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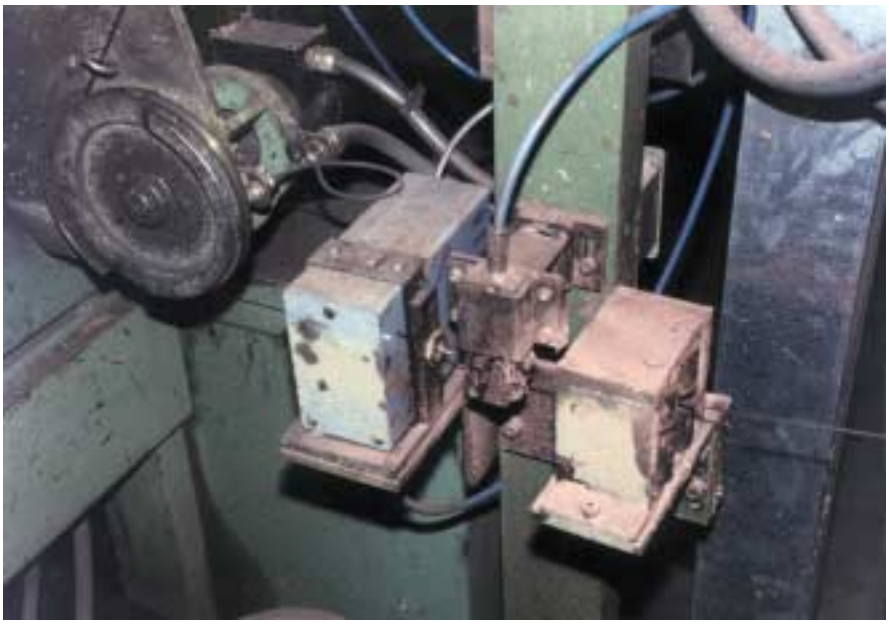
AEROEL



On-line diameter measuring of ferrous wire on dry drawing benches: how laser gauges can do their job in this very harsh environment.

Abstract

It is a well known fact that the major obstacle in expanding on-line diameter measuring practice in the Wire Industry is the high dust sensitivity of most optical instruments; which jeopardises applications on dry drawing benches, where soap and iron dust can strongly affect the measuring accuracy and blind the sensor in a short time. This report documents Aeroel's state-of-the-art laser measuring technology applied on dry drawing benches: ten years of field experience and continuous development have lead to a reliable and effective solution of the aforementioned problem.

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1 - Introduction

It is today widely acknowledged that the on-line diameter gauging of the drawn wire greatly improves product quality and process efficiency in the Wire Industry.
A number of different types of wires, especially the ones made of hi-carbon steel alloy, take great advantages from the continuous diameter surveillance.
The die wearing can be monitored in real time by checking the resulting finished diameter of the wire: when pre-set tolerance limits are exceeded, the process can be immediately halted to prevent manufacturing any out of specification product. This feature is essential when the manufacturing tolerances, the drawing speed and the weight of the collecting reel, increase to such an extent that the simple check at the end of each spool, cannot guarantee that all the wire inside the spool is within the specifications.
Additional great benefits come from the increased level of automation of the process: labour savings as manual checking is no longer required and the diameter data is immediately collected and processed to prove product quality and machine capability.
Since the very beginning, laser micrometers appeared to be the right instrument to perform this task, as only a contact-less measuring technology would have been able to gauge a product moving at high speed and possibly vibrating at a considerable rate.

Unfortunately it quickly became apparent that a number of factors would become critical to the application. The gauging accuracy; which must not be influenced by wire vibration and movement, and the cost of the equipment; which has to be consistent with the expected payback period, are surely two critical points that had to be considered. But, indeed, the most crucial point revealed was to be the sensitivity of all laser gauges (and in general of any optical instrument) to the contamination effect due to the dust depositing on the external optical surfaces. This effect is “tremendous” on dry drawing benches, because of the high amount of soap powder used as a lubricant for the die: during the drawing a mix of soap powder and steel particles is projected at high speed from the die towards the machine outlet, following the wire direction. This powder sticks to every exposed surface and especially to the laser gauge, which stays in the path of the travelling contaminants, as it must be installed after the die and before the collecting reel. Without any suitable protection, the glass windows of any optical instrument would be contaminated in a few hours (if not minutes), to such an extent as to make the gauge completely blind, making wire gauging impossible.

2 - Aeroel's know how and expertise in the Wire Industry.

Since the beginning of the 90’s Aeroel have made considerable efforts to design and develop a laser gauging system to be used specifically in the Wire Industry.
In 1992 the Wireline System was introduced and it immediately proved to be effective and suitable for the wire makers.
The System was based on an ALS12XY dual axis laser gauge (Fig. 1) featuring innovative design characteristics and a special mounting

Fig. 1: The ALS13XY dual axis laser gauge is the heart of the today WIRELINE SYSTEM, having replaced the previous ALS12XY model.

bracket with pressurising facility, to protect the gauge from dust (Fig. 2). The high dust immunity required by this type of application was obtained by combining three factors in a synergistic manner:

- optical design,
- electronic signal processing technique,
- suitable pneumatic protection barrier.

1) Optical design

The gauge's optical property is designed so as to produce a laser spot of elliptical shape and large area on the optical windows, although it is focused on the wire.

As they are very small compared with the laser spot, individual specks of dust or droplets of emulsion cause only partial attenuation of the total intensity of the signal which is proportional to the ratio of particle area/laser spot area (Fig. 3).

Although a large number of dust specks may cause the signal to attenuate appreciably, they will not cause the intensity to vary suddenly during the scanning.

2) Electronic signal processing.

A new and innovative method of electronically processing the optical signal ("video" signal), which enables the duration of the shadow of the wire (and hence its diameter) to be determined correctly, has been developed and introduced: this new technique has made it possible to extract the diameter information from a signal highly distorted and attenuated by the dust.

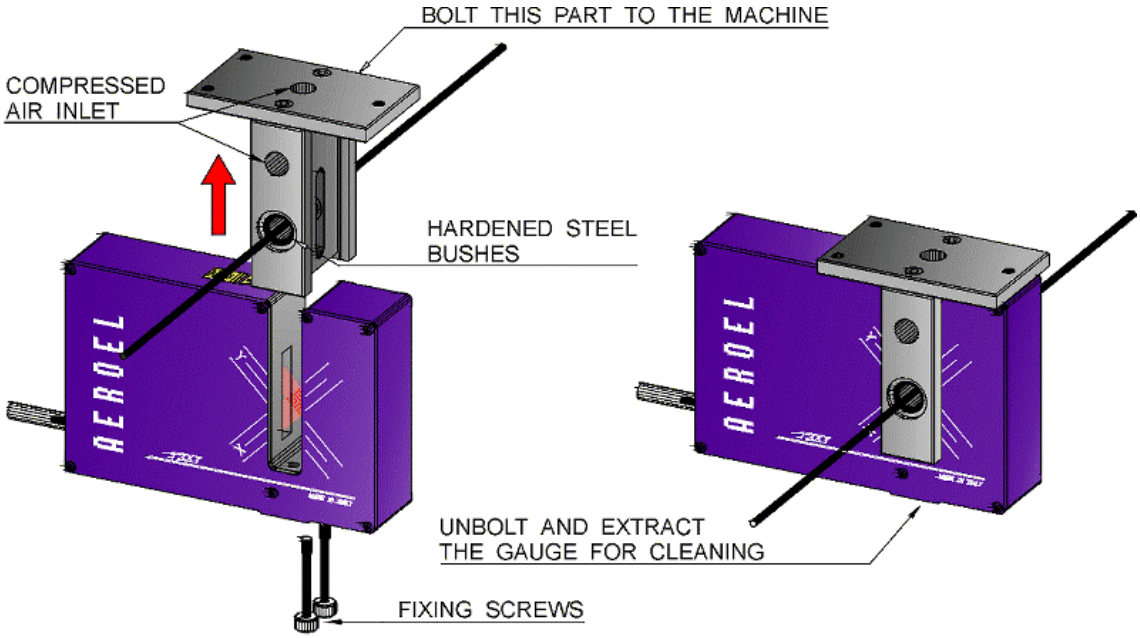

Fig. 2: Pneumatic and mechanical protection for ALS13XY gauge.

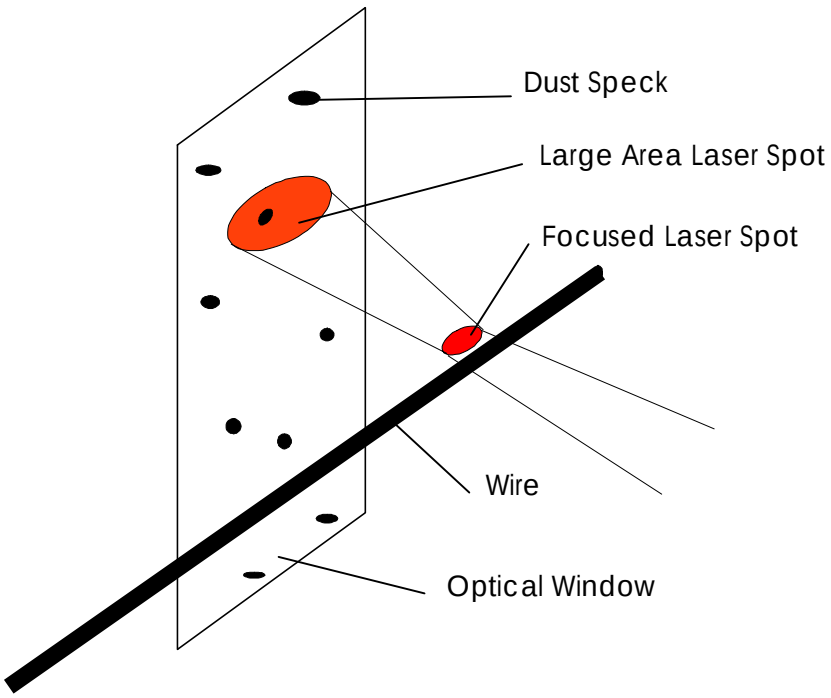

Fig. 3: The optical concept of ALS12XY and ALS13XY laser gauges.

The detailed explanation of this principle would take too long to explain here and would involve specialist electronic knowledge, which is beyond the purposes of this report: any way the figures 4.3 and 4.4 demonstrate that it has been possible to get measurements that are not significantly affected by a considerable amount of dust on the windows.

This technique is not influenced by the position of the wire inside the measuring field, even with a highly focused laser spot: thanks to this essential feature, the vibration of the wire doesn't influence, by design, the measurement accuracy, of course as long as the vibration amplitude is smaller than the width of the measuring area.
Another appreciable result is that because of its specific circuit characteristics, this method means that when there is excessive contamination, uncertain or erroneous measurements cannot be taken: instead, a measurement error condition which requires the operator to intervene to clean the gauge, is reported.

Thanks to these two specific characteristics it has been possible to install the gauges on wet drawing benches without any need for additional pneumatic protective devices, and to guarantee a minimum cleaning interval of 10 days without any risk of appreciable error caused by the contamination.
In view of the large number of gauges to be installed, the ability to work without any additional protective device has been revealed to be an outstanding feature: infact, the fitting of compressed air-fed pneumatic barriers would have greatly increased the costs to the user, both in the installation phase (pipes, filters, etc.) and in the course of on-going operations (air consumption, filter maintenance etc.). On the contrary, keeping the installation and operating costs as low as possible, several hundreds of machines in the Tyre Wire Industry have been equipped and all are perfectly working since 1992.

Although the gauge design has made it possible to obtain a remarkable resistance to dust, this was still not enough to guarantee an acceptable performance on dry drawing machines, where the working conditions are much more critical.
To afford the application on such type of machines, a special mechanical and pneumatic protection has been developed, to complete the Wireline System.

3) Pneumatic protection.

A "T" shaped bracket is locked to the machine: the wire is threaded through 2 steel tempered bushes and the gauge is simply inserted on the bracket and fixed by two screws. The bracket is fed by compressed air, which exits through the 2 bushes: a slight overpressure creates a pneumatic barrier against dust and other contaminants (Fig. 2). An additional air blowing ring is mounted some centimetres before the gauge, with the purpose of cleaning the wire and to blow back the soap powder mixed with metal particles which is formed by the wire and that would otherwise splash against the gauge. Besides preventing the gauge contamination, this type of protection has granted several remarkable advantages.

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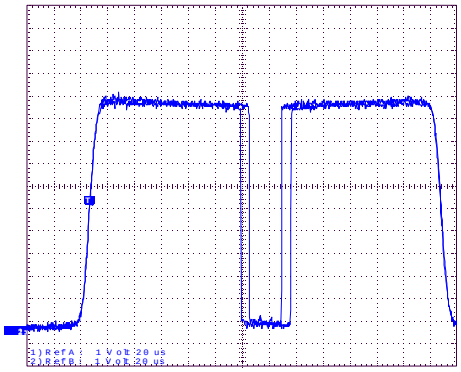

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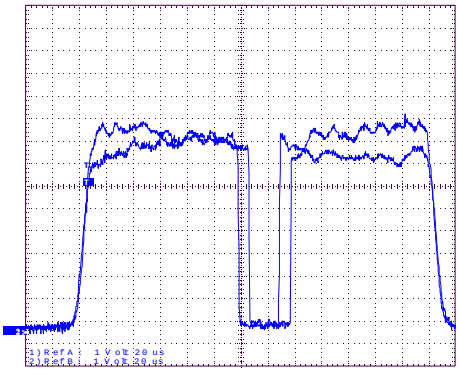

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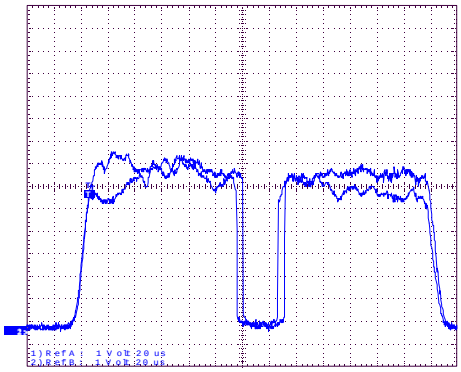

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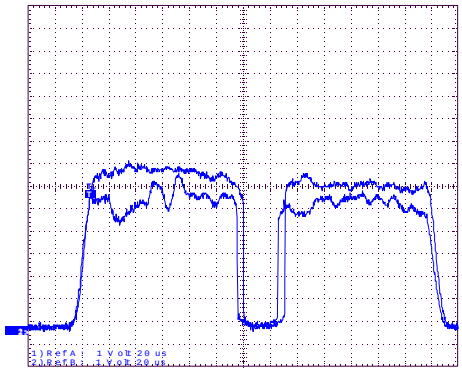

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Fig. 4: Recordings of the video signal waveforms during a long term test, to prove dust resistance. The new "self-cleaning" protection is used.

- The 2 steel bushes are an effective mechanical shield that prevents possible gauge damage in case of wire breaking.
- The gauge can be simply cleaned or serviced by slipping it out from the bracket, without being obliged to stop the machine and cut or remove the wire.
- The air to the bracket is supplied by a high pressure centrifugal blower, as the required overpressure is about 150-200 mm H_2O and the flow rate is about 20 m^3/h: the blower sucks the air from the ambient and a cheap paper filter, included in the blower, provides simple filtering from dust. One blower can supply several gauges, sharing the cost.
- No compressed air is used as the standard air available from the factory mains circuit is usually mixed with some oil and water and it would require additional filtering, using very expensive 2 stage, active carbon filters. In addition the compressed air cost would be prohibitive, due to the high flow rate required and to the periodical replacement of the filter cartridges.
- The blowing ring, fed by standard compressed air, improves the wire cleaning and the gauging accuracy.

Thanks to this solution it has been possible to install hundreds of gauges on dry drawing machines, assuring a typical cleaning interval ranging from 1 to 5 days, depending upon the type of machine, the diameter and the speed of the wire and the positioning of the gauge itself (Fig. 5 and Fig.6)

Fig. 5: Application of the ALS12XY on a dry drawing bench.

3 - The human factor

Our extensive experience in using laser gauges in the Wire Industry has underlined that another element can influence the performance of the measuring instruments and finally contribute to the success of the application: this is what we can call “the human factor”.

Although the technology of the equipment may be considered a “sine qua non” condition, which is absolutely necessary to make the application possible, it is evident that, due to the very harsh environment**,** the gauge’s cannot be simply installed and forgot about: sooner or later, it will be necessary to provide minimum service to clean the instruments.

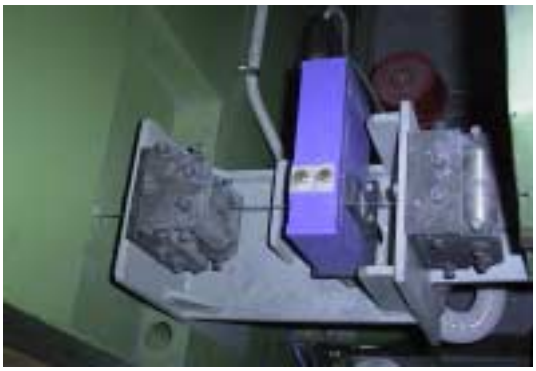

Fig. 6: Application of ALS13XY laser gauge on a dry drawing bench.

Suitable technology and specific application know-how can greatly attenuate this requirement but, since the very beginning and during the commissioning stage, the machine personnel must be made aware and trained to clean and service the gauge, in order to solve at an early stage some possible problems that would otherwise compromise the overall system performance. We also strongly recommend that formal procedures be set to define the schedule and to assign the responsibility for periodical service: only in this way is it possible to take the utmost advantage from the investment and to secure the full success.

4 - The latest improvements.

Although over the past years, most of the applications on dry drawing machines have been successfully afforded using the aforementioned pneumatic protection and suitable cleaning scheduling, some cases proved to be particularly critical. In such situations, because of the synergetic concurrence of negative factors like; the high speed and the large diameter of the wire or the type of machine or poor wire guiding or an unfavourable position of the gauge, the cleaning interval was reduced to some hours only. In these events of course the customers pushed us to find a more effective solution so as to improve the system resistance to dust and to alleviate the cleaning requirements.
A careful on-field analysis of these critical applications revealed some feeble points and limitations of the current protection system.

- The air blowing ring installed upstream of the gauge was unable to blow back and stop 100% of the dust formed by the wire, especially when the drawing speed was increased over 15 - 20 m/s.
- The air flow from the bushes of the bracket, although suitable to avoid the steady dusty air from contaminating the gauge, was not enough to push back all the high speed particles of soap and steel that by-passed the blowing ring. In addition sometimes the high frequency and amplitude of the wire vibration caused the detachment of some steel particles just inside the bracket.
- Some additional factors, like air turbulence induced by air blowing or the servicing of the machine after wire breaking, made it possible for the accidental entering of dust inside the bracket.

All the aforementioned factors allowed the progressive accumulation of dust on the optical windows of the gauge, because the bracket geometry was not designed to allow suitable dust evacuation.
Of course, the dust accumulation rate depended upon operational features and gauge installation but that would determine, sooner or later, the blinding of the gauge and finally the need of service for cleaning the system.
To overcome these inconveniences, last year an improved protection system had been developed and successfully tested in applications that would have been previously classified as “critical”.

- A new blowing ring has been adopted, based upon the Venturi's effect: the resulting air speed and the overall efficiency in cleaning the wire and stopping the dust has been enhanced, while reducing at the same time the compressed air consumption.
- The bracket has been redesigned to include a self-cleaning feature: inside the bracket itself, the air coming from the blower is driven to flow tangential to the glass windows of the gauge, so as to blow away the accumulating dust, downstream with respect to the wire direction. All the other features, that made the utilisation of this type of fixture so simple and effective, remain unchanged (Fig. 7).

An extensive test performed in the field, in real factory environments (Fig. 4), has immediately shown an excellent performance, much beyond our most optimistic expectation!

Fig. 7: Application of the ALS13XY gauge completed with the new "self-cleaning" protection.

The system worked correctly, without any cleaning, during the whole testing period: 45 days of uninterrupted on-line operation! But what is most interesting is the fact that the recording of the video signal versus time (Fig. 8), shows very clearly that the contamination level of the windows, after a start up transient, stabilises to a level acceptable for the gauge which continues to perform correctly.

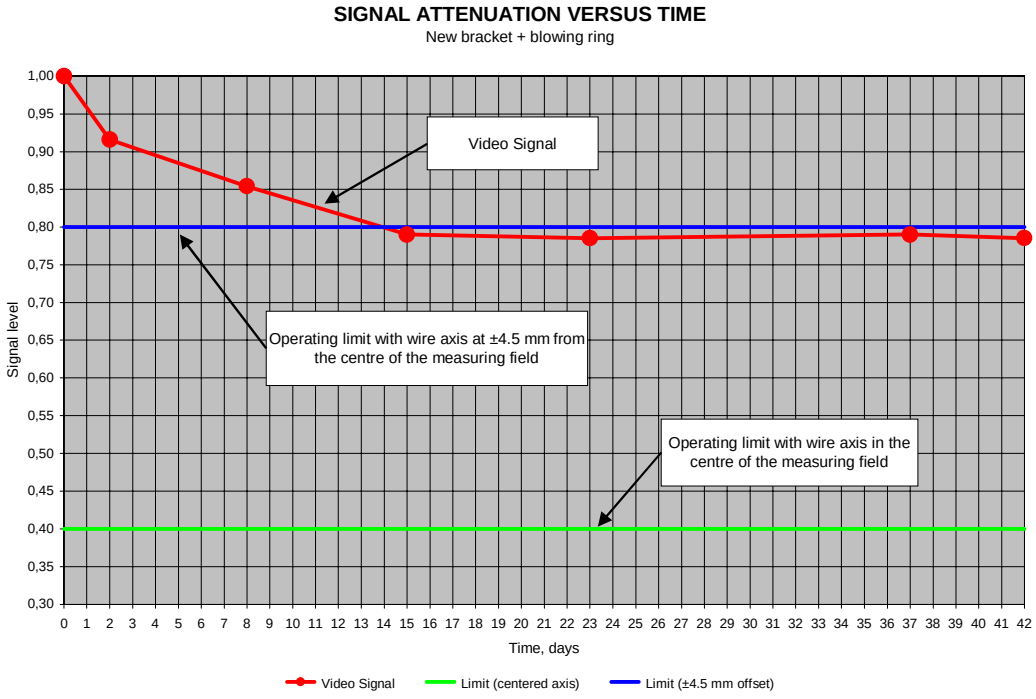

Fig. 8: The diagram shows the plot of the video signal level versus the operating time. No cleaning was needed during the test. The new "self-cleaning" protection has been used.

That means that the self-cleaning concepts work and probably the system might run for a much longer period, may be endless; until an accidental event possibly causes it to stop and require service for cleaning. A first layer of dust builds up and sticks on the glasses, but this can be tolerated by the gauge, thanks to its optical and electronic design: additional dust cannot increase the contamination as it is continuously blown away by the incoming air. Moreover, a sort of dust-to-dust lubrication effect has been observed, which makes it easy to remove the soap particles from the first layer sticking on the glass, provided a suitable airflow is used.

5 - Conclusions

Thanks to a remarkable specific know-how in the Wire Industry, coming from extensive experience and continuous improvements suggested by customer feedback, Aeroel is today in a leading position among laser gauge manufacturers, resulting in Aeroel being able to supply non-contact wire measuring systems, which have proved to be effective and reliable for on-line operation, even in the very harsh environment which is typical of dry drawing machines.

6 - Bibliography

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7 - Acknowledgements

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Mario Frigerio Spa, Lecco - Italy,
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