Investigation of Interactions between Cable Leveling and Heading Measurement

SA 2.2

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SUMMARY

Magnetic heading sensors continue to play a crucial role in marine 3D seismic streamer positioning. Despite a variety of apparently sophisticated pre- and post-mission calibration techniques, navigation processors are still routinely required to make subjective assessments of individual compass biases, or use modelling techniques to produce reasonable looking final location data.

Although several mechanisms may contribute to the time and spatially variant nature of these biases, the authors believe that a critical, and previously un-noted source of these biases has been isolated. Controlled experimental data is described, a mechanism is discussed, and some potential remedies are suggested.

INTRODUCTION

For more than 10 years, magnetic heading sensors have been the primary method for positioning marine streamers for 3D surveys. Initially, compasses were built into the streamer, in special sections. However, as it became required that regualar in-line group spacing be maintained, compasses migrated to pods externally mounted on the streamer. These externally mounted pods tended to act as sources of streamer noise, and over the last few years, there has been a very positive move to integrate heading sensors into the depth controllers (birds).

The estimation of compass biases (misalignment, non-linearity, etc.) has taken up considerable effort from manufacturers, geophysical contractors and oil companies. However, different techniques of bias estimation often give different results. The final judgement on what bias corrections to apply on a line by line, even shot by shot, basis is left to the navigation processors. Their judgement, sometimes aided by a computer generated model, relies heavily on a subjective perception of what streamer shapes are "realistic".

The assumption that is generally made is that since the streamer is a non-rigid body, fixed "kinks" in the cable are not acceptable. This often leads to the conclusion that some compasses exhibit different biases from line to line. In some cases, such compasses are simply excluded from the streamer.

In most cases, the ambiguity in "bias" is less than 0.5 degrees, but 1.0 to 1.5 degrees are not exceptional. Often biases are random down the streamer, and tend to self cancel, thus minimizing total positioning error. Vessel crews are trained to place better compasses at the front of the streamer, where biases would have the maximum detrimental effect. (The authors will suggest later that the putting good compasses at the front may well be a self fulfilling prophesy). As a result of all these phenomena, major positioning errors due to compass biases have been rare...but far from unique.

CALIBRATION TECHNIQUES

Regardless of the packaging of the compasses, 3 techniques have remained as the cornerstones of bias estimation technology. In varying degrees of sophistication, these techniques are:

1 : Bench calibration : The compasses are placed at accurately known magnetic headings, and C-O values comuted at each point on the compass rose. This is highly accurate, and generally repeatable technique, but it fails to comprehend the magnetic environment of the streamer, the magnetic inclination of the survey area, and any dynamic effects.

2 : Short Tow calibration : All compasses are placed as close as possible, without causing interaction, far enough behind the vessel to avoid any perturbation of the Earth's field. Given a sufficient drag, the assumption is made that all the compasses point in the same direction. Various statistical methods are used to extract bias estimates.

3 : Production calibration : Production compass data is statistically evaluated based on the assumption of a "water-pulley" effect, causing compass headings to be the same as they pass over the same point in space. This technique has little statistical merit over a few lines, but given sufficient statistics, good results can be achieved.

INITIAL OBSERVATIONS

During a visit to a vessel in late 1988, an observer on the vessel crew noted that during production, two compasses 4 meters apart at the tail of the streamer read 5-7 degrees different. One of these birds was at a fixed wing angle (10 degrees), while the other was in depth keeping mode, resulting in a wing angle of minus 8-10 degrees. When both birds were put to zero, their headings agreed. The experiment was repeated with the compasses on the other streamer, and results were similar. The tests were repeated with the two pairs of adjacent compasses at the head of the streamer, and no significant heading differences could be observed.

FIRST EXPERIMENT

A short tow compass calibration was performed prior to the start of a 3D survey. Thirty (30) compass-birds were placed on a 150 meter calibration section, 300 meters behind the M/V Cecil H. Green II. 1200 meters of streamer was towed behind the calibration section, to act as a drag anchor. The weather was perfect, and the streamer floated at 10 meters +/- 1.5 m with all the wing angles set to zero.

A 45 minute line was run in each line direction, resulting in 300 samples of each compass. Two compasses showed major failures, and one

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exhibited a bias of over 1 degree. (Fig. 1) Standard deviations on all 28 operational compasses were excellent.

The second line was extended by 15 minutes, and +15 degrees of wing angle was forced into the front 10 compasses, and -15 degrees in the mid 10 compasses. The standard deviations remained low, but significant biases of up to 6 degrees now appeared. (Fig. 2)

These wing angles are quite excessive for normal operation, and although it was realized that an important phenomena had been observed, the results asked more questions than they answered: -

1 : If the effect was due to some dynamic, mechanical effect, was it cumulative?

2 : Was the effect linear with speed/fin angle, or was there some threshold level?

With these questions in mind it was agreed to perform a more controlled experiment at the next opportunity.

CONTROLLED TESTING

The objective of the second experiment were: -

1 : Eliminate any possible cumulative effect, by changing fin angles only on a small number of birds within the data set.

2 : Determine differences between different manufacturers.

3 : Determine the linearity of the mechanism, by using more reasonable incremental fin angles.

4 : Determine the effect of streamer tension.

To this end, 10 Syntron RCL-4 integrated compass-birds, 22 Digicourse model 396 compass-birds and 6 Digicourse model 321 pods were assembled aboard the M/V Northern Surveyor. The calibration cable was configured as in the first experiment described above.

A continuous line was run at 5.7 kts, taking 60-120 samples at each of 9 configurations. Wing angles were only adjusted on 6-30 per cent of the birds. Three degree increments were used, from 0 to 15 degrees.

RESULTS

The sea state was 2-3, but a strong cross wind caused the vessel to crab up to 6 degrees, with a feather of 3-6 degrees in the opposite direction. The crossed winds and seas caused a strong hypercyclic near surface current. Unfortunately, with 38 birds on the calibration section, a strong slant was observed on the cable. This caused a systematic "bowing" of the cable, somewhat obscuring any curvature induced by compass-birds. Figure 3 shows the variation in depth and heading deviation on Cal Line 1 - with all zero wing angles.

Of the 38 units deployed, only compass 30 failed to work throughout, and has been excluded from all calculations.

Figure 4 shows the effect on heading deviation caused by putting the birds in depth keeping mode on Cal Line 2a. Note that the algorithm used to minimize bird battery usage causes a steady state to be reached in which adjacent birds are forced to fight each other on the calibration section.

Figure 5 shows the results for Cal Line 8, in which discontinuities in heading can be seen at each compass-bird with non-zero wing angles. The data collected on Lines 5 through 9 showed a near linear increase in the spread of deviations apparent at the compass birds.

MECHANISMS TO PRODUCE FIN ANGLE BIAS

Several people have noted that acceleration in a magnetic field can induce systematic bias in the observed heading. Since compass birds undergo more dynamic movement than pure compasses, it has been suggested that this could cause the effect. However, the magnitudes of this error are not consistent with our observed biases. Nor would this mechanism explain the streamer tension dependency which has been circumstantially observed.

Another common theory concerns the movement of the motor within the compass-bird. This theory breaks down since tests conducted in flow tanks by various other groups, with compass-birds attached to rigid beams indicate no such significant bias.

The authors believe that the compasses are in fact working correctly. They are measuring the heading of the cable directly above them. Unfortunately, in the real world, the birds pull not directly down, but have some component of pull to left or right. The cable is thus systematically, locally "kinked" by the bird. This theory is by no means proven, but fits the data well. The process of birds pulling to left or right is generally referred to as "kiting". It should be noted that if this is the case, the compasses are sampling the cable heading at the most anomalous possible point.

CONCLUSIONS AND RECOMMENDATIONS

1 : One component of perceived heading sensor bias is the local deformation of cable shape caused by fin angle, in integrated cable leveller/heading sensors. The magnitude of this deformation is approximately 0.6 degrees for 1200 meters of streamer, with 15 degrees of fin angle. This magnitude may not be accurately estimated from this data set, due to the presence of the noise induced by the hypercyclic current observed in the survey area.

2 : If the authors' hypothesis on the mechanism is correct the effect should be: -
(a) only a weak function of vessel speed. (at higher vessel speeds, the streamer tension is increased, and the water flow over the bird wings is also increased. This would result in some cancellation between the two effects.)
(b) inversely proportional to the amount of streamer behind the compass.
(c) approximately directly proportional to the fin angle in the bird.

3 : The effect can be minimized by: -
(a) careful streamer ballast at zero wing angle,

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(b) Use of heading sensors in pods at the tail of the streamer.

(c) A new fin angle control mode for short tow calibrations, in which depth is maintained, but the birds constantly seek to return to zero fin angle. (This would result in excessive battery usage in production.)

4 : The observed strength of the depth dependency implies that in some area, considerably more sampling may be required, especially if flared streamer work is to be considered.

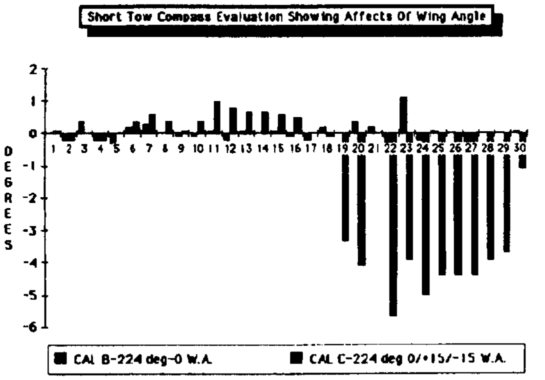

FIG. 2. Heading deviations observed with excessive wing angles.

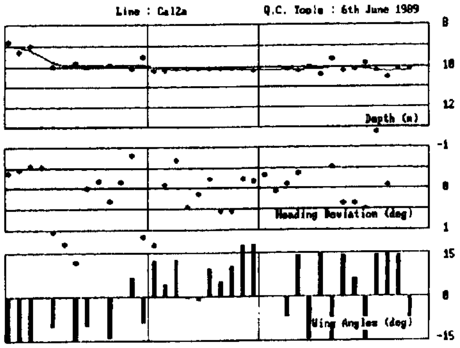

FIG. 4. Heading deviations due to depth-keeping activity.

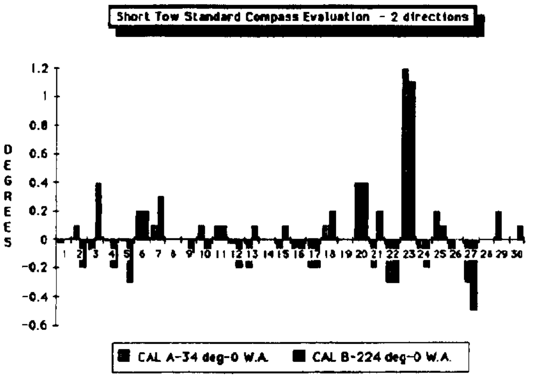

FIG. 1 Heading deviations observed at zero-wing angle.

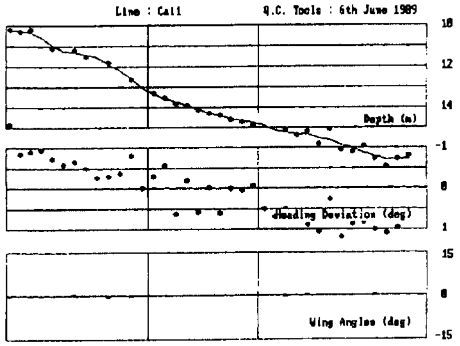

FIG. 3. Heading deviations due to hypercyclic currents.

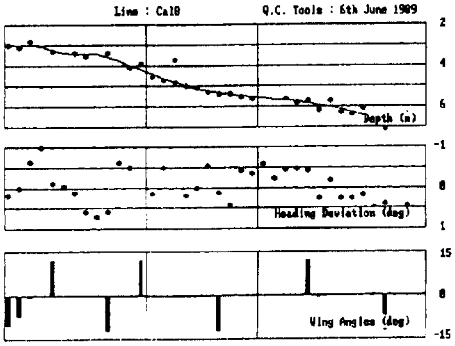

FIG. 5. Heading deviations due to controlled wing angles.

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