Automatic surface inspection in hot and cold strip mills

The time is coming for general installation of reliable, economical automatic surface inspection machines, which are changing from delicate, relatively complex-to-use machines giving a qualitative indication, to a reliable commodity measuring instrument. SIAS® automatic surface inspection systems provide an accurate description of surface status in hot and cold mills, and support the aim for better process understanding and a higher predictability of production.

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Conventional wisdom attaches automatic surface inspection to quality improvement programs in steel plants. The demand started at the end of the 1980s in sheet continuous annealing lines (CALs) on steel for exposed body parts in the automotive industry. The purpose was to reduce the bottleneck in visual inspection lines which were less productive than the CALs themselves. The technology then developed to include automotive galvanising lines for which the coating and skin-passing process variability offered an additional challenge to production and process departments in their aim to improve surface quality for ever more demanding automakers. The demand for improved, automated surface inspection also spread to tinning lines, pickle lines and hot strip mills.

While inspection performance has dramatically improved over the past ten years, the total cost of ownership of inspection facilities has reduced by a factor of more than three. We are thus now observing an inflexion point towards a wider distribution of automatic surface inspection, as today' s classification performance permits accurate decision making, stabilises production and effectively reduces operation cost, even for non-surface critical products.

REDUCTION IN COST OF OWNERSHIP

In recent years the investment price of automatic inspection machines has sharply dropped, followed by reductions in the cost and time of installation work, tuning effort and maintenance. After the move to PC hardware, more powerful PCs enabled the number required to be reduced, then the shift to local pre-processing rather then centralised image calculation simplified the interfaces and data transfer. The single linescan camera concept of SIAS machines, applicable to most configurations, has also contributed to the part number and complexity reduction and thus to maintenance cost savings.

Nowadays, the complete tuning of a machine may take approximately four months for a full or part time engineer, and still is a significant investment in competence and time. Naturally, some variations are observed in tuning time, depending on product occurrence in the schedule and the nature of defects the machine is requested to learn, but actual pay back results indeed start after only two weeks of commissioning. For example, identification of periodic defects such as roll marks are practically immediately operational.

PERFORMANCE IMPROVEMENTS

Detection stage The first automotive and tinplate applications handled a relatively uniform surface background, and the `objects` - labelled with their name by the automatic classifier - were easily picked-up by the detection device, pulled out of the video stream and analysed as pictures. In 2003, SIAS introduced the XLine, a PC-based technology leap with a dedicated programmable hardware board, designed to perform fast detection algorithms, in parallel, on several picture planes way beyond the simple thresholds. The powerful versatility of this XLine technology allowed the development of direct video analysis in real time with no overflow, opening the path for a wide array of novel and finer detection and surface analysis techniques, the aim being:

- Simplification of the detection tuning phase
- Acquiring macro information on the background substrate for further interpretation
- Performing a fine differentiation of simultaneous different defect families, such as isolated defects, generalised defects, smooth large `soft` defects, and of course, the repeating defects
- 100% of the surface analysed with no missing parts, even in severe defect crisis conditions, because the system does not saturate
- In real time for immediate decision making by operators and inspectors

The result is a machine which is extremely adaptable to ▷

all observed surfaces: smooth, medium or heavily textured, bright or dull, with large clusters of defects or small isolated dots. Auto-adaptive algorithms have been introduced to cope with the increased variability observed in the surface texture within a same incoming steel grade, automatically adjusting the sensitivity to background noise, thus accelerating and simplifying the on-site tuning. *Figure 1* shows an example of object detection.

Classification performance Right from the beginning SIAS started with recognised excellence in classification using the `Coulomb spheres` method. This has the significant advantage of being accurate, stable and convergent over time. Fully traceable, it is well suited to additional defect learning without regressing on the previously tuned knowledge base. The convenient tuning software, `Dacôdac` updates the knowledge base to include new representative images of defects as selected by inspectors and process engineers. Further advances such as an automatic second stage classifier, designed to reduce doubts on similar looking objects, have improved the confidence level *(see Fig. 2)*.

The result is an identification of pseudo-defects of more than 98%, and confidence levels over 85% on most defect families and applications.. The directional light and single linescan camera technology contributes to the consistency of raw video capture and limits the side effects of the unavoidable contrast and light up-front normalisation on further interpretation of objects by the classification algorithms.

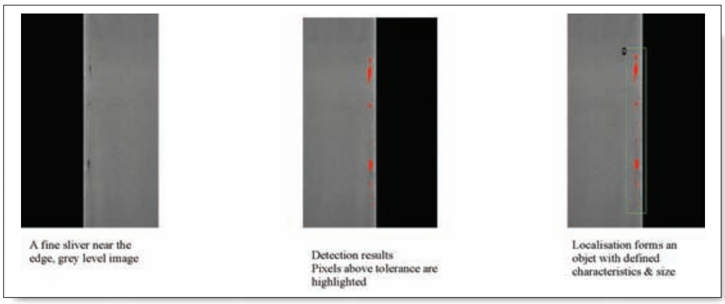

Fig.1 **Example of object detection**

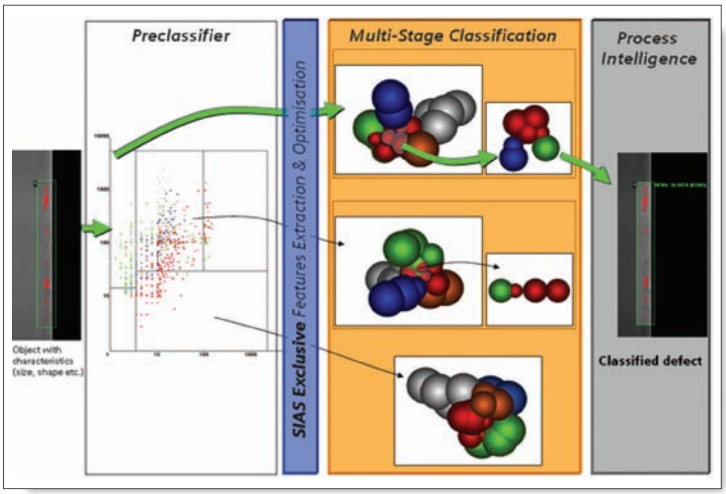

Fig.2 **Classification principle schematic**

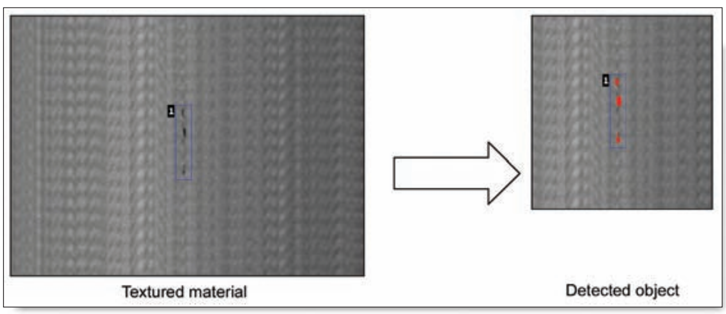

Fig.3 **Textured material application**

NEW APPLICATIONS AND PRODUCTION COST REDUCTION

Textured surfaces such as spangled zinc or aluminium-zinc coatings are now the subject of interest, and SIAS developments in background texture characterisation are finding industrial application on low cost production lines. *Figure 3* shows an example of a textured material application.

Other examples are surface inspection machines tuned to detect and prevent tandem mill strip breaks at high speed in coupled pickle and tandem mills, and checking pickled surface and edge quality. The obvious gains are yield improvement, effective utilised time increase and reduction of incidents. For some machines, their specialisation to a small number of important criteria renders the tuning time short, and thus reduces the overall implementation cost.

Hot strip mills are being gradually pushed to process steel grades previously impossible to inspect but thanks to the advanced new detection algorithms an ever increasing range of grades can now be inspected. Head and tail display and analysis support the down coiler and separate cut optimisation management. Predictive schemes and fine secondary scale analysis assist in mill roll change management, and also contributes to production time optimisation. The yield savings by a drastic reduction of outer wrap cropping for inspection after hot mill delivery is another cost cutting example.

On tinning lines, SIAS systems artificially erase the differential coating line marks in the analysed image so as to detect defects superimposed in those very areas. This is done by parallel image processing on several image planes, then combined together, as illustrated in *Figure 4*.

The accurate coil defect maps which are much more

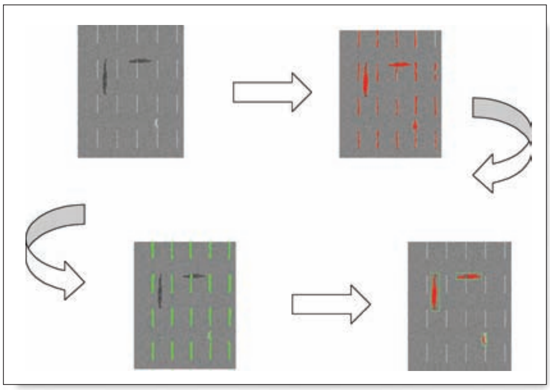

Fig.4 **Tinning line application**

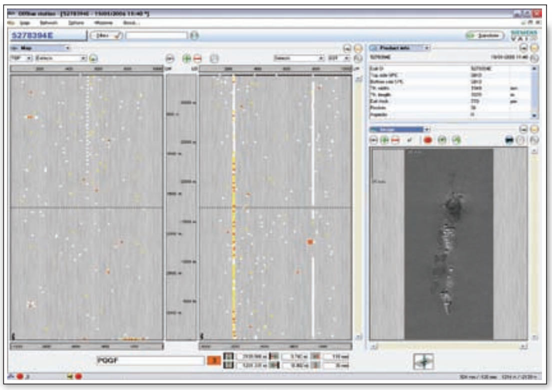

Fig.5 **A dynamically reconfigurable Coil Report screen**

comprehensive then really needed by the end customer, also permit a substantial economy by reducing over quality cost that, for example, would otherwise have led to pre-emptive batches for which an upstream incident might have a probability of impacting surface aspects. Savings on claim management are also well established.

Applications on CAL and electro-galvanising lines (EGL) are well honed and efficient for reducing coil reprocessing by over 50% via a repair / inspection line. On automotive hot dip galvanising lines, savings of $300,000 per month have been published by our customers.

Stainless steel and silicon steel inspection, with textured brushed hot band, bright annealed or uneven magnesia coatings respectively, are other advantageous applications.

On the data analysis front, our latest `Coil Report` *(see Fig 5)* is equipped with functions such as `Coil Compare` and `Coil Search`, that tap into any coil defect map database for tracing upstream and downstream coil defects, collect aggregated statistics on surface defect information of entire hot and cold mill plants, and study defect evolution over time. *Figure 6* shows a typical automotive galvanising line surface inspection pulpit.

CONCLUSIONS

The steel mill community shares with other industries and financial markets a search for predictability. Compared to other materials, the flat steel production process requires a considerable number of different steps, with the time from the ore/scrap to finished sheet and coil counted in weeks. Although shortened over the past twenty years, the production path is still subject to several days of buffer storages between many production steps, each comprising hundreds or thousands of pertinent process and logistics variables.

SIAS automatic surface inspection systems by Siemens VAI provide an accurate description of strip surface status in both hot and cold mill shops, and support the aim for

Fig.6 **Automotive galvanising line surface inspection pulpit**

a higher predictability of production in providing crucial and accurate information for better process understanding and mastering. The rapid elimination of defect crises and incident reduction reduces production costs on both high end and lower grade steel products.

Automatic gauge and flatness control began in past decades as specialty sensors and actuators for high end production mills. Who would buy a new hot or cold mill without these facilities today? In a similar way, the time is now coming for general installation of reliable, economic automatic surface inspection machines, which are changing from delicate, relatively complex to use pieces of equipment giving qualitative indication, to a reliable commodity measuring instrument, as our machine has now evolved into. Integrated at each manufacturing step, these machines will routinely contribute in the future to overall production monitoring and cost control on standardised criteria, comparable between different plants and at different times.

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