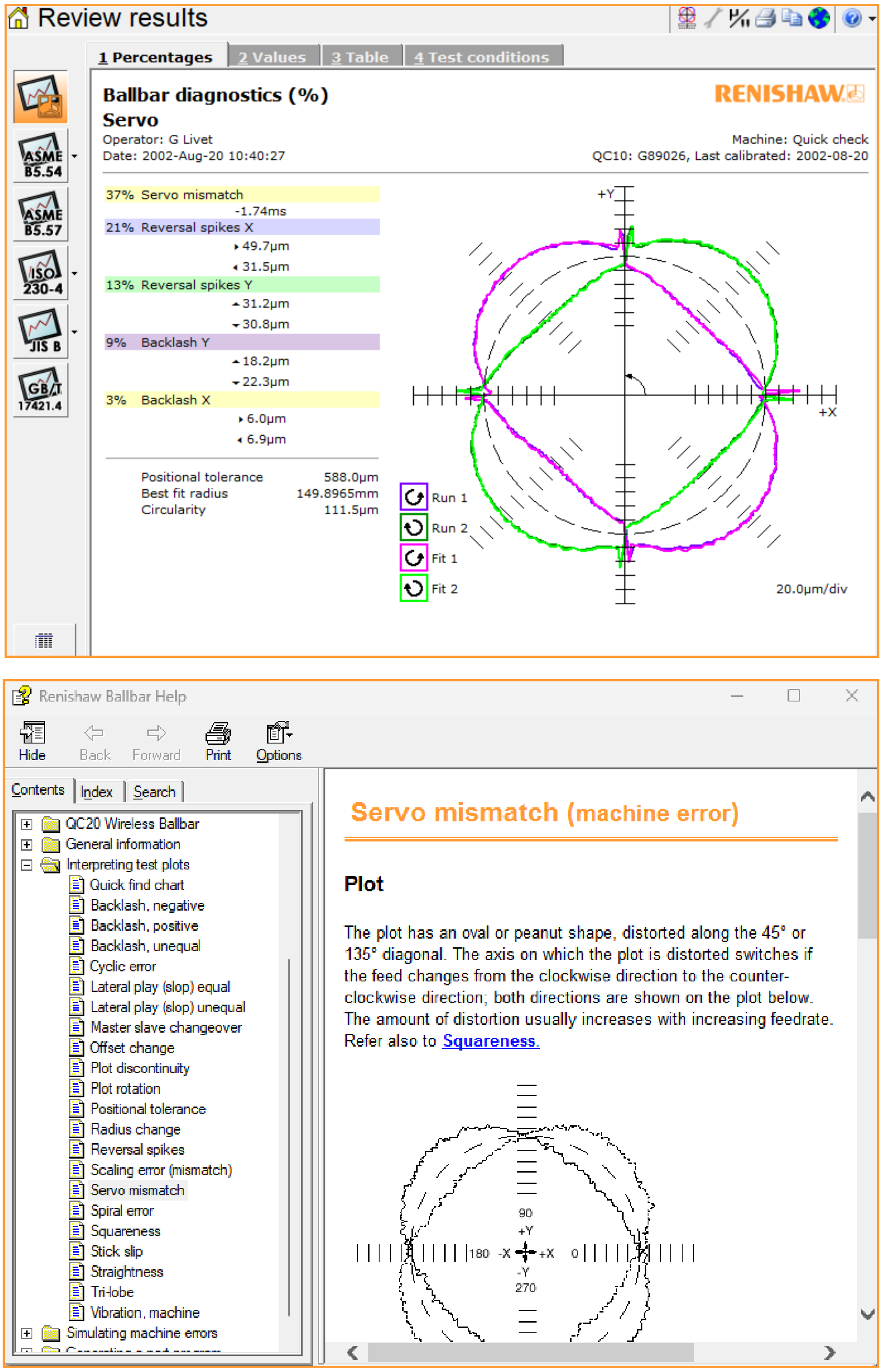

Figure 5

Figure 6

Users can refer to different typical ballbar test graphs listed in Figure 6 to identify the errors in the machine.

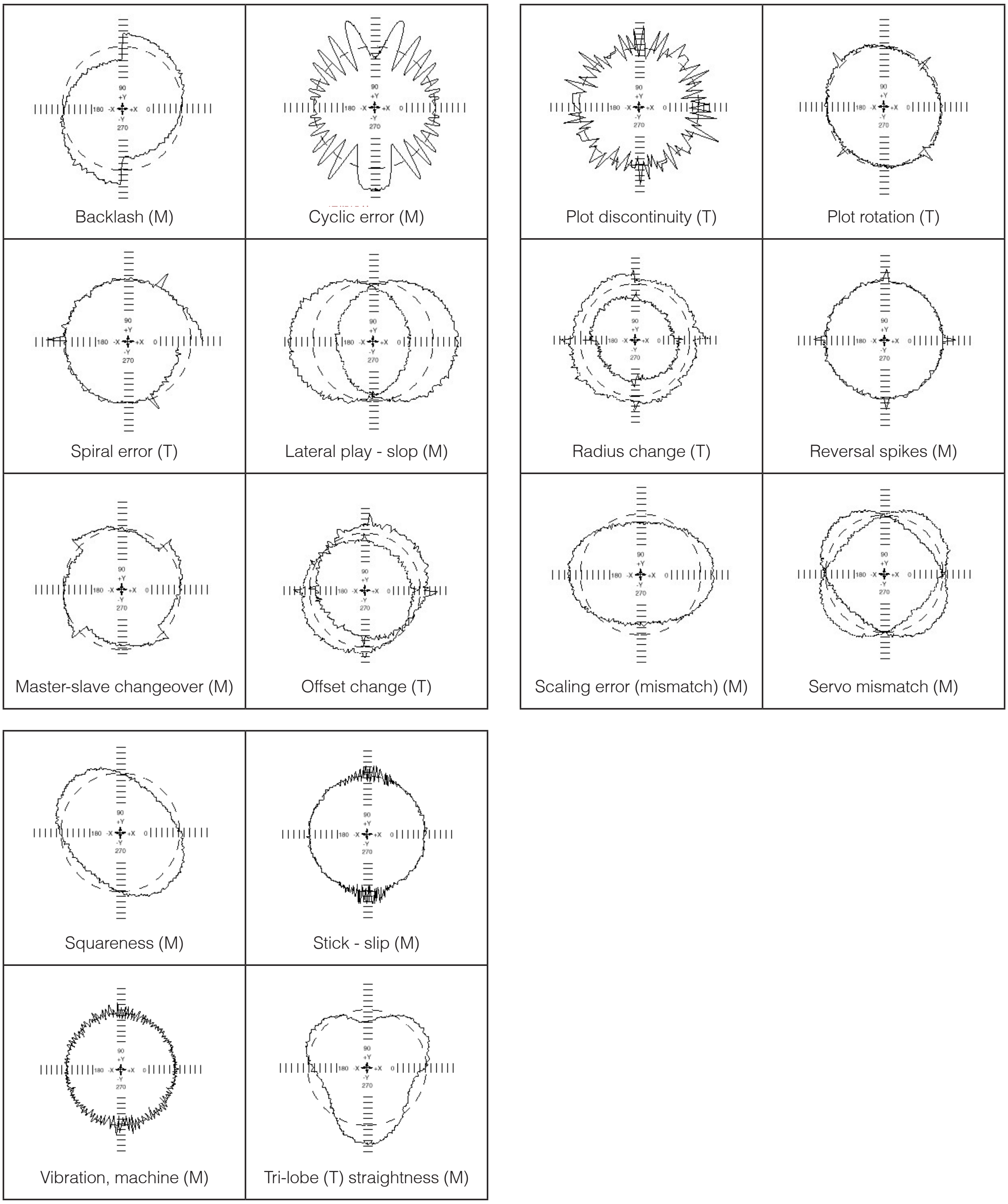

Figure 6

Part no.: H-8014-9055-01-A