

Internal Technical Trip Report.

Velocimeter Field Trial at Customer's Site

David Coffey . 19th May 2006 (re-edited 4-Sep-2006 by Stan.B.)

Arrival and introduction.

We arrived at the plant at 10AM and met briefly with Mr. P. who is the Radiological Protection Officer. This preliminary meeting was necessary, since the company needed assurance internally that the Velocimeter unit did not constitute any radiation hazard. We informed Mr P., that the unit operated at 77GHz and below 50mW (approx 17 dBm). He was happy that these levels did not constitute any radiation hazard.

Production Line Trial.

Following this, we were brought to the 4 Stand Cold Rolling mill where an installation point had been prepared and a mounting bracket made in advance of our visit. The unit was mechanically mounted and powered from a 24V DC switched mode power supply. The company provided a 0-10V chart recorder to monitor the live data from the unit. This was connected to the velocimeter's 4-20mA current loop output, in parallel with a calibrated 250-ohm resistor. The unit was also connected to my laptop via an RS232 – USB Bridge to facilitate a high level diagnostic and data-dumping interface using the auxilliary Velterm application.

Initial attempts at obtaining an echo from the primary installation site were fruitless. Firstly, it appears that although the optimum distance in lab trials using a rotating disc were approximately 60cm, with the E-field vector polarised in the rotation plane of the disc. However, experimentation at the line demonstrated that the optimum configuration at the line (using the current antenna and lens) appeared to be 30cm from the strip with the E field polarised at a 45-degree angle to the strip. Initial assumptions are that because the strip in practice is thicker than the rotating disc used in the laboratory setup, the backscattering profile is different. I have since also looked up some literature on the subject and found that the effective RCS (Radar Cross Section) for a disc and rectangular slab are quite different. I will investigate this further and submit my findings on this as a follow-up.

Secondly and perhaps more significantly, the initial mounting position was on a solid metal block which contained vertical guide rollers which actually ran against the strip. This setup was conducting significant mechanical vibration into the sensor housing which at the least was having a microphonic effect on the system and at worst (which is suspected but yet to be confirmed) causing the soldered transmitter module joint to go intermittantly open circuit. This would explain the total inability of the unit to obtain an echo since even off focus, we would expect to find some form of echo if even at low amplitude.

Another change that had to be made to the system in order to facilitate measurement was the removal of the 24V switched mode power supply in favour of powering the unit from a linear DC lab supply. In an industrial environment, particularly as we were situated within metres of a 27000HP electric motor (that's 20.133 Megawatts in new money!), the concept of an electrical ground is a myth. Switched mode power supplies are notorious for poor ground isolation, so in this case a linear supply was preferred. The fact that the input circuitry was being saturated at 60Hz was confirmed by the fact that first, second and third harmonics of mains were observed in the signal spectrum at almost equal amplitudes.

Line trial in earnest.

After much nailbiting, gnashing of teeth and a smoke break (during which, I was surprised that Stan didn't start smoking!) an echo was obtained with Stan physically holding the unit about 30cm from the strip (in the middle of an oil-water emulsion shower). After improved aiming and polarisation adjustment, the echo was quite strong (over 2Vpp). The first coil measured on a customer's plotter is shown below:

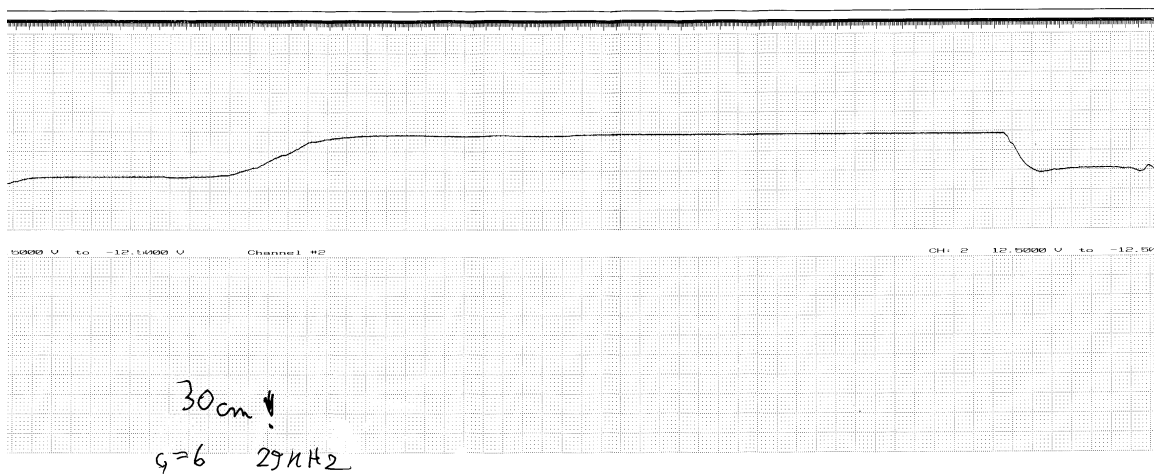


Figure 1. First Live profile.

This trace constitutes one complete coil from beginning to end, the first 'live' field data obtained with the velocimeter.

Although the new position provided a significant echo there were still problems in terms of other aspects of the mounting location. There was a metal sheet (head) which rests on top of the strip within the field of view of the velocimeter. At certain velocities, on the larger gauge strips (0.205") this sheet resonated and was vibrating significantly and modulating the field, this is shown in the trace below.

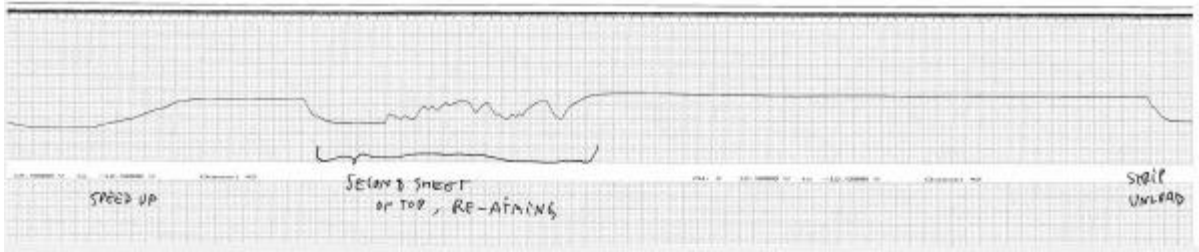


Figure 2. Resonating Head

This effect however is not a major problem as the velocimeter can be mounted in a permanent location away from the head. However, for the current trial, this was the only place available for aiming. All in all we tested the velocimeter on a number of coils. Of particular interest, the two gauges tested (0.075" and 0.205") almost constitutes the full range of thicknesses. I thought I had seen the last of 'singing heads' when I left AME but apparently not.

Post Trial Meeting.

After the trial was completed at 3pm, we had an informal meeting with Andy and Anil (the shift engineering supervisor). We presented them with the data from the chart recorder and they were positively encouraged. In principle, they were very pragmatic about the problems we had experienced, to the extent that I believe they had expected them to be worse. Indeed, Andy intimated that the 4 Stand was probably the worst case scenario and making it work there would mean that it would comfortably function in other locations they have in mind in the plant, namely the galvanising line and the tempering line (the fact that their internal thought processes are focusing on other applications, bodes well for us). We agreed that the next step would be to review the trial, address the immediate issues at hand and install an unattended demo in the near future to allow them to test the system over the full ranges of gauge and strip widths that they produce.

Summary of open issues, observations and recommendations

Effect of vibration on the unit operation.

As a first attempt to ameliorate the effect of vibration, perhaps the unit should be mechanically isolated with Viton or Neoprene grommets. Further isolation may be necessary such as separating the cavity and horn antenna from the enclosure with a threaded plastic NPT coupling. Stan will carry out further investigation on the transmitter module connection joint to evaluate the impact of the vibration on the soldering. As the transmitter internal and connector junctions are the most critical assembly step, this is probably the most crucial issue to be resolved.

Optimum unit operating range.

It was discovered in practice that the optimum distance from the strip was 30cm however we had envisaged 60cm and this had been borne out by measurement with the rotating disc in the lab. This demonstrates that the polar pattern of the current horn/lens

combination is less than optimum at the desired distance. I have been working on a new horn design with a wider aperture (57mm). I will revise this design to a larger aperture (75-80mm). I have also designed an astigmatic (hyperbolic) polypropylene lens for the 57mm horn to collimate the beam. I will redesign this lens for a larger horn aperture and also create two more experimental lenses focusing at 30 and 60cm distances. I had done some far field modelling of the 57mm horn to optimise the beamwidth (currently approx 6-7 degrees at 57mm aperture diameter). I will remodel the larger aperture to optimise the design. In addition to this I will use simulation package to derive near field simulations of the various horn/lens combinations as a final check on the design before the new horn and lenses are manufactured. For the next trial, the customer is amenable to test at 30cm however in production and in wider practice, 30cm would not be considered as a safe operating distance, as a strip break could wipe out the entire unit. Another issue pertaining to optimum distance, is the issue of how to deal with the different strip widths encountered in practice. The customer uses a Fife optical guidance system which is mounted on a hydraulic ram and always maintains a fixed distance from the strip edge. Although this is a workable solution, it would be poor engineering practice rely on this fact in the industry in general as each installation may vary by a significant amount. We will also investigate the possibility of designing an optional waveguide so the measurement electronics can be further removed from the strip such that a strip break would only wipe out the antenna, which can be supplied as an optional spare part.

System Software.

The unit software worked well and Stan's prior insight in terms of the menus and operating parameters, which were field changeable such as gain etc, were invaluable. In terms of the difficulties in aiming the unit and parameters that needed to be frequently changed during the installation, it was definitely a two man (person) job. Stan (the greasemonkey) was at the line adjusting target distance and polarisation angle while I (co-pilot) was at the laptop taking time series and spectra and giving Stan thumbs up or down to improve the signal strength. A number of steps could be taken in the software to ease the effort involved in installation. Firstly, a crude spectrum could be displayed on the LCD display during installation to facilitate one man aiming and polarisation adjustment. A simple bargraph displaying a log power spectrum could suffice. Secondly, adjusting parameters in situ, using the push buttons required frequent removal of the lid and exposing the electronics to potential water damage. One potential solution to this would be the ability to change system parameters via the diagnostic serial interface from a remote PC or PLC. I have added an experimental expression parser to the firmware that would allow parameter changes by sending 'C' like ASCII strings to the unit. The original reason for doing this was to facilitate a scripting interface to the customer to allow them to upload source code like strings so they could define the system response to various fault and process conditions which we can not envisage at compile time. The basic principle is that the software enters a Finite State Machine loop after each measurement iteration and depending on the current and previous states, the unit will take an action, which is pre-defined by the customer such as triggering the relays, outputting pre-defined loop currents etc. The general idea is that each installation will most likely be unique and it is undesirable to provide a separate firmware revision for each unit.

Other Hardware Issues.

Other than the issues with the antenna and lens, the remaining hardware issue is that of mains rejection. The unit currently has a high pass filter with a corner frequency of approximately 200Hz. In addition to this, the signal chain requires a sharp 50/60Hz-notch filter to prevent saturation of the signal channel with mains pickup, which may find it's way to the unit via ground return or induction.

Conclusion.

The trial was a success. The velocimeter concept was proven and demonstrated to the customer to their satisfaction. The issues, which did arise, were by no means insurmountable though nonetheless hair-raising at times. The main objective of demonstrating the ability of the velocimeter to measure a moving strip and output the result through an industry standard 4-20mA current loop were fulfilled. Valuable lessons were learned and improvements are already afoot and will appear in the next product iteration.

Footnote.

This was my first visit to the production floor of a steel mill. In future I will not wear a suit and tie. As a further observation, we owe Stan a new shirt and a new pair of trousers – *and that's just based on the soiling that was visible from the outside!*

