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Signature Analysis in Four Slide Machines

There are two important benefits to be gained from applying signature analysis technology to slide machines--reduction of setup time and improvement of overall product quality.

By Mark F. Lozelle
Signature Technologies, Inc., Dallas, TX

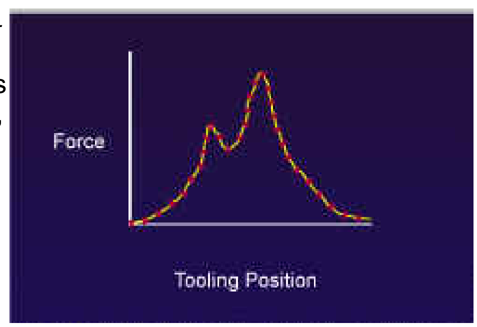
Signature analysis is a method of establishing the measurement of a discrete manufacturing process. Signature analysis is not a new technology. In fact, its roots go back into the mid-1970s. Still, migration of this technology from the laboratory to the plant floor has matured only during the last 10 years. During this time, signature analysis has advanced to provide what is now referred to as signature-based process control (SbPC^{tm}).

Signature-based process control is the basis with which to close the loop on the process by taking the application from measurement to benefit. As stated above, this article outlines two primary benefits of this technology for slide machines (four-slide, multi-slide, coilers and spring): 1) reduction of setup time, and 2) improvement of product quality.

In order to use signature analysis, we first must understand its purpose. The purpose is for process improvement, or specifically the objective is to improve quality. Once this objective is attained, process control is realized. Currently quality measurements are related to raw material going into or product coming out of a process.

These measurements do not measure the process directly--they are the result of it. Thus, these measurements do not link to improvement opportunities directly. If we do not measure what goes into or out of the process, then what do we measure? We measure the process itself. But first, the process variable must be identified.

Fig. 1--The process variable is force vs. tooling position, not time.



In metalforming applications, the process variable is not force, but force as a function of tool position (Fig. 1). Material thickness, hardness, "N" factor, lubrication, machine condition/adjustment and temperature have an influence on the process. Therefore, these variables can be measured by extracting them out of the process as they occur.

To test the application of signature-based process control on decreasing setup time and increased consistency, we established two beta sites within the United States. The first was Walker Corporation in Ontario, CA. The second was Perfection Spring and Stamping in Mount Prospect, IL. Both companies use four slide machines extensively within their business. The biggest production problems they have are time-consuming setup procedures before they can run and the part variations they experience from setup to setup.

Setting up a slide machine is an art, not just a procedure. The setup may be only as good as the person setting up the machine. This is not a problem for those who are highly skilled at this profession but it causes the process to be person dependent. What must be established is a balance between technology and the unwritten "tricks of the trade."

A four slide machine primarily consists of four independently moving slides, each with its individual adjustments. Each slide has two variables that must be set. One variable relates to timing of the slide drive cams. The other relates to the depth adjustments of the tooling mounted on the slides. Any adjustment on an individual slide can interact with the settings of other slides, affecting either the timing, or the force, or both. Since, in many cases, the machines have no reference markings or calibrations, recreating or establishing a setup for a part is a major challenge.

Currently, the machine is rolled by hand to make sure the setup is correct. An experimental setup is performed and the machine is turned over by hand to check its accuracy. If it is off, the necessary adjustments are made and the process is repeated. To bring all of these corrections together in order to produce a good part can be a time-consuming experience. To add to the problem, a number of four slide machines are more than 20 years old and it is not surprising to see some machines that are more than 40 years old. The age factor can create extra play in the machine, which can contribute to setup inconsistencies.

In order to track setup inconsistencies, we use signature-based process control. To collect process data we use a force sensor (or load cell). In older machines where there is wear and lost motion, proper placement of the force sensor is essential for obtaining valid data. There are several places where a sensor can be mounted effectively.

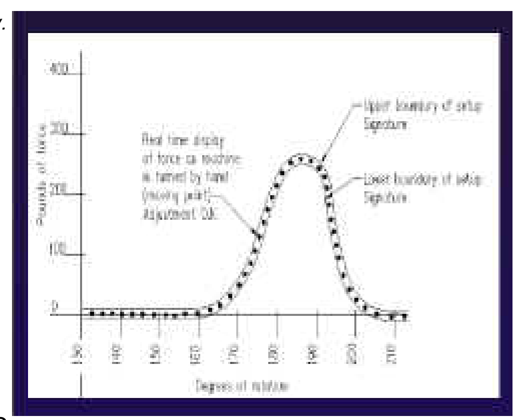
Each application needs to be analyzed to find the most advantageous placement. The preference is to incorporate the sensor into the slide since this enables the same force sensor to be used with different tooling, and will be found to be the most cost-effective approach in cases where the forces are sufficient to make this a practical solution.

In cases where the forces are extremely small, it may be necessary to build the sensor into the tooling itself to get the required sensitivity. Both of these placements will create the ability to detect specific features within the process. Putting the sensor in the correct location is the difference between monitoring the process and monitoring "noise." In the case of our beta sites, one gaged the tool and the other gaged the slide. The results were equally impressive. They indicated that set-up was reduced significantly.

For the first run of a job, the machine would be set up without the use of prior signature analysis data. This is due to the fact that the system relies on previous data and if no data has been saved there is nothing to compare. However, there still is a benefit to having signature-based process control in place. The setup technician has the ability to view force and the interaction between tools. Once the machine has initially been set up and the operator is confident that a good part is being made consistently, the process must be "captured" within the processor. This will serve as the reference when that same job needs to be run in the future.

The first major advantage is that the setup technician has the ability to see when (in the stroke) the slide is engaging the workpiece and how much force is being produced (all calibrated in degrees and pounds). This will help in setting up different slides and cams since quantitative information now is available to the tool setter instead of only judging by "touch and feel." Also by going into the setup screen and loading the same tool, the setup technician can use the initial results as a cross reference.

Fig. 2--The tool change assist screen shows when adjustments are okay.



The setup technician can roll through a revolution manually and see a series of dots in real time on the setup screen. These represent force as a function of tool position.

In Fig. 2, we see the dotted signature produced by a properly adjusted and timed slide. It travels solely within the setup boundaries. At this point, the portion of the machine represented in the signature is ready for production. If the signature, however, deviates at all from the pre-established boundaries, the tool or cam settings must be different than they were when the job ran last. Specifically, if the location of the signature "peak" is in the proper location, but the force is significantly lower, then the depth of the slide needs to be adjusted because it is too light.

On the other hand, if the slide is set too deep, the signature balloons up. The peak still is in the right place, but the force is much too high.

Fig. 3--This tool change assist screen indicates the slide is set too deep and the timing is too late.

If the signature has the proper height, but the peak is displaced horizontally several degrees, timing is off. Early timing will shift the peak to the left. Late timing will shift the peak to the right. Adjusting the angular position of the drive cam is the correction needed.

The definition of too early or too late refers to the angular position when a slide makes initial contact with the material. Signature-based process control can help, particularly when there is a combination of things wrong. In Fig. 3, the timing is late and the slide is adjusted too deep. The deviation from normal clearly is indicated by the shape and position of the signature and its relationship to the reference limits.

Multiple slides can be displayed together with their limits (Fig. 4). This is a tremendous aid to establishing the proper interaction between slides. The setup technician needs only to understand that if the current dotted signature is outside the limits, the machine needs to be adjusted until it is comfortably within the limits.

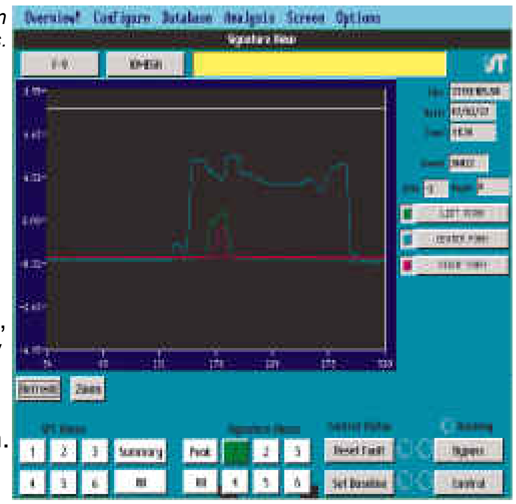


Fig. 4--Multiple signatures can be displayed at the same time to assist the setup person in establishing the proper interaction between slides.

The setup technician has a visualization of what is going on within the process by using signature-based process control. This is important because currently there is a tremendous shortage of good setup technicians and for long-term survival in the four slide industry, the dependency on "black magic" must give way to documented consistency.

Once the four slide machine is fully operational and making good parts, the verification of a consistent repeatable process can be monitored by signature-based process control. It will watch for variations in trends and notify the operator. Trends, such as drifts due to temperature or material variation, will be detected and appropriate action can be taken.

If the signature generated by the machine deviates from its upper and lower limits anywhere during the working cycle, the system immediately detects the discrepancy and stops the process. Several scenarios can happen here--eject part, automatic adjustment or stopping the machine.

During every revolution of the machine, the point-by-point signature data acquired from each channel, as shown in Fig. 5, is analyzed by the processor. It then is compared to limit tables and a decision is made either to continue machine operation or stop due to a fault. The operator can be assured that if the process remains within the specified limits, the parts being made are good. Also, this will reduce the countless hours it takes quality control personnel to manually gage parts because if the process deviates, even a little bit, there will be a dramatic change in the signature.

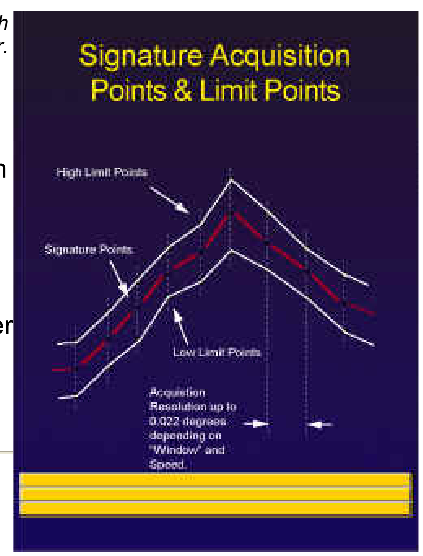


Fig. 5--During each revolution of the machine, the point-by-point signature data acquired from each channel is analyzed by the processor.

Our two beta sites have tested and proven that the use of signature-based process control can decrease setup time significantly and maintain a consistent, repeatable process. Setting up a slide machine needs to move from an art to a science. The shortage of good setup technicians requires that new and innovative methods be established to fill this void.

Signature-based process control provides the means to make the setup procedure less operator dependent and more historical analysis driven. In order to ensure the ultimate quality of a part we need to ensure the quality of the process. To improve the process we must be able to measure it. **MF**