

# THE DECI REPORT

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July 2002

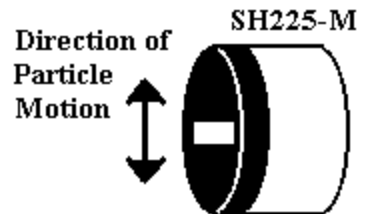
## **In this Report:**

Using the SH225-M to measure shear velocity of plate materials.  
The difference between out-of-plane and shallow in-plane sources  
**Sensors useful for Modal Ratio with the AESMART®**

### **Using the SH225-M as a shear wave pulser**

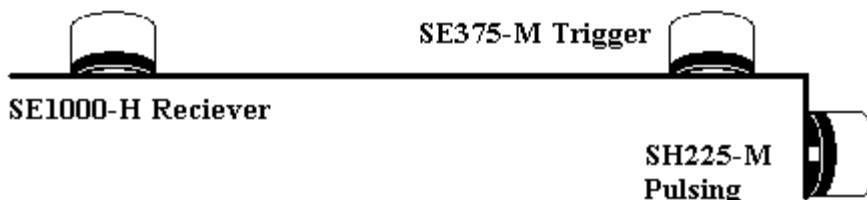
The SH225-M was developed as a means to couple to shear waves, especially as a shear wave generator. Some experiments are described demonstrating the utility of the SH225-M. The DECI model 600 pulser is used to excite the SH225-M in each case. The AESMART® is used for AE data recording.

The SH225-M has a distinctive wearplate pattern that helps to make it easy to distinguish from other sensors. The white wear plate is rectangular within the black protective area on the shear face. The primary direction of particle motion is perpendicular to the shorter length of the wearplate, as shown in the diagram.

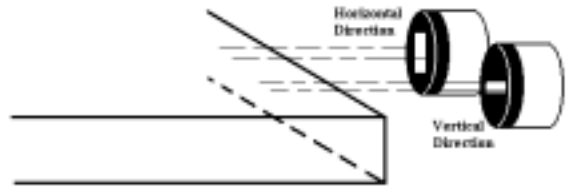


The simplest experimental configuration is when two SH225-M's are placed face-to-face and coupled with petroleum jelly, one sensor acting as a pulser and the other as a receiver. When the active areas of the sensors are lined up, the sensitivity is at a maximum. As the sensors are rotated with respect to one another, the signal received will drop to 1/10th or less when sensors are oriented at 90 degrees from their alignment. With the AESMART®, you will be able to see the coupling falls even more dramatically in the low frequency range, dropping to less than 1/20th of the peak signal at full alignment.

One function of an SH225-M sensor is to induce bulk shear waves in a plate. Here an SE1000-H sensor is placed at a distance of 14 inches (350 mm) from the edge. An SE375-M is used as a trigger sensor. This experiment is similar to the experiment reported in the October 1997 DECI report, "Modal Analysis of AE Signals." The primary difference between this experiment and that described in the 1997 report is that this experiment is using off-the-shelf commercial components. The SH225-M replaces the piezoelectric crystals bonded to the plate in the previous experiment. Advantages of this include flexibility to better control and change experimental conditions, one SH225 can be used and simply rotated to perform the entire experiment.



When The SH225-M is oriented to produce vertical displacements, as shown in the diagram, mode conversion to low frequency wave occurs. When oriented such that horizontal displacement occurs Sh waves are produced and the low frequency waves are no longer present.

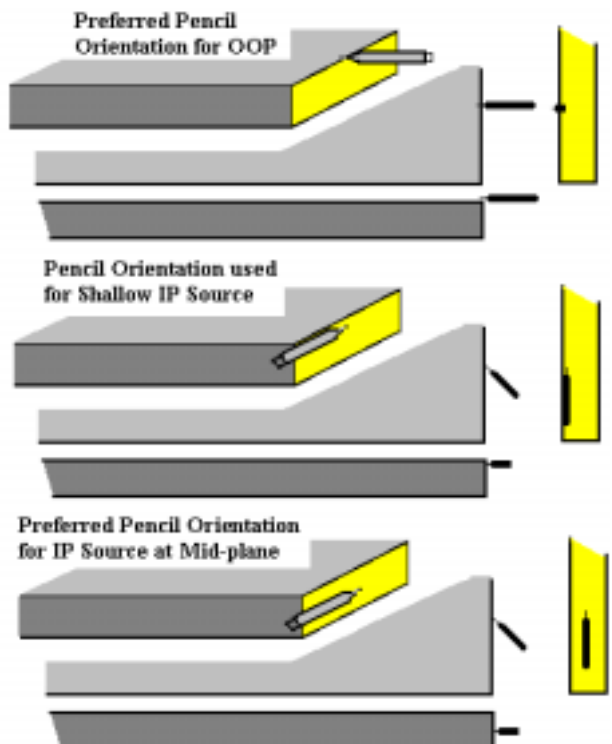


One can easily measure the shear wave velocity of plate materials. One example is to place one transducer at the end(edge) of a 2 inch thick plate and use the model 600 pulser to make this sensor the source of shear waves in the plate. Another SH225-M should be placed with the same orientation at the opposite end of the plate (46 inches away) to act as a receiver of the shear waves in the plate. When both sensors are oriented such that the particle motion is parallel to the surface of the plate, (Sh) signals are generated and detected. For this example a very accurate value of the shear velocity in the plate can be obtained due to the sharp rise time of the signal with no noticeable extensional wave arrival. When the sensors are oriented such that particle motion is vertical to the plane of the plate, mode conversions occur as mentioned in the previous report that prevent an accurate measurement of the shear velocity. Therefore when making shear velocity measurements in plate like material always align the sensors such that Sh and not Sv waves are produced.

### The difference between out-of-plane and shallow in-plane sources

One of the prominent differences that the AESMART® helps to distinguish with modal ratio is the depth of in-plane (IP) sources. With this in mind, it has been asked if it is difficult to tell the difference between a shallow IP source and an OOP source. More specifically, is using the modal ratio to discriminate noise from cracking still effective when the cracking is near the surface. The simple answer is yes.

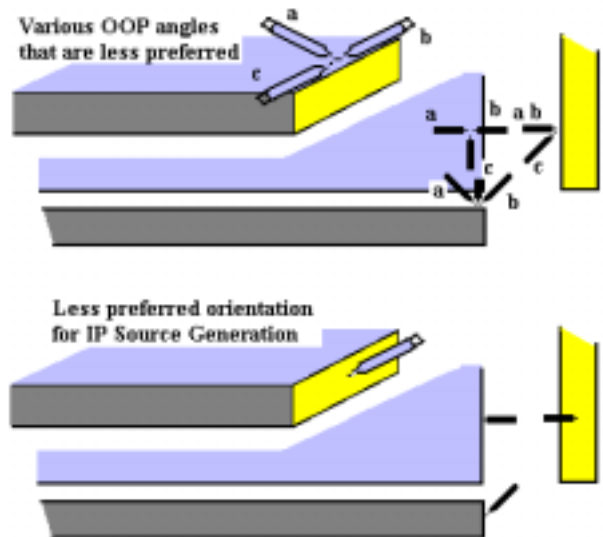
The confusion may arise when one forgets that the type of source affects the modal ratio. In fact, a variety of sources can generate wider ranges of modal ratios than the shift in modal ratio due to depth. One aspect of different source types that deeply affect the outcome is the direction of forces that are generated. In the case of cracks, a shallow crack and a surface crack are one in the same. Another way to look at this is that a crack at the surface is in fact a shallow crack. This is not the case of pencil lead breaks at the surface and at shallow inclines, as the direction of forces are completely different.



With pencil lead breaks, a simple experiment shows the large difference in modal ratio between a shallow in-plane break location and an out of plane break. IP pencil lead breaks produce modal ratios

similar to cracks, whereas OOP pencil lead breaks produce modal ratios that are more similar to many noise sources. In a 3/16th inch Aluminum plate with an SE9125-M sensor 9" from the plate edge, the OOP pencil lead break produced a modal ratio of about 1 under repetitive breaks. Note that we are trying to produce a normal force in this case, the previous diagram shows the optimal angle for the pencil lead to achieve this normal force. The shallow in-plane pencil lead break at almost the same location produced modal ratios near 5.5 under repeated breaks. The pencil lead should be held parallel to the plate to best simulate a crack, as shown in the previous diagram. Modal ratios for this plate reached 8 or 9 when the pencil was held near or at the center of the plate span. There are other variables involved in the final modal ratio measured, but generally this is the relationship to look for. In a half inch steel plate, the same series of experiments produced modal ratios of 0.4 for the OOP, 1.3 for the shallow in-plane and 2 for the center in-plane.

The preferred orientations shown for pencil lead breaks are used to introduce specific force directions. While these other orientations for the pencil lead break do not produce greatly different results, they introduce forces that are not intended for the simulated testing. Holding the pencil lead perpendicular to the plate will reduce the overall modal ratio, in the case where an IP source is being simulated, the modal ratio dropped to the vicinity of 2. The modal ratio for OOP pencil lead also fell to as low as 0.6 when the pencil was pointing toward the sensor. So the various angles of pencil leads on the surface tend to scatter the results, while various angles of the pencil leads on the plate edge will produce less than ideal IP sources, usually with correspondingly lower modal ratios. Again, the pencil lead break best simulates a crack when it is held parallel to the plate.



Another source of AE that is of interest is impact noise. This is a much less directional source than a crack or a pencil lead break. In fact an in-plane impact still does not resemble a crack from the modal ratio standpoint. On this plate, two impacts were made: a simple free falling impact and an impact focused by an external focal point. The simple impact maybe as simple as hitting the plate with a screwdriver, the focused impact is hitting an object resting on the plate. Both impacts produce very low modal ratios. The simple impact produced modal ratios as low as 0.05, while the focused impacts produced values near 0.2. Incidentally, when these impacts were made at shallow in-plane positions instead of OOP, modal ratios as high as 0.5 could be registered. It should be noted that this later case does not represent any known source conditions for AE testing.

### **Sensors useful for Modal Ratio with the AESMART®**

Because the AESMART® system works on the principle of detecting and separating two distinct modes, the choice of sensor for use with the AESMART® is important. Many AE sensors are not appropriate for the Modal Ratio analysis, which is not surprising. Perhaps what is surprising is the variety of sensors that have proved useful with Modal Ratio.

The best all-around sensor for modal ratio is the SE9125-M (or SE9125-MI). Best in this case means the sensor has balanced sensitivity to the in-plane (IP) and out-of-plane (OOP) signals. In fact they are equal for high frequency OOP sources, so these sources have modal ratios of 1. The IP sources have higher modal ratios.

The SE650-P sensor also works well with modal ratio and is helpful in very noisy environments. This is because it is both a higher frequency sensor and it has additional isolation against environmental noise. The higher frequency helps to better isolate it from intense low frequency vibration. A practical check is recommended on the structure when environmental highly active noise is present. The check should include an adequate simulation of a crack signal while the noise sources are active. If the simulated signal is still detectable with the sensor and the AESMART® modal ratio system, the noise rejection is sufficient. An SE25-P excited with a model 600 pulse generator and attached to an edge of a plate in the structure works well as an IP source. Additional lower frequency gain may be needed when using the SE650-P which will reduce the dynamic range. The high frequency airborne noise rejection of this sensor is enhanced by providing 20 dB of additional isolation between the case and the crystal.

The SE150-M provides an appropriate sensor for use with an AESMART® in some practical circumstances. The SE150-M has higher overall sensitivity than the SE9125-M and does a much better job at detecting high frequency signals. The sensors balance for modal signals is less desirable than for the SE9125-M for instance, high frequency OOP sources will produce modal ratios around 3.

There are many sensors that find use with the AESMART®, but not as a means to detect modal ratio. As previously mentioned, the SE25-P is very useful as a sensor to pulse. It is also useful as a receiver for modal ratio analysis of small thick coupon specimens. The high fidelity performance of SE1000-H makes it an ideal candidate for frequency analysis of plate waves. The SE375-M is a sensor well suited to triggering with the AESMART®, although its main use is with traditional AE.

The pico sensor is a very small sensor used by researchers in Tribology, metal cutting, and polishing applications using the ASL feature of the AESMART® 2000 and 302A. The low frequency sensors, SE40-Q and SE45-H, have application oriented uses, such as for detection of leaks and termite infestation.

The SH225-M, the newest DECI sensor has special uses in studies using the AESMART®. This sensor has a shear response with a rectangular footprint. Designed for use as a pulser or receiver mounted on the edge of a plate with petroleum jelly as couplant, the orientation of the shear waves generated or received from the SH225-M can be adjusted by simply rotating the sensor case. In this manner, Sv and Sh shear waves can be generated and received in plates.

In summary, the AESMART® exploits special characteristics of certain AE sensors to obtain unprecedented levels of discrimination between AE signals. The special sensor characteristics required for modal ratio does not mean there is not a choice of sensors with the AESMART®, as evidenced by the success of the SE9125-M, SE650-P and even the SE150-M with the modal ratio concept.