Force Based Condition Monitoring of Railway Infrastructure

Abstract: A South African transportation company has implemented a force based condition monitoring system to reduce the infrastructure / vehicle interaction life cycle costs of a railway infrastructure. It has been demonstrated that force measurements can be used to successfully prevent catastrophic failures in the Overhead Track Equipment from occurring and recurring. Opsens' OSP optical strain gages were used for the measuring system because they suit perfectly to this harsh environment. These sensors provide accurate and repeatable measurements in electromagnetic interference, mechanical vibrations and in adverse weather conditions.

There are many benefits that can be obtained by measuring the vehicle /infrastructure interaction contact forces in order to identify defective components in the infrastructure system. It has been estimated that eighty percent of the railway infrastructure life cycle costs are spent on the maintenance and renewal phases. It is therefore imperative for any railway wishing to reduce life cycle costs to optimise maintenance methods and strategies. On the rail, parameters such as the gage, vertical and lateral alignment are commonly measured. On electrified railway systems, contact wire height and stagger are the parameters most frequently measured and used to plan maintenance interventions. However, geometry measurements alone cannot be used to identify defective equipment or components. Spoornet Railway, a South African transportation company, has established focused research work to develop and implement a force based measurement system to detect faults on the Overhead Track Equipment (OHTE) that cannot be detected using traditional methods.

An instrumented pantograph was developed to measure the dynamic interaction between the pantograph and the OHTE so that this complex interface could be studied. Measured data were used as input parameters into simulation models that were developed. The results from the dynamic simulations were used to optimise settings of the pantograph as well as those on the OHTE. In the process of conducting the research, both experimentally with the instrumented pantograph, and theoretically with the simulation models, it became apparent that defective components / components whose settings need to be re-adjusted could be detected.

After this initial success, an overhead condition monitoring system was developed to plan overhead maintenance. Figure 5 shows the block diagram of the system. The following parameters were measured: the tri-axial contact force between the pantograph head and the contact wire consisting of the vertical (Q), longitudinal (L) and lateral (Y) contact forces (see Figure 6), the contact wire height above the rail and the stagger of the contact wire. Special load cells needed to be designed and built to enable the measurement of these parameters. Opsens OSP optical strain gages were bonded to the load cells to create the sensing element. The gages, with their immunity to electromagnetic interference (EMI), their robustness and their high sensitivity, always gave accurate and repeatable measurements even under electrical and electromagnetic interference, mechanical vibrations and climatic stress.

Three overhead condition monitoring systems are currently being used in the Spoornet network. The first is a 25kV AC locomotive that has been specially modified and fitted with the measurement system. The second system is a mobile system that can be fitted to any class of electrical locomotive operating in South Africa. A third system has been fitted to Spoornet's track geometry recording car. Once the measured data have been post processed, a detailed report together with the detailed graphical reports, summary graphs and exceedance lists is compiled. (See Figures 7 and 8).

To facilitate the interpretation of the measurements, software was developed by the client to process and display the data in real-time. The program uses multiple treads to execute three functions simultaneously: the data acquisition, processing and storage functions; the GPS polling and distance calculations functions; and the monitoring of the control signals function. An example of a summary graph is shown in Figure 8. This summary is used by the maintenance planner to prioritise his scheduled maintenance. By glancing at such a summary, the locations that need priority corrective interventions become apparent. He can then refer to the detailed graphical summary to determine the exact cause / nature of the fault so that recurring faults do not occur. This process allows the planner to optimally schedule and allocate the resources that are necessary to perform the corrective maintenance at a particular location. The methods that have been developed can be easily extended to identify faults on the track structure as well.

Figure 1: Scrape marks on contact wire, caused by pantographs bouncing due to low tensioned contact wire

Figure 2: Cause of vertical impact force due to pantograph hitting cross-span. This was due to low tensioned OHTE causing abnormally high contact wire uplift.

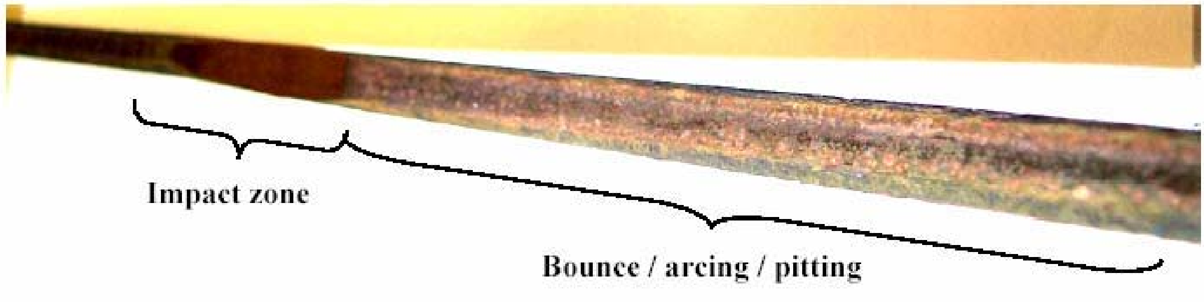

Figure 3: Example of a kink that resulted in a severe vertical impact force. The arcing caused by the bouncing of the pantograph head as well as the wear caused by the impact force can be clearly seen.

Figure 4: Side view of contact wire showing the presence of a kink

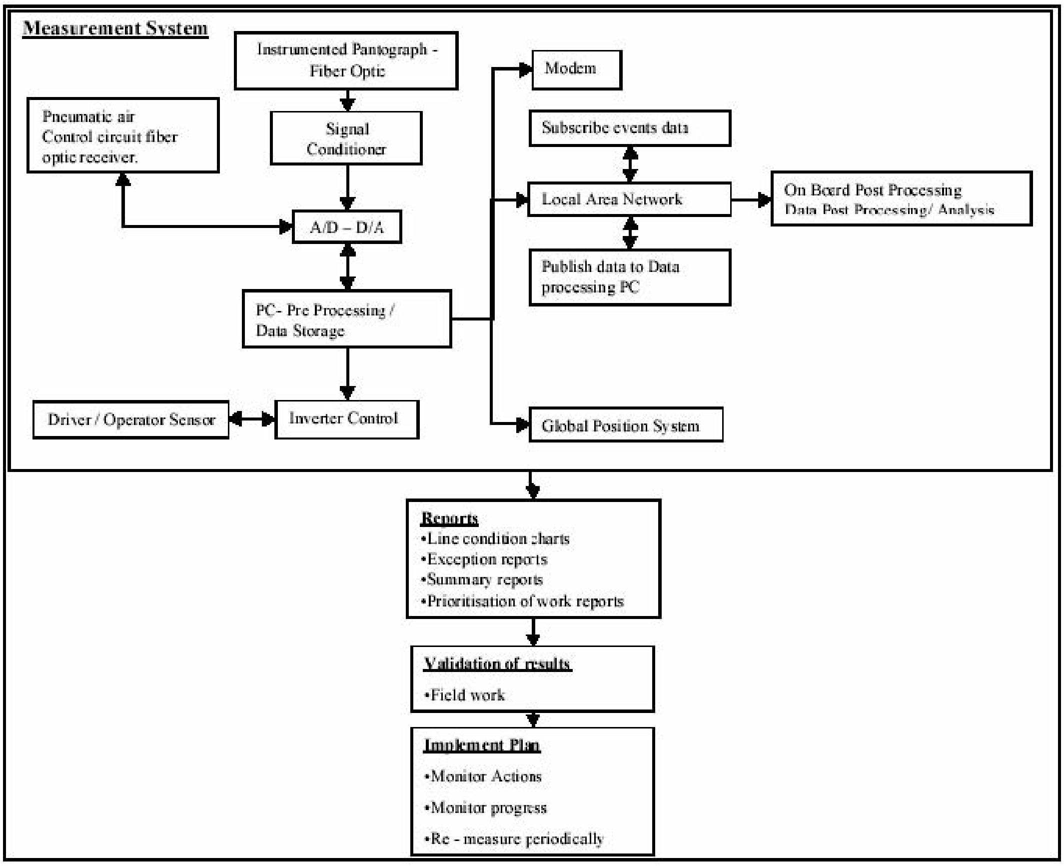

Figure 5: Block diagram of Condition Monitoring System

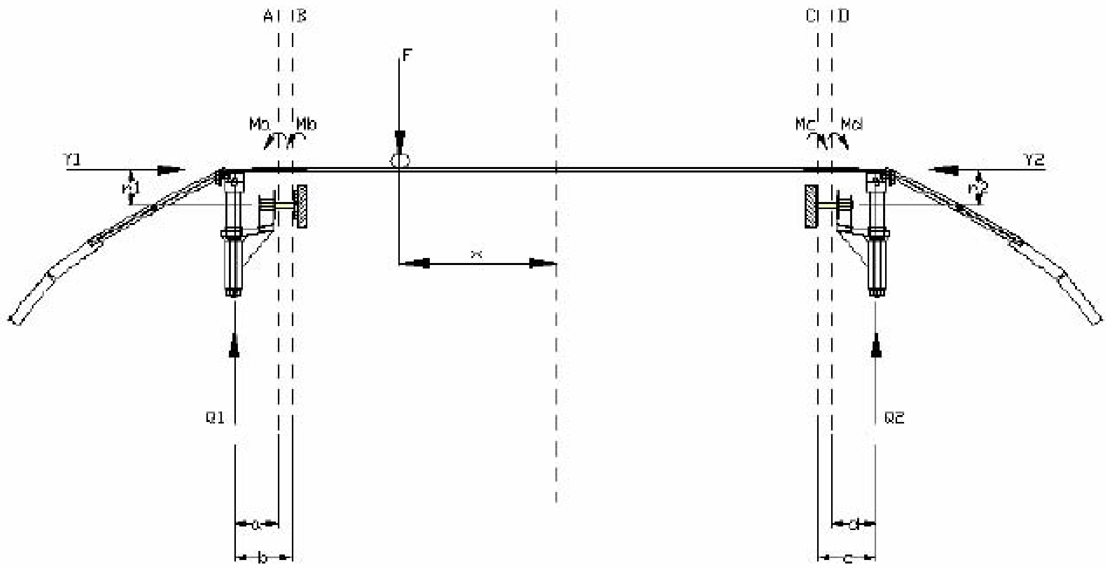

Figure 6: Free body diagram of pantograph head illustrating load cell position and input forces

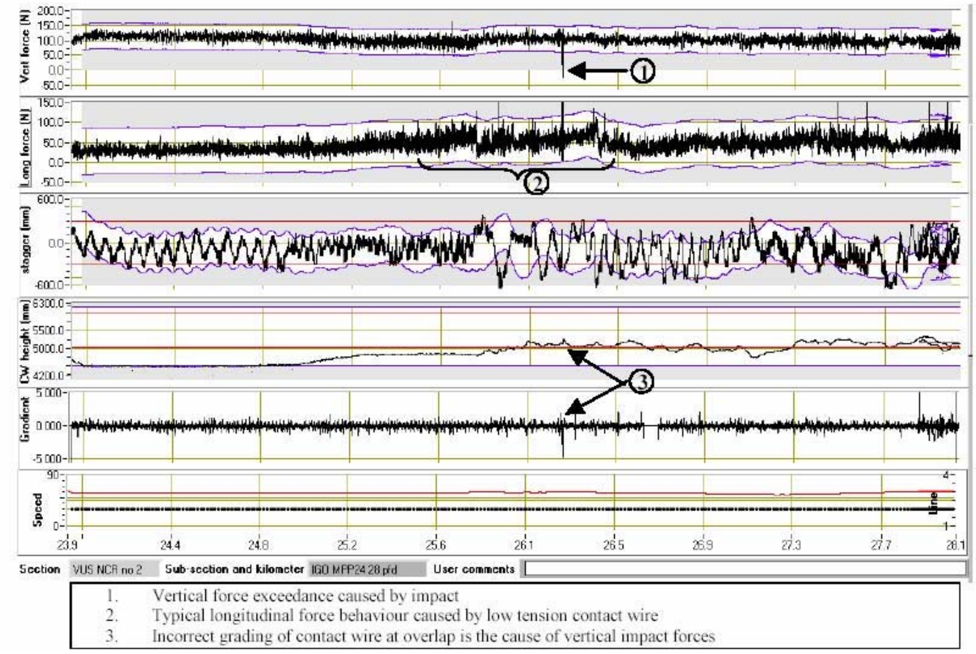

Figure 7: Example of a detailed graphical report showing some exceedances

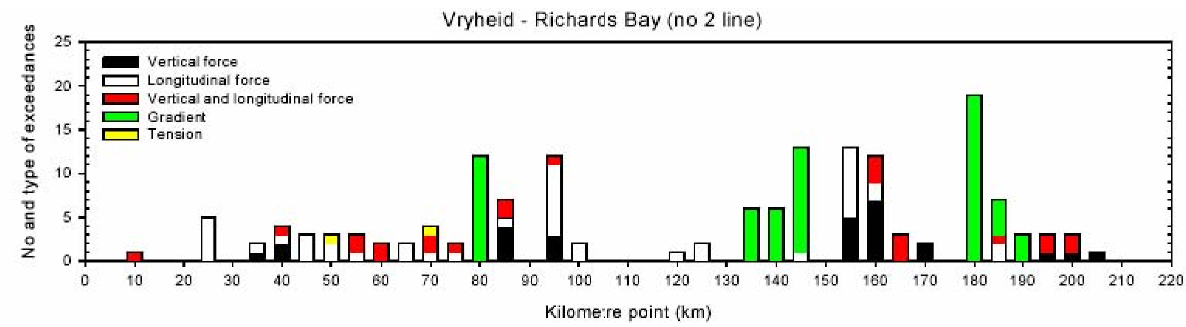

Figure 8: An example of a summary report