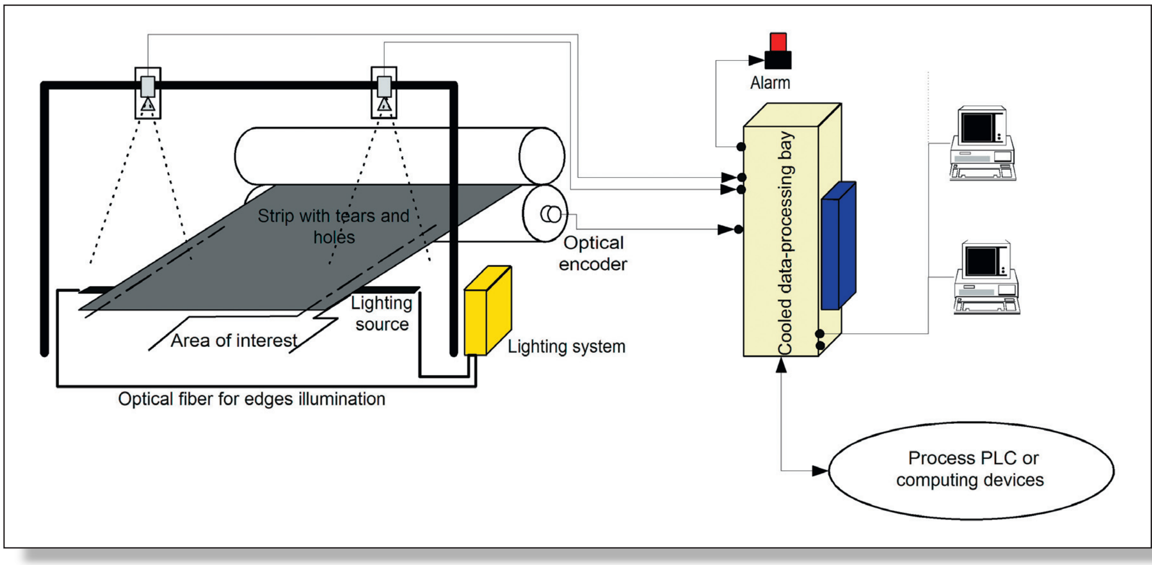

Fig.1 ETHD system arrangement

Detection of holes and tears in cold rolled strip

Real time detection and classification of holes and tears in strip using a non-contact optical device provides automatic control of line speed to minimise strip breaks. Defects as small as 5mm² can be detected at strip speeds of 900m/min.

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During cold rolling, strip cleaning and coating processes, strip breaks cause loss of production and incur costs associated with clean up operations and repairs. In order to avoid such breaks Arcelor and Amec Spie jointly developed in 1996/97 a real-time optical detection system at Sollac Florange to detect defects at or near the strip edges. This system is able, in real-time, to define defect severity levels and to reduce strip speed, thus avoiding strip breaks.

This edges, tears and holes detector (ETHD) is an optical non-contact inspection system using the linear high speed cameras and image treatment software available at that time. Three installations are already in production use, and others are in the planning stage.

The first system architecture was done using VME standards, but with the continuous development of computers, processors and software, the latest system installed in 2004 was completely redeveloped to be able to run with Windows XP™ and using the latest optical technologies. *Figure 1* shows the system arrangement with which defects as small as 5mm can be detected.

THE INSPECTION UNIT

This latest system is installed on a packaging steel tinning line of Arcelor Packaging International in Florange, France, where the strip travels at speeds up to 900m/min. Two linear cameras are mounted on fixed assemblies and scan a 100mm wide zone at both edges of the strip. The cameras, which are compact line-scan imagers with 1,024 pixel resolution with 14 x 14μm² pixel area, and up to 36,000 lines per second, are synchronised pulses coming from an optical encoder. They are available with standard objective lenses as C-mounts and are 50 x 50 x 88mm in size, weighing less than 300g.

Data are sent to a specific frame grabber using LVDS standard electronics. Because of the high strip speeds and very small defects to be detected, a special lighting system is used. Instead of a high-power lighting, special lighting sources were developed using high frequency iodide lamps, bundled optical fibres and a semi-cylindrical focussing lens. Optical calculations to define the lighting system specifications were developed with ▷

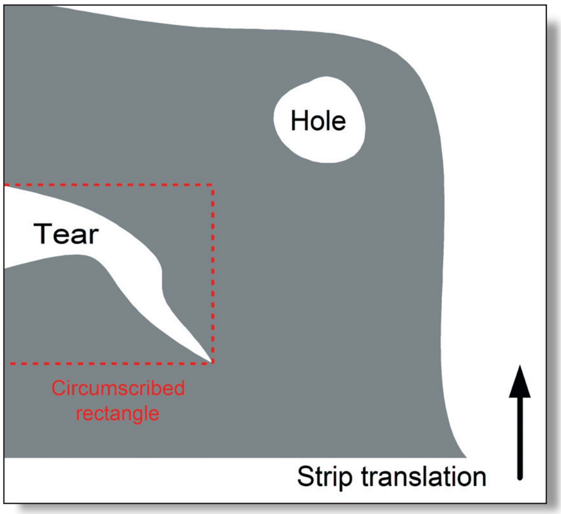

Fig.2 Theoretical defect shapes

Defauts Rive Moteur

	Pos X	Pos Y	Longueur	largeur	Prof	Emb	Surface	Type	Classe
	5163.150	75.3	1.8	9.9	65.2	0.0	15.0		2
	5171.250	74.8	0.7	10.4	65.2	0.0	7.3		2
	5172.300	74.8	1.4	10.4	65.2	0.0	13.5		2
	10278.800	74.8	2.5	10.4	65.2	0.0	20.8		2
	10281.600	74.2	3.1	11.0	65.2	0.0	30.4		2
	15762.250	77.0	0.3	8.8	65.8	0.0	9.0		2
	15763.649	75.3	0.3	11.0	66.3	0.0	26.0		2
	15766.450	75.9	0.3	9.9	65.8	0.0	9.6		2
	20815.049	74.8	3.8	11.0	65.8	0.0	35.8		2
	20823.250	75.9	0.7	9.4	65.2	0.0	6.0		2
	26358.850	75.3	0.7	8.8	64.2	0.0	6.2		2
	26359.500	73.7	1.8	11.0	64.7	0.0	18.3		2
	26362.000	73.7	1.4	11.0	64.7	0.0	14.1		2

Defauts Rive Operateur

	Pos X	Pos Y	Longueur	largeur	Prof	Emb	Surface	Type	Classe
	3306.450	63.8	11.6	13.8	77.6	0.0	117.6		2
	3811.950	0.0	14.0	5.5	5.5	14.0	41.6		2
	6990.450	0.0	10.1	4.4	4.4	10.1	31.0		2
	9216.200	114.4	7.0	4.4	118.8	0.0	25.0		2
	13448.050	64.3	11.2	13.2	77.5	0.0	112.2		2
	14047.950	0.0	11.6	5.0	5.0	11.6	37.5		2
	14274.750	114.4	5.6	3.9	118.2	0.0	19.5		1
	18509.400	64.3	8.1	13.8	78.1	0.0	128.1		2
	19115.250	0.0	12.9	5.0	5.0	12.9	37.5		2
	19353.949	114.4	4.9	3.9	118.2	0.0	15.6		1
	24040.449	64.3	11.2	13.2	77.5	0.0	108.1		2
	24642.449	0.0	10.5	5.0	5.0	10.5	32.0		2
	28866.449	113.9	3.1	5.5	119.4	0.0	38.2		2

Fig.3 HMI screen

the French engineering school, l'Ecole Supérieure d'Optique – Orsa.

A zone of 700 x 5mm is illuminated on one side of the strip, while on the other side, cameras detect the light transmitted through the holes and cracks, or beyond the edges of the strip. It should be noted that because coils of different widths can be welded end to end and processed continuously, the 700mm wide strip of illumination ensures at least 100mm coverage at the strip edge is scanned.

In order to optimise system settings and align the CCD camera, which is complex due to the 5mm width, other technologies such as linear lighting systems based on 400 watt metal halide lights supplied with high frequency power and a 25mm wide aperture are currently being tried.

Each pixel saturation level is scaled using a 255 (8 or 10 bits) gray level scale, then the absolute threshold of the signal is determined and the binary image of defect reconstructed. The processing unit then derives four quantities describing the current defect: surface area, opening, length and width of the circumscribed rectangle shown in *Figure 2*. When the system considers that the defect has a high severity level, it can be stored in a bitmap file to be replayed later by the user.

DEFECT CLASSIFICATIONS

The classification of defect severity level is only possible based on the experience of specialists. Discussion with these experts led to the definition of a number of severity levels and the circumstances leading to the attribution of each of these levels. All these data are held in databases, mainly dependant on strip thickness. A statistical study has made it possible to establish an optimal representative database of limited size.

Two criteria are used: the first indicates the absence of steel and the second the main defect spatial orientation. Three severity levels were introduced: green, orange and red and, depending on its area and its shape factor, the tear is considered as not dangerous (green), dangerous (orange), or critical (red).

The automatic classification procedure is made using current defect specifications impacted by its neighbourhood – the 'k nearest neighbours' method. One tear can have a green level but due to its neighbourhood (for example, large holes or several others tears closest to it) it can be classified as red. The method is simple, requires little calculation time and gives results immediately intuitive for the operator. They do not require special operator knowledge or specific interpretation tools.

SYSTEM ACTIONS

ETHD is calibrated during commissioning by putting a specific certified object in the measurement fields then, after row-image acquisition and thresholding operations, ETHD is able to give shape factors and dimensional data in numeric values. The central host unit is generally placed into a cooled data-processing bay. The image

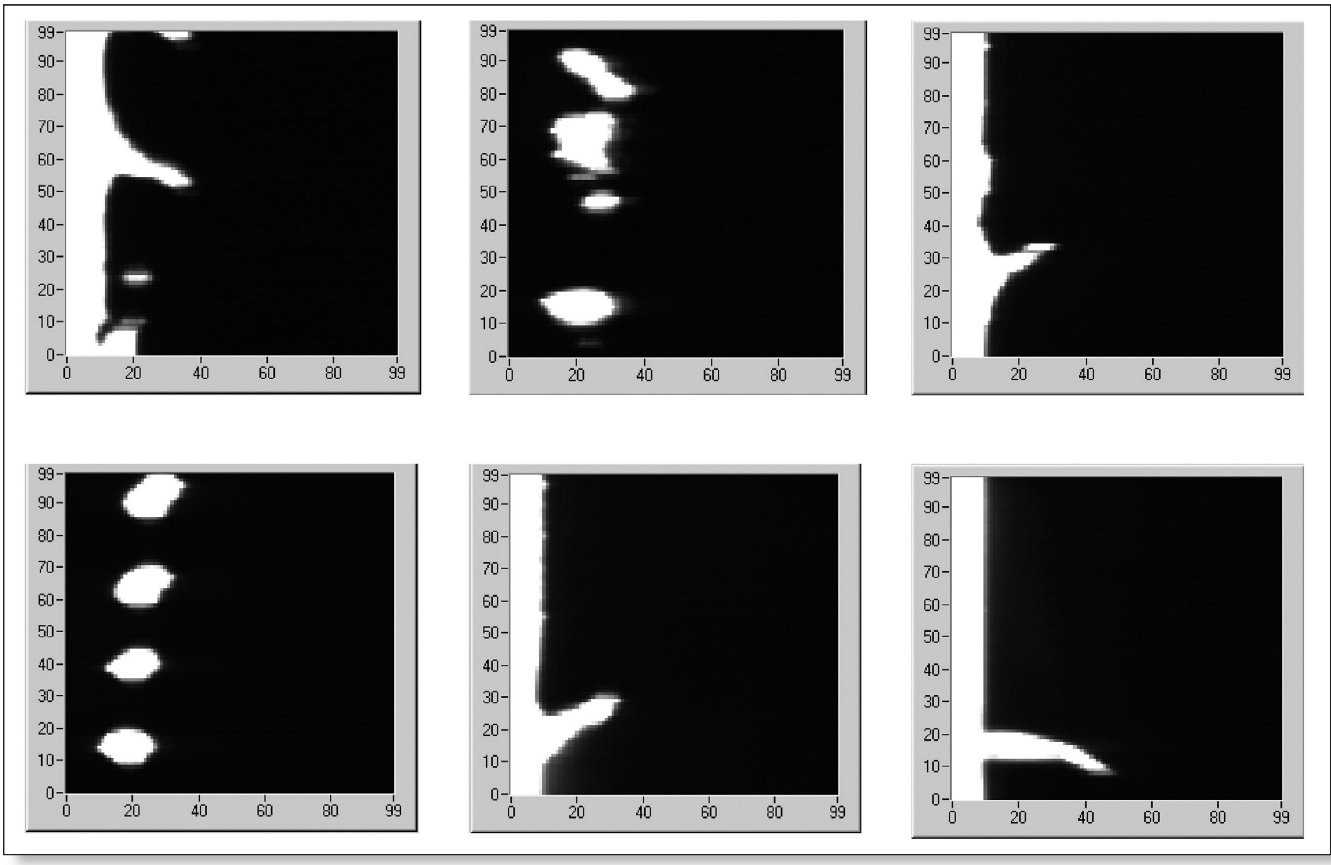

Fig.4 Bitmaps of defects detected

acquisition rate is synchronised with strip movements using optical encoder pulses or other pre-existing positioning system. The ETHD is connected to process managing devices (computer, vax, etc) and drives optional outputs able to reduce or to stop strip movement. It can also be connected via TCP/IP network or to several low level host computers allowing operator access at the human-machine interface (HMI; see *Figure 3*).

RESULTS

Several test coils have been inspected in order to assess the level of defect detection. A success rate of about 98% detection was found, of which about 89% were correctly classified even under signal analysis corresponding to a simplified choice of reference vectors and small k value. Examples of defects detected are shown in *Figure 4*.

ETHD can be used to inform operators and/or to adapt strips speeds, and data coming from it can be used to drive all downstream processing lines. An additional benefit is that the system enables measurement of strip width with an accuracy of better than +/-0.25mm.

The experience gained with this inspection system is very positive and the number of breaks at Sollac Florange has significantly decreased.

CONCLUSIONS AND FUTURE PROSPECTS

This article has presented an overview of the detection of edge tears and holes, and their classification and use as a tool to satisfactorily prevent strip breaks. As this is a complete system entirely developed and manufactured by Amec Spie, any variations and adaptation required to match specific customer needs can be accomodated.

Several ETHD systems have been in production use for many years without problem and are planned to be upgraded in 2005 to the Windows XP software version. Other European plants are also looking to adopt this system in the future.

Moreover, with this kind of system all devices that are on-line, such as strip length, edge and shape measurement, will be accessible via use of adapted software and, based on this experience, it is planned to apply this technology in other areas of strip processing. **MS**

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