IN SITU TESTING OF LARGE MACHINES: ALTERNATIVE METHOD FOR RADIATED EMISSION MEASUREMENT

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ABSTRACT

On the legal aspect, the new European Directive on ElectroMagnetic Compatibility 2004/108/EC concerns also large machines. On a technical point of view, the special situation to characterise the EMC behaviour of large machines imply that current procedures are complex and very expensive, and in some cases even not possible. Adapted measuring methodologies and procedures are needed.
As a response to this situation and within the European R&D Frameworks, the TEMCA2 project aimed to develop new and adapted methodologies for the assessment of EMC related to this type of industrial large machinery.

KEYWORDS

EMC, large machines, EMC directive, standards, emission, alternative measuring methods.

1. INTRODUCTION

Regarding EMC, the machinery-industry drags along a set of problems that makes testing and characterising very complex and expensive. Therefore, adapted procedures are needed. Machinery manufacturers have a wide experience in mechanical engineering, but a lack of expertise in electromagnetics, electromagnetic wave propagation and EMC, both in certification/testing and design for compliance. One of the important aspects is that they are basically system-integrators of electrical and electronic modules, assembled inside the final product. In this way, they “inherit” the responsibility of the final machine compliance with the European EMC Directive 2004/108/EC.

Moreover, most of the machines have characteristics (size and dimensions, weight, supply voltage, power consumption, other auxiliary provisions as cooling water, pressured air …) that make the self-certification based on the complete machine testing on an EMC test-site or in an EMC laboratory very complex, expensive or even impossible. Most of the times, it is not feasible to transport the machine and evaluation must be carried out “in-situ” at the manufacturer or user premises.

2. EMC DIRECTIVE AND STANDARDS

First of all, the EMC legal aspect should be considered. The new European Directive on EMC 2004/108/EC [1] concerns also large machines.

Large machines, in the usual sense of this term, are normally *apparatus* and have to be treated as such, except if they could be considered as *production lines*”. When considering a large machine as an ‘apparatus’, the conformity assessment procedure has been simplified to a single procedure. Even if harmonised standards are not applied, there is no more a compulsory involvement of a third party.

Concerning standards and based on the last Harmonised Standards list published in September 2007, one should consider the product family standards for machine tools EN 50370-1 [3] and EN 50370-2 [4], respectively for emission and immunity. Regarding the scope of these standards, machine tools may include motors, heating elements, sensors, transducers and activators, electric and electronic circuits and may be powered by the mains or any other electrical power source. These standards do not cover *fixed installations* as considered by EMC Directive, neither safety consideration as in the Machinery Directive.

Of course, large machines are not only machine tools but this couple of standards might be applied for other kind of machines as a reference when there are no European harmonised standards or where they do not cover all the protection requirements applicable to the machine.

The test approach described in these standards is quite informative. Type testing of a finished product should be the normal method for conformity assessment. In the case of a complete machine tool or in the case of large machines, a complete testing is only technically and economically feasible for a limited number of machines.

Three procedures are applicable:

- procedure A is a type-test on the complete machine,
- procedure B is a type-test on the entire electrical set of the machine, and a visual inspection of the machine regarding the correct installation of the components and cabling,
- procedure C is to divide the machine in EMC relevant modules and test them separately under lab conditions, if not already done, followed by a visual inspection, and a test as final check at the manufacturer premises.

The methodology is given in the flow chart in table 1.

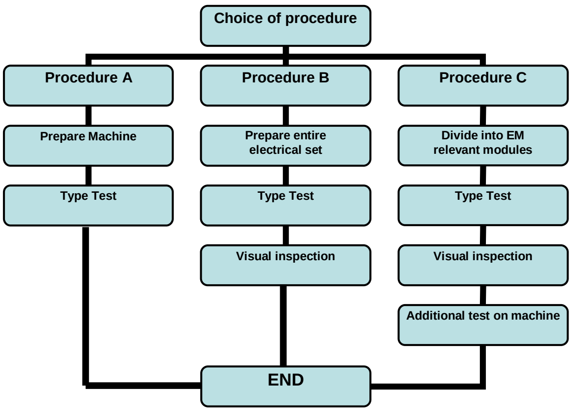


Table 1. Procedure for compliance as given in EN 50370

It is clear that procedure C sounds interesting to the machinery community, also because this allows a flexible way of handling, especially for these machines including a lot of customer based options. It allows an in-depth characterization and validation of all separate modules, and only an additional test is needed on the complete machine. This final testing may be performed using alternative methods, as developed in the research project TEMCA2. This project was conceived and proposed by a joint Working Group formed by CECIMO (European Committee for Co-operation of Machine Tool Industries) and CENELEC. This group prepared also the EN 50370-1/2 standards, dealing with EMC and Machine Tools.

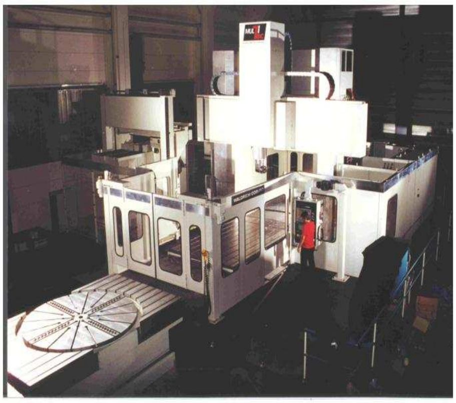


Figure 1. Example of a large machinery

3. RADIATED EMISSION

The main problems for in-situ measurements for radiated emission are:

- the lack of space to perform adequate measurements using antenna's
- the background noise in an industrial environment

Therefore, an alternative methodology has been developed, by putting a simple wire over the machine. This wire acts as an antenna, and is able to capture radiated emissions. The problem is to identify and define a correlation factor (or antenna factor) for this "test-wire" method. The general concept of measuring setups using antenna's and using a "test-wire" is sketched in figure 2.

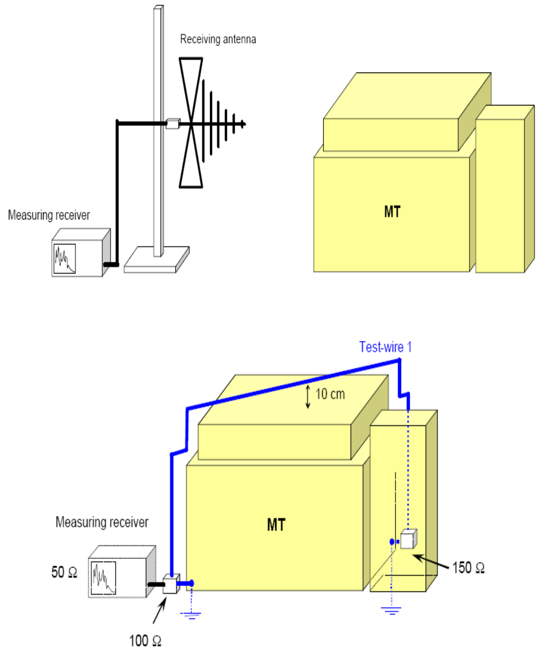


Figure 2. Antenna measuring setup (left) and test-wire setup (right)

3.1. Generic Test Object (GTO)

In order to understand the underlying phenomena, theoretical models have been developed, as well as a representative test-specimen GTO (Generic Test Object). A round-robin test was organized among the partners, in order to compare classical antenna measurements and the results forthcoming from the test-wire method.

The GTO has been designed as a generic machine. This means a type of metal enclosure, with noisy components inside (typically frequency converters) and a lot of cabling coming out for capturing data of external sensors. The noisy content was generated by an appropriate comb-generator, and the external cabling was provided by some wires near the ground and at a larger distance from the ground. The GTO is shown in figure 3.

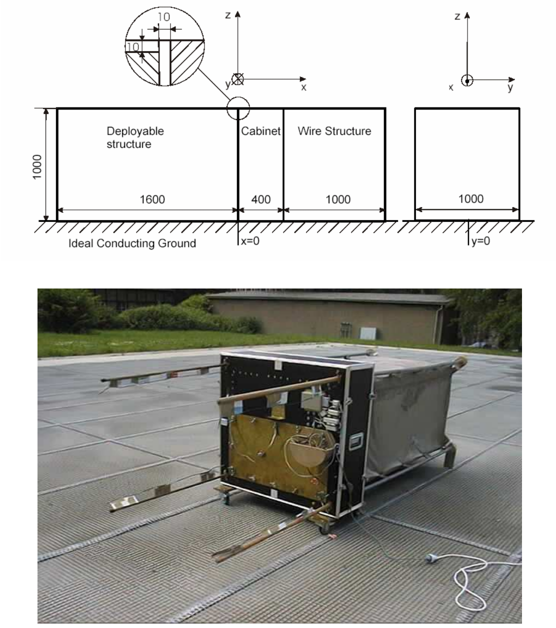


Figure 3. Drawing and picture of the GTO on a test-site

3.2. Simulation of radiated emission by GTO

Using the simulation software CONCEPT, both the field strength at 3m distance and the induced voltage in the test-wire have been calculated. The model is shown in figure 4. The calculated field strength is the reference to be used, when judging the radiated emission levels against the actual standards and the specified limits. An antenna-factor or k-factor for the test-wire is obtained by calculating the ratio between the field strength and the induced voltage in the test-wire. In the next figure, the k-factors obtained from simulations and measurements of the GTO are compared, and a suggestion for practical use is shown.

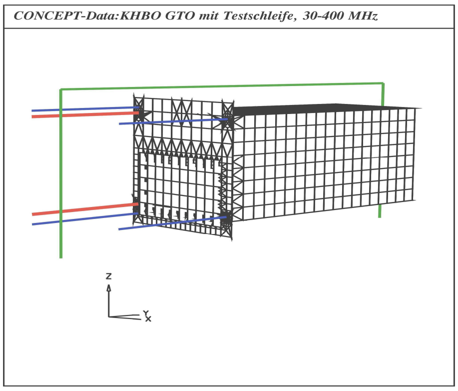


Figure 4. Picture of the GTO: the CONCEPT equivalent for simulations

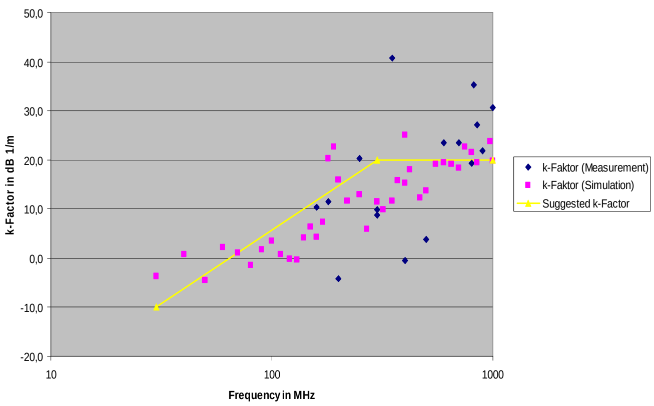


Figure 5. First proposal for an antenna-factor (k-factor), resulting from simulation and measurements

Another simulation has been performed, by introducing a set of "sources", simulated by wiring carrying currents, and a larger "receiving" test-wire. This setup is shown in the figure 6.

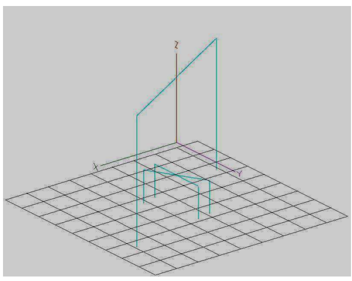


Figure 6. Set of smaller wiring, carrying currents, and the larger "test-wire" for simulations

A set of 6 cables was placed at 60 ° interval, each carrying a current generated by the same reference source, but using different load resistances. The induced voltages in the test-wire were recorded. By taking sources at both ends of the generator wires, 6 different situations were obtained. In the next figure, the induced voltages are shown. A first figure shows the influence of each wire/source combination, and the final one shows the average over all 6 combinations.

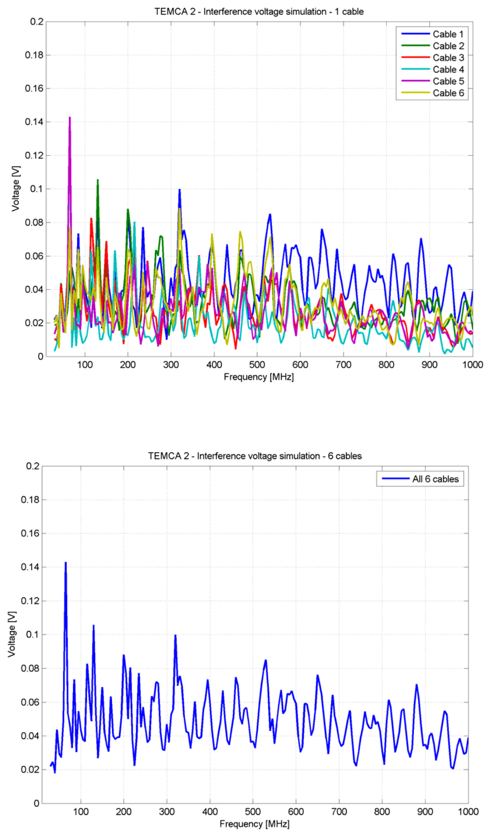


Figure 7. Induced voltages in a test-wire, by different cabling (left), and as an average over all cables (right)

As a result, different proposals for the "antenna-factor" have been formulated. An on-going evaluation action is capturing data, in order to get a better statistical overview of different types of large machines, and to formulate a final proposal for an adequate antenna-factor.

The antenna-factor or k-factor was obtained by calculating the ratio between field strength at 3 m distance (antenna measurement) and the induced voltage in the test-wire.

The next figures show 4 different proposals for this k-factor. From the first CONCEPT simulations of the GTO, a first proposal was made as **"-10 to 30 dB at 300 MHz, and than flat"**, by curve fitting of the calculated data. During the further evaluation process, based on more simulations and measurements, different proposals were formulated. One of the "corrections" was based on the fact that antenna's, acting as passive circuits, should fit into a "n x 20 dB/decade" slope. In that perspective, the k-factor **"-5 to 15 dB at 300 MHz, constant 15 dB up to 700 MHz, then constant 25 dB"** seems to give reasonable results.

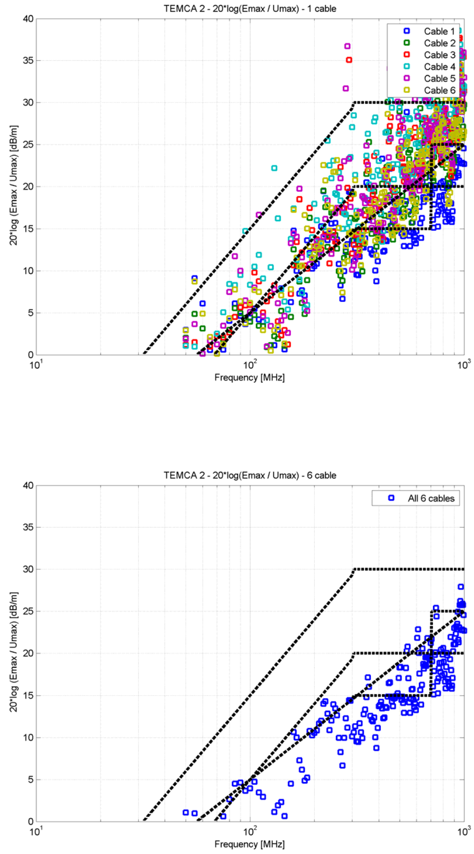


Figure 8. Different proposals for antenna-factor, given simulated results cable per cable (left) and all cables (right)

3.3. Measurements performed on GTO

Different measurement sessions have been performed by the 4 EMC laboratories, participating in the TEMCA2 project. Tests were performed as well as on the GTO, under controlled lab conditions, as "in-situ" on large machinery. An example of measuring results is shown in figure 9. More details are shown in section 4, especially about the termination of the test-wire in a Common Mode 150 Ohm impedance.

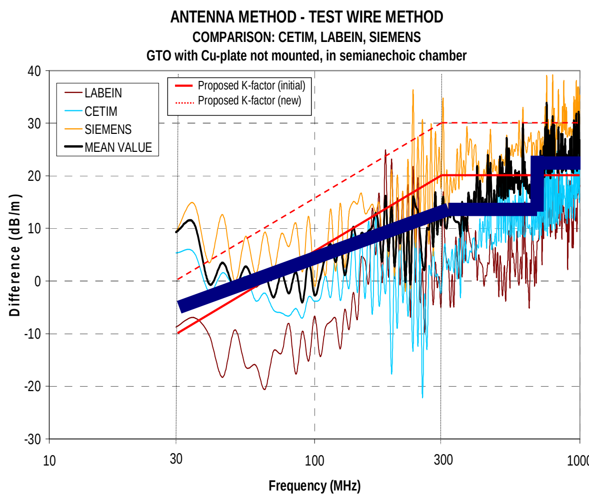


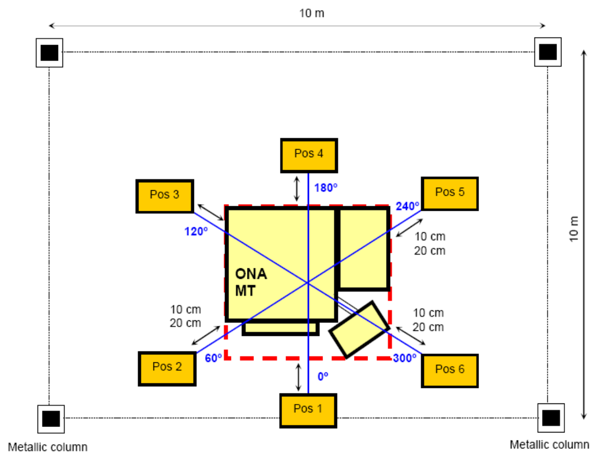
Figure 9. Example of measurements using antenna method and test-wire method, for GTO in EMC labs

4. EXAMPLE OF TESTING OF A LARGE MACHINE IN PRACTICE

In this section, an example is given how to apply the methods discussed above and to perform the tests under practical conditions. The machine to be tested is and Electrical Discharge Machine (EDM) tool from the company ONA ™. The machine uses a wire for spark erosion machining and has been used as a reference machine in the TEMCA2 project.

Figure 10. Picture of the EMD from ONA ™ (spark erosion)

Concerning radiated emission, the next pictures and figures show the setup using 6 positions of the test-wire and the practical layout of the test-wire, as well as the measured results for radiated emission, using an antenna method at 3m distance, and the test-wire method. Again, no k-factor or adapted antenna-factor has been applied to the test-wire measuring results (see section 4 for a detailed analysis about the k-factor to be applied when using the test-wire setup).



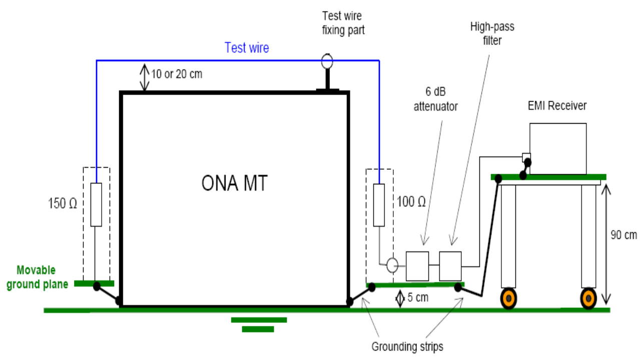


Figure 11. Sketch of the measuring setup for radiated emission using the test-wire method

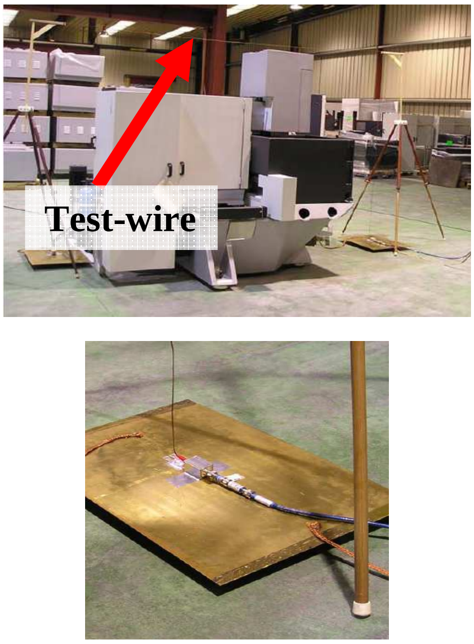


Figure 12. Applying the test-wire in practice (left) and its termination in 100/50 Ohm

From the pictures in figure 12, it can be seen that the method is very simple and easy to apply “in situ”. A couple of wooden supports are carrying the wire, and a set of two movable metal ground planes are used to connect the 100 and 150 Ohm terminations.

The most important factor is the need of a low-impedance connection between these ground planes and the (earthed) chassis of the machine.

The measured results for this test machine are shown in figure 13. Two measurements were performed using the classical antenna set up, at 3 m and at 10 m distance. The test wire was placed at 10 cm above the machine.

The differences between the antenna measurements at a distance of 10 m and the rough results (no antenna factor applied) obtained from the test wire method are shown in figure 14 and the proposed k-factor is highlighted.

It is clear that the proposed k-factor, resulting from the earlier research work, both from the simulation results as forthcoming from the GTO round-robin tests, is in a fair agreement with the measured results on this test machine. It must be noted that the actual available data and first conclusions are only based on these preliminary results.

More validation work is needed on more machines of different sizes and applications, in order to get enough data for a statistical analysis of the proposed k-factor under practical (industrial) conditions.

The only conclusion at this moment is that the method looks very promising for use as the final control measurement, when applying procedure C of the standard EN 503780-1. But it is quite possible that “fine-tuning” of the k-factor will be necessary after a larger number of validation measurements (ex. other cross-over points).

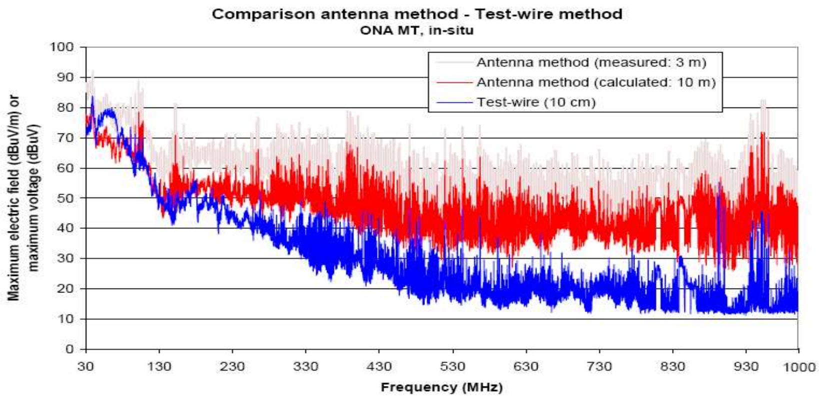


Figure 13. Comparison of measured radiated emission by antenna method (left) and test-wire (right)

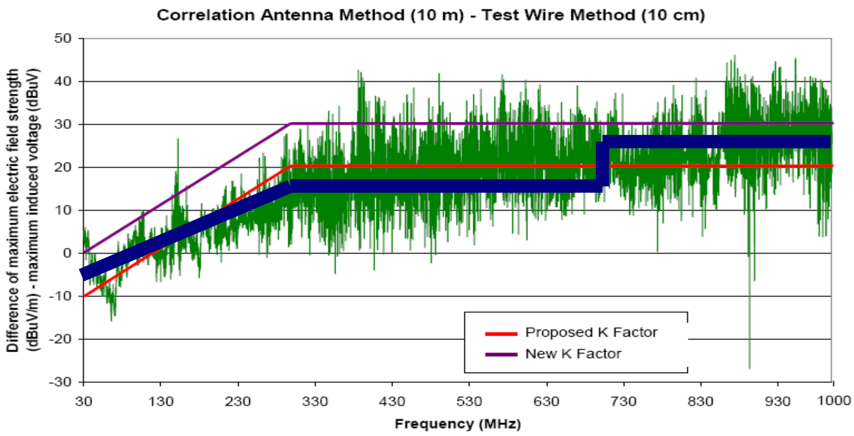


Figure 14. Example of comparison between antenna method and test-wire method, and proposed k-factors

5. CONCLUSIONS

In this paper, an overview has been given on the work performed and the results obtained during the TEMCA2 research project, on "Alternative EMC testing methods for large machines", especially for checking radiated emission by large machinery.

For radiated emission, a simple test-wire method has been identified and discussed. This paper shows first results from both a research part, and a preliminary validation part of the method. More measurements must be performed on large machinery, in order to be able to perform a valuable statistical analysis of the method, and of the proposed k-factor.

It is the aim that in the near future more validation tests will be performed, so that the proposed k-factor may be confirmed, or should be "adapted" or "fine-tuned", based on a realistic and valuable set of statistical data.

People interested in such a validation program may contact the main author, johan.catrysse@khbo.be

Anyway, it must be clear that the proposed method of a test-wire is only intended for the final control measurement of large machinery, referring to the standards EN 50370-1/2 [3,4] procedure "path C". This procedure allows to show evidence of compliance for EMC testing of large machinery, by characterising relevant subparts and modules, and by checking the final implementation in the machine by combined visual inspection and simple testing.

ACKNOWLEDGEMENT

The work reported was obtained during the research project TEMCA2, No. G6RD-CT-2002-00865 for the 5th European Framework Program. The full report can be obtained from johan.catrysse@khbo.be.

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