

Dynamic Measurement Of High-Speed Spindle Runout

by Robin Wilcox

Determining causes of poor hole quality.

PCB manufacturers continue to face increased production and quality requirements. Pressure for cost reductions and new emphasis on improved productivity must be dealt with daily. Trends toward tighter tolerance specifications further cloud the picture. In particular, drilled hole diameters are becoming smaller and creating new quality challenges. The following discussion focuses on a critical problem associated with small hole drilling -- excessive runout-- and what can be done to identify and eliminate the problem.

SMALL HOLE QUALITY CONCERNS

The general term "poor hole quality" can be further categorized into several different types of problems, including:

- 1) out-of-roundness
- 2) out-of-perpendicular
- 3) nailheading
- 4) off location.

While these problems have been present in PCB manufacturing for some time, they tend to be exaggerated with small hole drilling. Rough hole wall and smearing are more likely to occur with small hole drilling. And although hole diameters of

0.006" can be difficult to achieve consistently, the direction of the industry is toward even smaller drilled diameters. Suppliers of state-of-the-art drilling equipment now provide machines capable of drilling diameters of 0.004 " The reason for interest in smaller holes is obvious; smaller holes allow more circuitry to be placed on a PCB of a given size. Meeting and maintaining these specifications in a production environment, however, is not an easy task. The quality issues identified earlier, such as out-of-round holes, can be caused by excessive runout of the drill spindle, incorrect chucking of the drill bit or out-of-balance collets or spacers on the drill bit. Vibration conducted through the drilling machine base can also be translated into runout and result in quality problems. A recent study at a PCB manufacturer showed a drilling machine bed was being displaced 80 micrometers during vibration when the neighboring drilling machine was operating.

The quality improvement process at any plant includes the identification of problems and the development and implementation of corrective action. While it has been understood that increased runout

affects hole quality, until recently it has not been possible to effectively study this area of PCB drilling.

Management of the drilling area has often resorted to elimination of probable causes rather than a true identification of the problem. For example, when dealing with out-of-roundness, the operator may have replaced a spindle and requested it be rebuilt without truly knowing if that step was required. Alternatively, a plant may periodically change or rebuild spindles, not knowing the extent of a problem or whether a problem actually exists with the spindle.

DYNAMIC MEASUREMENT

To fully analyze drill spindle, collet and bit dynamics, the drilling machine must be operating. This ensures all contributions to runout and vibration will be present. The most commonly used method of measuring spindle runout involves a dial indicator and can only be used when the drilling machine is not operating. Here the indicator is positioned against a gage pin which has been inserted into the collet. The spindle is manually rotated and runout evaluated. Unfortunately, this method (as discussed

later) does not give a proper indication of the runout experienced at operating speeds.

Another technique, accelerometer vibration analysis, has also been attempted on ball bearing spindles. This method is an improvement over the dial indicator in terms of repeatability. However, loading of the spindle during measurement changes the dynamic behavior of the spindle and will affect the accuracy. In addition, the distance between the mounted accelerometer on the spindle and the drill bit prevents accurate detection of vibration at the drill bit.

Dynamic measurement of spindle runout is now possible using capacitive based noncontact measurement systems. Utilizing a noncontact transducer and the driving electronics, the system measures and displays high speed spindle, drill bit or collet runout (Figure 1). Since the rotating surface is not touched, there are no concerns about distortion of the measurement through loading. The advanced circuit design of the system makes it possible to measure dynamic characteristics of a spindle turning at 80,000 RPM or more. This is important with air bearing spindles where operating speeds of 120,000 RPM are achieved.

Noncontact capacitance equipment has been used for years to precisely measure the dynamic runout of spindles in the computer industry. The technique used consists of two parallel surfaces which act as the two plates of a capacitor. In this application one plate is the end of the noncontact transducer, the other the gage pin. Any change in the distance between the two surfaces results in a proportional change in capacitance, which is sensed by the transducer and associated electronics. High repeatability and accuracy are possible with these systems. Resolutions of one to ten microinches (.000001 to .000010 inch) are typical. This resolution is critical for measuring spindle



Figure 1. Measurement of high-speed spindle runout is now possible using a noncontact transducer and electronics.

runouts in the 0.0002" to 0.0008" range.

USEFUL RESULTS

To measure the spindle runout, the fluted drill bit is replaced with a gage pin for a continuous measurement surface. A pin of about .75 " in length is recommended since "wobble" of a longer pin can cause inaccurate readings. The noncontact transducer is mounted on a base and positioned on the drill bed next to the gage pin. The face of the transducer and gage pin should be parallel for the optimum measurement. After zeroing the system in the static mode, the spindle is turned on. The runout is then displayed on the digital meter and can be output to additional analytical devices.

As described, the system is easy to set up and perhaps more importantly eliminates operator variability, resulting in improved repeatability. Once the transducer is positioned correctly there is no reason for the operator to handle the equipment. The panel meter on the front displays the TIR (total indicated runout) measured by the noncontact system. In addition, the ± 10 volt analog displacement signal is fed into an oscilloscope. More detail

of the spindle runout as well as environmental vibration contributions can be determined using this device.

Figure 2 shows a printout of runout information. Data collection can be helpful in determining the average life of spindles, as well as determining how a specific spindle is performing during Preventative maintenance checks. Dynamic runout measurements over various operating speeds can also be very helpful. The printout shows the runout profile of a spindle from 20,000 RPM to 80,000 RPM. It has been found that the runout may actually peak and then improve at higher speed. This type of analysis is useful in optimizing the drilling process.

Dynamic information can also be collected over time for comparison. Premature spindle rebuilding can be prevented by using this dynamic measurement system. For example, if a spindle has a large runout in the static mode which is reduced as the spindle is brought up to speed, measurement using a dial indicator would incorrectly suggest the spindle should be sent out to be rebuilt. Alternatively, if a spindle did not show excessive runout except during operation, it would not

be possible to detect the true problem using a dial indicator, and hours of poor production quality could result. Furthermore, the improved resolution available from this type of equipment will gain in importance as hole diameters continue to be reduced and the measurement of runout becomes more critical.

The dynamic measurement of runout can also be used to eliminate communication problems between the customer and spindle vendor. Disagreements over definition and measurement of the problem can often get in the way of a quick solution. The electronic measurement system eliminates operator variability and offers high repeatability and accuracy. The validity of the collected data can be assured. In addition, incoming inspection of new or repaired spindles can now be easily accomplished.

CONCLUSION

Dynamic runout and vibration is a costly and elusive manufacturing concern in the PCB industry. It is elusive because it can be difficult to isolate and costly in terms of random, unexplained failures that can occur. Until now there has not been an effective means of measuring

runout of PCB drills and spindles at operating speeds. The tools available did not have the resolution needed to accurately measure critical runout, nor was it possible to measure runout dynamically. Accuracy could also be affected through loading of the spindle. These concerns have been addressed, and it is now possible to measure spindles operating at 120,000 RPM or more with a noncontact measurement system.

Use of a dynamic runout system will result in improved quality and production rates for PCB manufacturers. Runout measurements can be taken quickly and easily, reducing production downtime. The accuracy and repeatability available from the system will ensure the cause of poor hole quality is quickly identified and allow the proper corrective action to be taken.

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Robin Wilcox is sales and marketing manager, Lion Precision, St. Paul, MN. Phone 651/484-6544, Fax 651/484-6824, 563 Shoreview Park Road, St. Paul, Minnesota 55126-7014

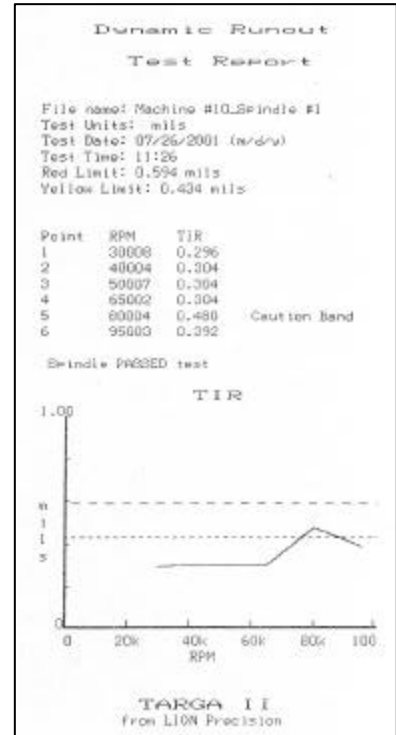


Figure 2. Printout charting runout vs. RPM. This document can be filed to track long term performance or as an ISO9000 quality record.