HARDY INSTRUMENTS

TECHNICAL NOTE

Strobe Light Applications For Machinery Problem Solving

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Strobe Light Applications For Machinery

Problem Solving

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STROBE LIGHT APPLICATIONS FOR MACHINERY PROBLEM SOLVING

Strobe lights (or stroboscopes) have been used to study the behavior of rotating machinery, oscillating vibration of components or structures and for balancing for a number of years. Functionally, strobe lights can be very different. This is why the price range is so wide. The following discussion may help you decide which strobe light is best suited for the tasks you have in mind for your plant.

Today most strobe lights come standard with rechargeable batteries making them truly portable and easy to use in the field. The idea behind the strobe light is to fire a high intensity light at a specific frequency or at a precise sub-multiple frequency which is usually measured in flashes per minute (FPM). This allows the light to be synchronized with machinery running speeds or at the frequency of a vibration condition one might be concerned about. The major difference in strobe lights is in how they are triggered to fire.

Strobe light trigger options include:

1. Basic accessory strobe light works only with external triggering circuit. Always requires a companion instrument or a once per turn speed reference signal.

2. Stand-alone strobe light that has built-in oscillator and flash control knob and digital RPM readout. User can adjust to machinery speeds of interest like drive belt speeds, for example. It may also have the ability to be triggered externally.

3. Stand-alone strobe light that has built-in vibration sensor triggering ciruit with phase adjustment knob, plus built in oscillator and flash control knob and digital RPM readout. It has the functionality as in 2 above, plus the user can lock onto the vibration sensor, which is a signal that contains phase information. In the lock mode, a speed reference signal that has related phase information is available as an output which can be used for recording by data loggers, as shown in Figure 1, or other instruments. The strobe may also have the ability to be triggered externally.

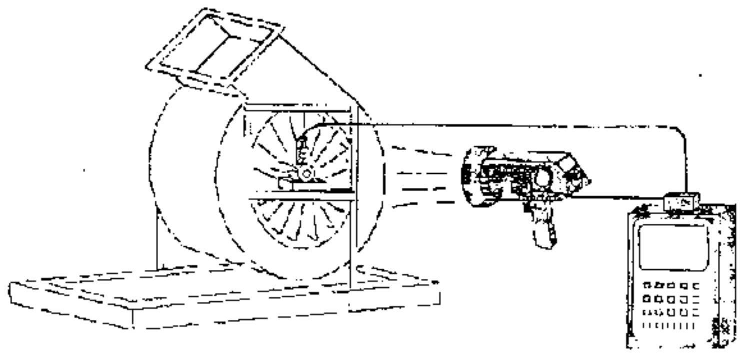

Figure 1

Strobe Light Connected to Data Collector

THE STROBE LIGHT AS A TROUBLE SHOOTING TOOL

The strobe light can be a very useful tool for helping determine the causes of rough running machinery, vibrating brackets or pipe hangers and for adjusting machinery that is supposed to vibrate as in the case of nonrotating product conveyors. If the strobe light has the ability to measure phase it can be used for balancing, verifying alignment, checking for looseness and platform or piping system motion studies.

RUNNING SPEED CHECKS

With a strobe light tuned to running speed there is much that can be learned by visually observing machinery. If the strobe can be tuned externally by once per turn event signal you can be assured of it flashing at the correct rate. Otherwise it must be manually tuned to running speed. It is a good practice to adjust the strobe to running speed by starting at a flash rate above running speed and slowly make the adjustment until rotation appears to stop. The reason for starting above running speed is that the stopped rotation will occur with the strobe tuned at half running speed as well as other sub-multiples. There is less chance for error if you start above running speed.

Many times the exact running speed of a machine is unknown. By tuning the strobe and "freezing" motion, the speed will be displayed on the digital readout. Tuning is easier if you can focus on a shaft keyway or some other distinct feature. If none is available a mark should be made using a paint spot or tape. For repeated use a durable mark is best.

With the strobe set to the rate where motion is frozen, slowly survey the machines parts. Every moving part that is frozen is rotating or vibrating at running speed frequency while parts that are not frozen are rotating or vibrating at a different frequency. This information in itself is often very helpful in determining the cause of excessive wear, looseness or breakage. A word of caution; if you are working around people who have not seen a strobe light in use they might be inclined to reach for a part that is frozen and appears to not be moving. Severe injury could result.

Belts on belt driven machinery can be examined for irregular operation using a strobe light.

For example, in the case of multiple belts, a loose belt will exhibit more motion than belts that have the proper amount of tension. This condition will cause vibration. The strobe light is tuned to the belt speed.

A strobe light can be used to check over speed trips on machinery. This is accomplished by first tuning running speed and then following speed as it is slowly increased until trip speed is reached. At this point release the tuning knob and read the speed on the digital display.

WHAT CAN BE LEARNED BY THE ADDED ADVANTAGE OF PHASE

The ability to measure phase from the vibration signal offers the user many advantages when trying to diagnose machinery problems. Vibration phase is the vectorial direction of the predominant force responsible for machine vibration. Think of it this way; if a rotor could come out of its bearings, which way would it go? Or if a machine could jump off of its mounting, which end would go first? Vibration phase provides this type of information. One phase reading has one bit of information that by itself does not offer much insight about a vibration condition. But a group of phase readings begins to "paint a picture" for the user. For example, if you thought you had an unbalance condition, phase analysis could reveal the problem was actually misalignment.

SOME BASICS ABOUT PHASE MEASUREMENTS

Phase is a relative measurement. Placement of the sensor determines the phase reading. When measuring radial vibration in a vertical and horizontal direction on a bearing, the phase readings will show a 90 degree difference (a 90 degree phase shift). Knowing this is used to the analysts advantage. It is important to put the sensor back in the same location when trying to repeat measurements for trending or when balancing.

Since phase is being read by observing a part of the machine that is rotating with the strobe light, it is important to establish some general practices. One is to take along a tripod to hold the strobe if you are gong to be taking a lot of phase measurements. It makes the job easier and it also allows for consistency.

Of course, the mark being observed must be unique. The most common part of the machine to observe is the end of a shaft. It is important to have only one mark on the surface. If the end of the shaft has two keyways, mark one so it can be distinguished from the other.

It is good practice to have a standard convention for measuring phase. While you are going to want to relate phase shift findings in terms of degrees, it is a lot easier to make your notes in the field in terms of the clock face, especially when you are beginning. That is, 12:00 o'clock is 0 degrees and 6:00 o'clock is 180 degrees, see Figure 2. It is very easy to recognize a mark appearing at 4:30 as opposed to trying to relate to its location directly in degrees.

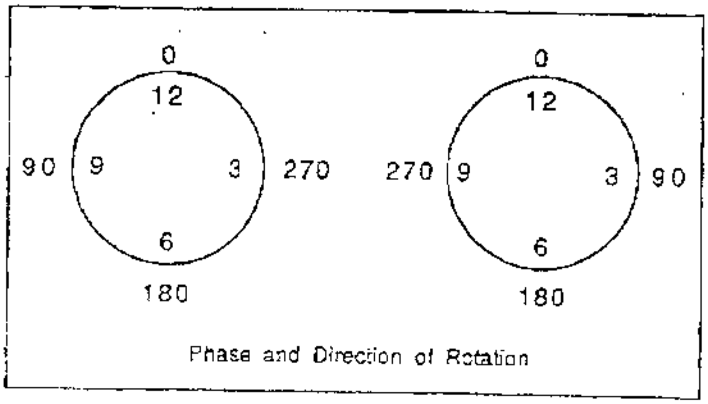

Figure 2

Phase Angle and the Clock Face vs. Rotation

When you are setting up for your reference reading and you are locked onto the vibration signal, rotate the phase adjust knob on the strobe light to bring the mark up to the 12:00 o'clock position. Make all other phase readings relative to this initial condition but do not rotate the phase adjust knob for relative readings. Make good pictorial notes recording phase readings using the clock face reference as you proceed. It is a good idea to put a "R" for radial and an "A" for axial readings below the clock face for reference after you return to the shop. You can not make too many notes when you are in the field!

Remember, the only good phase is that which occurs at running speed. We have not learned to consistently interpret phase at multiples of running speed. Be sure the strobe light is locked onto the once-per-turn vibration signal. Do not use the keyphasor signal. No relative phase measurements can be made with the strobe light connected to the key phasor signal.

If you have a data logger that records phase and the strobe light you are using has a phase reference signal output, you can use the data logger to record both vibration level and phase.

RADIAL PHASE ANALYSIS

Making phase measurements in the radial direction on a bearing or bearing support structure can confirm a suspected unbalance condition. When unbalance is the problem phase will follow the sensor. As the sensor location is moved around the bearing the phase angle remains the same. This is because the heavy spot is rotating with the shaft and does not change due to rotation. Since the strobe light is firing based on the sensor seeing the heavy spot go by, moving the sensor is not going to change what it sees in terms of phase. It may change in vibration level but not in phase.

Phase in this case is the delay in time or distance (measured in degrees) from when the heavy spot passes beneath the sensor until the sensor can respond to the forces produced. The delay comes from the "mechanical path" that the energy must travel through to get to the base of the sensor. (Technically referred to as the transfer function characteristics of the mechanical system.) As long as the mechanical path does not change as the sensor is moved, the phase response in the previous paragraph will hold true.

If the phase reference angle changes slowly and continuously it is due to a separately rotating unbalance component of the shaft. This can be caused by a loose collar or thrust ring. As the shaft rotates the loose component rotates at a slightly lower RPM distributing the loose component unbalance around the shaft, adding and subtracting with any shaft unbalance during each rotation cycle. This results in a constantly changing heavy spot and causes a continuously changing phase angle. This condition will also follow the sensor as its location is changed radially on the bearing.

As the sensor location is changed, if the phase angle also changes so the spot remains in the same location (does not follow the sensor) the bearing cap is being forced in only one direction. Severe misalignment or a locked coupling could cause this.

PHASE AND UNBALANCE

Three ingredients are required for balancing. These are speed, running speed vibration level and phase. The strobe light can be used for balancing since it provides speed and phase data. It can be connected to a data collector which reads vibration but needs a phase reference signal. Some data collectors have built-in balance programs for single and dual plane balancing.

Balancing is a subject of its own so it will not be covered extensively in this writing. What is covered is some hints on how the strobe light might be used to help understand some characteristics of an unbalance problem.

After setting up the strobe light and taking a vertical or horizontal reading (depending on the bearing support stiffness), move the sensor to the bearing on the other end. It is very important to keep the position orientation of the sensor the same on both bearings. Do not move the strobe light, only the sensor. Check the phase by observing the position of the mark. Make notes according to the following:

UNBALANCE BEARING PHASE RELATIONSHIP

Same Phase	Static Unbalance
180° Difference	Couple Unbalance
90° Difference	Combined Static and Couple
Less than 90°	Combined, more Static
More than 90°	Combined, more couple

The solutions for correcting these types of unbalance problems are explained in many writings on the subject. Using the strobe light to diagnose the type of unbalance you are dealing with before you attempt to correct it can be very helpful.

AXIAL PHASE ANALYSIS

Axial phase measurements can reveal useful information about machinery faults. A series of axial measurements at a bearing taken at the top, right, bottom and left (12:00, 3:00, 6:00 and 9:00 positions) will indicate characteristics about the shaft. If the phase angle stays the same so the mark follows the sensor as it is moved, the bearing is wobbling (nonplanar motion). A bent shaft or bow in the shaft due to unbalance is forcing the bearing away from the machine as the rotor turns.

Axial phase measurements can be used to determine which machine in a train is misaligned. Phase is measured at each bearing. Set the strobe light to read a convenient mark on an exposed shaft or coupling. A coupling is not a good place due to limited visibility but it is often the only place. With the sensor at one end of the train, adjust the phase knob to see the mark at 12:00 o'clock. Move the sensor to the next bearing at the opposite end of the first machine and read the phase by the position of the mark. Since the sensor orientation is reversed an "in phase" condition puts the maker t 6:00 o'clock (180 degree phase shift) so care must be taken when analyzing the results. You will see another 180 degree phase reversal at the next bearing across the coupling.

Since a 180 degree phase shift is imposed by the nature of the sensor locations, an out of phase condition is found when the 180 degree shift is not seen. The bearing on the machine that shows the axial phase to be out of phase indicates which machine is out of alignment, see Figure 3.

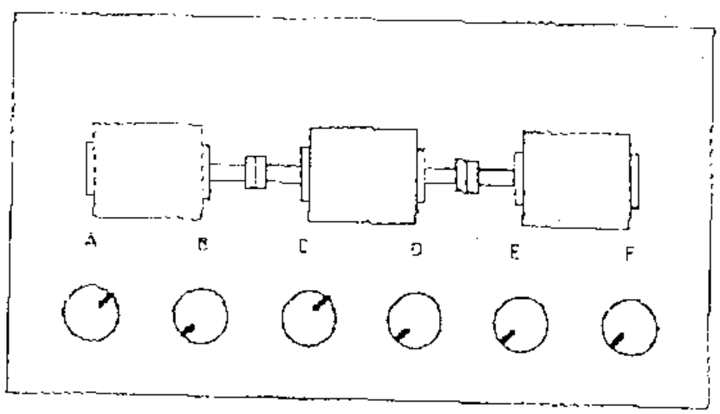

Figure 3

Checking Alignment Using Phase

PHASE AND MECHANICAL LOOSENESS

Mechanical looseness is another problem which can be detected using the phase comparison technique. When mechanical connections (bearing cap to pedestal or machine foot to base) are tight they will vibrate together or in phase.

By making phase measurements (vertical sensor orientation) at each mechanical connection from the ground to the bearing cap, looseness will be seen by an out of phase condition, see Figure 4. If all the phase measurements show no change in the phase angle then no looseness was encountered.

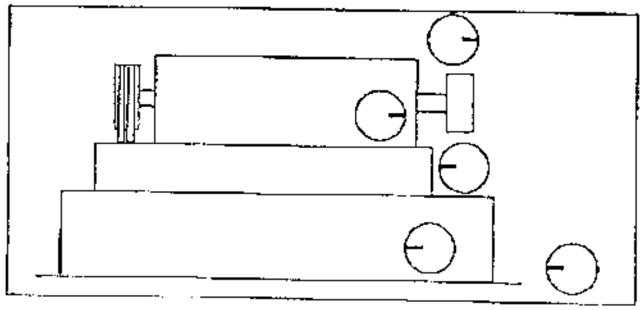

Figure 4

Checking for Looseness Using Phase

Cracks can be found using a measurement technique similar to looseness. A vibration sensor is moved along the surface in question while observing phase. An abrupt change in phase angle will occur as the sensor is moved past the separation.

Cracked shafts in machinery can be found using phase analysis to help detect a lowering of critical speeds during coast down. The strobe light does not lend itself to analysis tasks where speed is changing too fast. A tracking filter analyzer that can make a Bode plot is better suited to finding cracked shafts.

PHASE AND MOTION STUDIES

Changes in processes, running speeds or machines themselves can often cause vibration where there was no vibration before. These changes can cause shifts in resonances of the mechanical system that will cause a piping system to vibrate and break brackets or cause a bearing vibration to be higher than what was seen before the change was implemented.

A strobe light can be setup to observe a mark on the shaft of a machine to which a questionable piping system in connected. The vibration sensor is mounted on the piping system near the machine end flange. The sensor is moved to locations at measured intervals along the piping system while recording the phase as noted by the location of the mark. Plot the phase on a graph and also note the location of hangers or brackets on the same graph, see Figure 5.

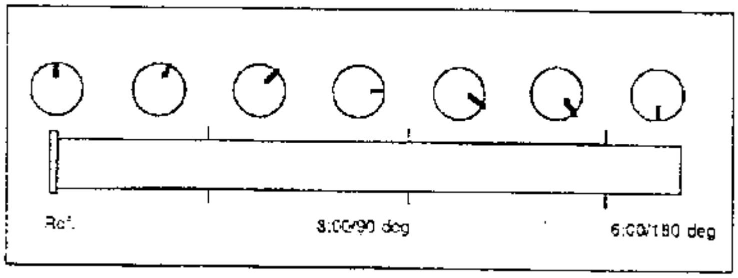

Figure 5

Piping System Motion Analysis Using Phase

The phase readings show the direction of motion (deflection shape or Mode). Study the graph for areas along with the piping systems where changes in direction were recorded. Pick points between the noted readings where a change occurred. These points have little or no motion because they are the pivotal points (called node points) for motion.

Now compare the node points with the noted locations of hangers or brackets. If a hanger or bracket is located at a node point, it is doing little to restrain movement of the piping system. If you have been breaking hangers or brackets, chances are they are located between node points (called anti-nodes) where maximum deflection can be found. In general, a fix will comprise moving hangers or brackets away from node points and adding them to the anti-node point area.

The motion, caused by vibration, of a machine platform or skid can be measured and plotted in a manner similar to that outlined for the piping system. It is not unusual to find a resonance of a platform being excited by a machine's running speed. This is especially true after modifications to the machinery have been made. A motion study, using phase analysis, will reveal nodes and anti-nodes which can be used to modify the structure.

There are software programs available that help the user understand the results from motion studies. Such programs display this data in what is called an "Operating Deflection Shape.." It is an animated display showing deflection. Amplitude is exaggerated but nodes and anti-nodes are clearly illustrated. Often the user is able to determine possible corrections by moving braces or by adding new ones. The phase data for these studies can be derived from using the strobe light.

SUMMARY

The basic strobe light is a handy tool for any plant. It allows the user to find and replace worn belts, springs, valves and dampers. Adjustments to machinery can be made to improve performance. Even nonrotating machinery can be observed and adjusted to maximize product handling.

A strobe light with the added functionality for phase analysis offers the user another level of machinery diagnosis and problem solving. These tasks include balancing, alignment verification, looseness checks and platform or piping system motion studies.

Phase analysis offers the user the ability to find out how a machine is vibrating or moving. Once the pattern of machine deflection or movement is known, a combination of vibration frequency analysis, phase analysis and knowledge of the mechanics of the system allows for an accurate diagnosis of a problem.

ACKNOWLEDGMENTS

The use of strobe lights started many years ago and many have written about their use over this period. It is difficult to credit any one person or company with specific applications. Much early work has been done by Entek IRD, Ralph Buscarello in his Update International, Inc. training notes, Charlie Jackson, Consultant and author of a Vibration Primer series and so many other users in various industries and in plants all over the world.

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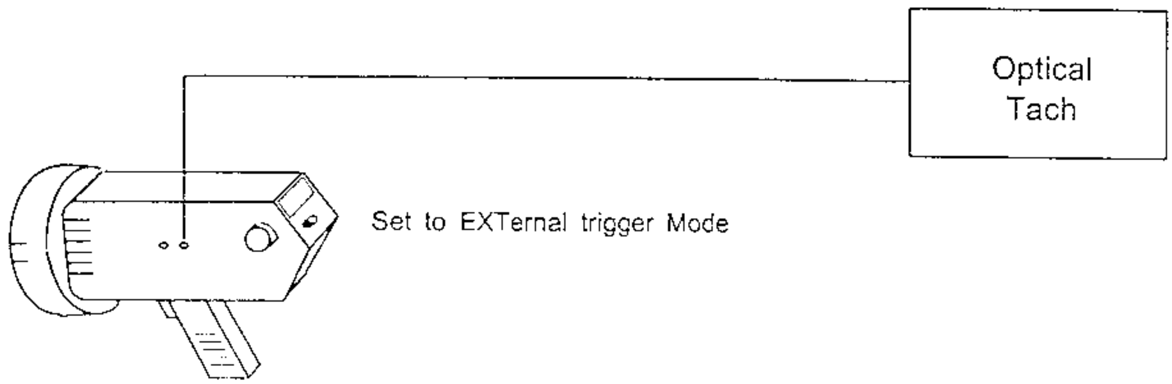
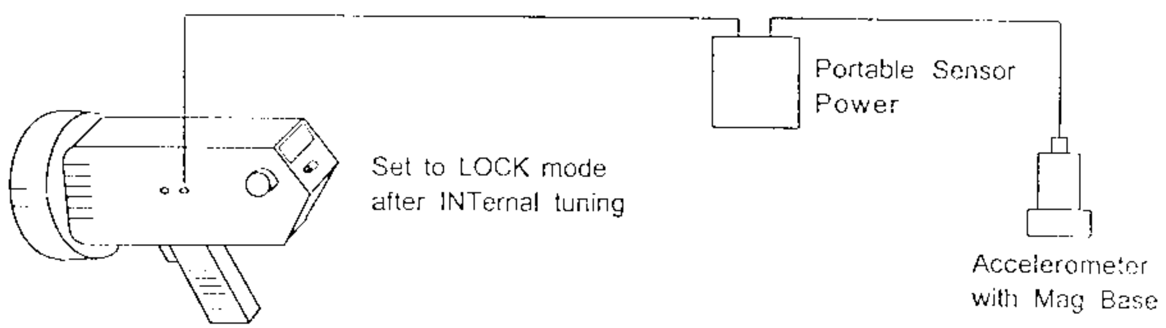
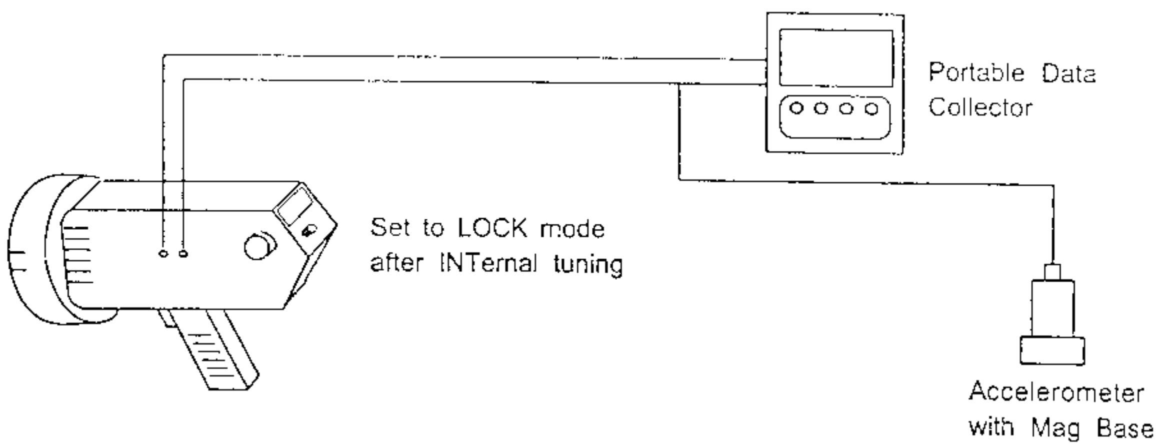
Typical Strobe Light Connection Diagrams



Vibration Strobe used to perform speed referenced motion studies



Vibration Strobe used to perform phase studies



Vibration Strobe used to obtain synchronous phase data for analysis and balancing

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