Laser Scanning in an Industrial Environment

Prof. Rudolf STAIGER, Germany

Key words: Laser scanning, as-built-documentation, steel production, scanner data combined with tacheometer data.

ABSTRACT

Thyssen-Krupp Steel, one of the leading steel producers worldwide, purchased for the plant Duisburg the laser scanning system CYRA 2500 last year. The 3D-measurement system is mainly used for the as-built-documentation of the extended production facilities. The paper describes typical measurement tasks for the laser-scanning-system and the related external conditions. The general performance of the scanning system and the often needed combination with tacheometric data are discussed.

ZUSAMMENFASSUNG

Die Thyssen-Krupp Stahl AG, der größte Stahlproduzent Deutschlands, beschaffte im vergangenen Jahr für den Standort Duisburg das Laser-Scanning-System CYRA 2500. Das 3D-Erfassungssystem wird hauptsächlich zur sog. As-built-Dokumentation der ausgedehnten Industrieanlagen genutzt. Das vorliegende Paper beschreibt typische Aufgabenstellungen und die damit verbundenen Rahmenbedingungen im Stahlwerk. Neben der allgemeinen Leistungsfähigkeit des scannenden Systems wird auch die häufig notwendige Verknüpfung der Laser-Scans mit tachymetrischen Messungen diskutiert.

CONTACT

Prof. Dr.-Ing. Rudolf Staiger
University of Essen
Henri-Dunant-Strasse 65
D-45 131 Essen
GERMANY
Tel. + 49 201 183 7325
Fax + 49 201 183 7311
E-mail: rudolf.staiger@uni-essen.de
Web site: www.vermessung.uni-essen.de

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1. INTRODUCTION

Thyssen-Krupp Steel AG produces with 18 000 employees 15 million tones of crude and rolled steel products, which leads currently to an annual turnover of around 5.5 billion €. The company has concentrated production on flat products and couples tried and tested technology with innovative processes e.g. combined casting and rolling in a compact strip production line. The flat product mix comprises heavy plate, hot strip and cold strip in a wide range of grades. A great number of these are processed and supplied as coated products. One specialty is the comprehensive surface protection of the steel sheets and weight reduction in automobile construction through the use of new ultra-high-strength and high-strength steel grades as well as the use of tailored. Thyssen Krupp Stahl AG is Europe's biggest flat-steel producer and foremost in production technology and material development.

Last year Thyssen-Krupp-Steel AG decided to buy the laser-scanning system Cyra 2500 (Leica). The main purpose is the as-built-documentation and the part inspection in the plant Duisburg. The CYRA-System is a 4D-Laserscanner (DEUMLICH and STAIGER, 2001), which delivers not only 3D-coordinates from the scanned points, but also the intensity of the reflected beam. This information is very helpful for the representation of the acquired point clouds in the CAD-model.

2. THE CYRA 2500 LASER SCANNING SYSTEM

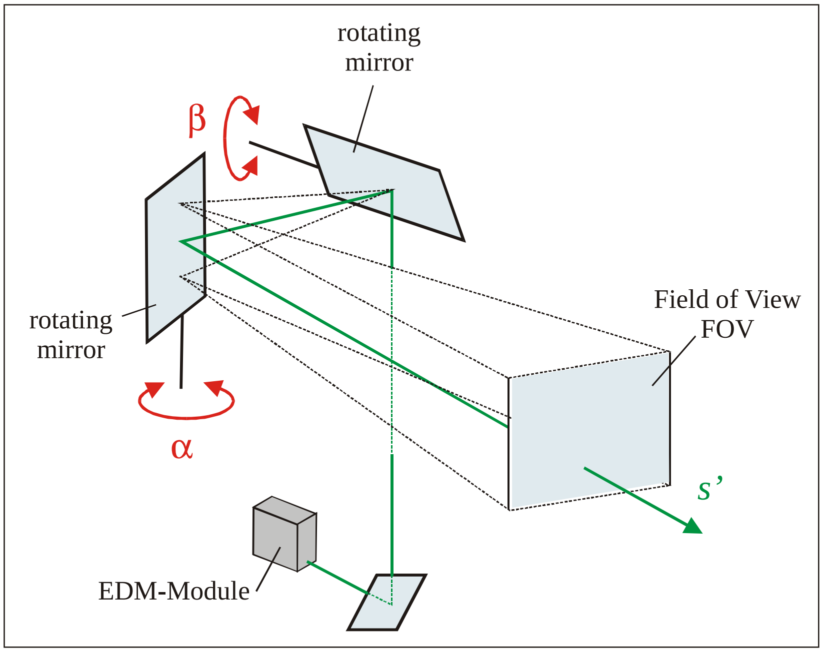


Figure 1. Measurement principle of the laser scanning system (Cyra 2500) for technical details and system specifications refer to (CYRA, 2002).

2.1 Performance of the system

In order to evaluate the quality of the measurements, different tests were performed

2.1.1 Quality of the geometric elements

The main geometric elements in a steel manufacturing environment are plains and cylinders. Perfect plains and cylinders in different sizes with known geometric parameters were scanned and calculated within a rms from 1 to 5 mm.

2.1.2 Quality of the measured distances

Plain geodetic targets were placed in one line and in known distances. All targets were scanned in one scan-world. Afterwards the planes were modeled and the distances between the plains were evaluated. Figure 2 shows the deviations from the known distances.

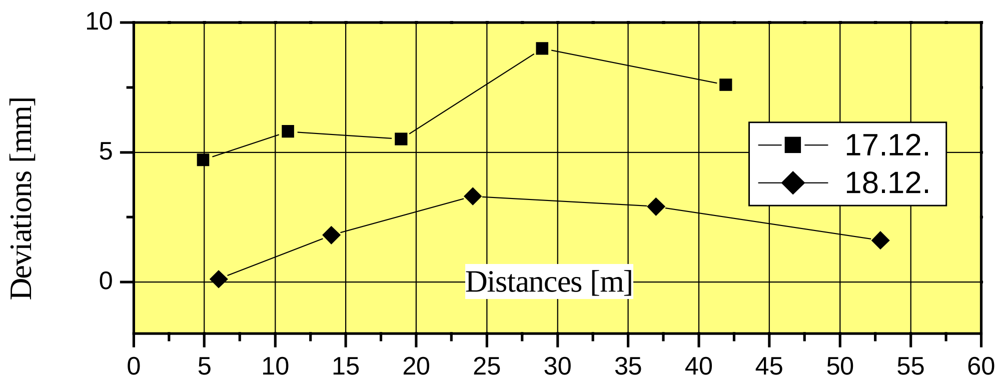


Figure 2. Deviations of evaluated distances between plane targets in one line

As the main scanning axis is orientated towards the line of the targets, the issue from the deviations in the distances is the distance measurement module. All deviations are below 10 mm in the distance range from 5 to 55 m.

2.1.3 Quality of the Tie-points

Tie-points are necessary for the orientation of more than one scan-world (relative-orientation) and for the transformation in an object oriented coordinate system (absolute orientation). The center of Tie-points is determined with so-called fine-scans, which deliver the center of the circular point by 500 to 3000 single point measurements. In the majority of the measurements the fine-scan procedure runs automatically.

A test field of 10 targets was established and arranged in a vertical plane (Figure 3)

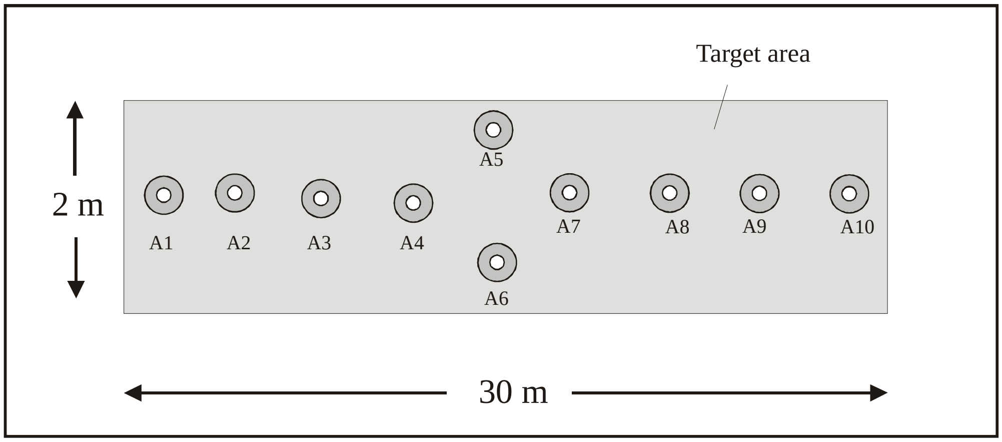
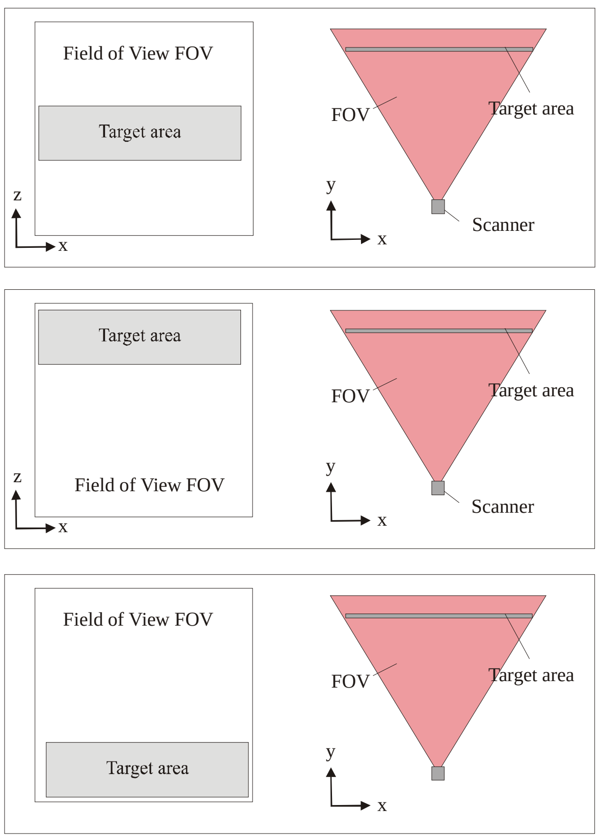


Figure 3. Arrangement of the Tie-Points

The targets were scanned in the “automatic Tie-Point-mode” from different positions and in different angular orientations (Figure 4a and b). The fist position was frontally to the target wall whereas the second position led to an oblique aiming axis.



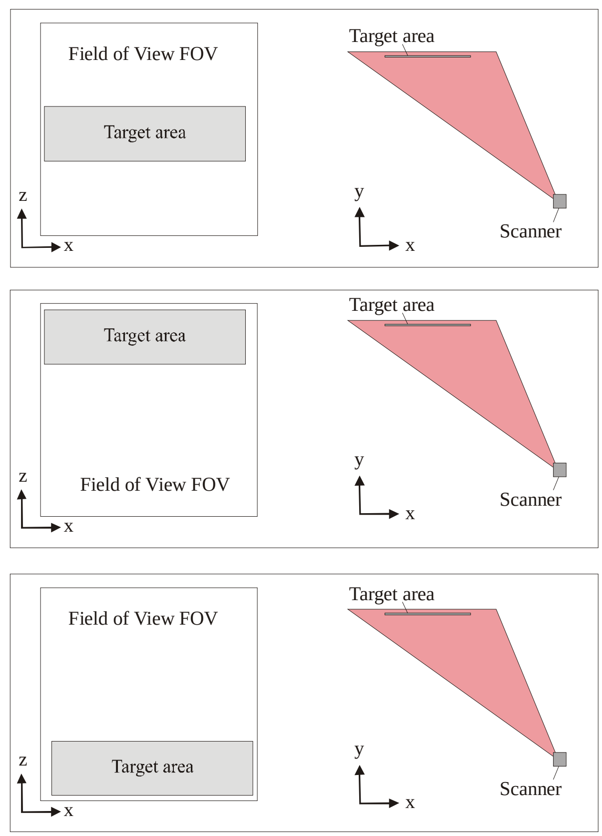


Figure 4a. First scan position

Figure 4b Second scan position

As reference the coordinates of all targets were determined with a electronic tacheometer. Four out of the 10 targets built the base for the new home scan-world, so that the scanner coordinates were transformed in the tacheometric coordinate system. Then the differences in the coordinates of the remaining 6 points were calculated. The differences in all positions are between 1 and 10 mm for the evaluated Tie-points. Figure 5 shows the results for one scan-world.

Point-ID	Deviations [mm]		
	x	y	Z
A1	3	0	5
A2	4	-1	4
A3	0	1	-7
A4	-2	-1	0
A5	3	-1	-1
A6	1	1	1
A7	-3	0	-1
A8	-2	0	1
A9	-3	-3	2
A10	-5	-2	3

Figure 5. Differences to tacheometric coordinates

2.2 The combination of multiple-scans

The Cyrax 2500 has a scanning angle of about +- 20° relative to the principle axis. In order to register complex structures it is very often necessary to combine several scans with different orientations resp. positions. In the CYCLONE-Software the combination of two or more scans is called Registration.

2.2.1 Registration with common Tie-Points

The standard case is the combination of several scans (images) through common Tie-Points. Two (or more) scans can be combined, when there are at least three common points, defining a spatial plain, which are Tie-Points in a pair of scans.

2.2.2 Registration with Tie-Points with external coordinates

A more flexible and powerful way for the combination of several scans is the use of Tie-Points, of which the coordinates are determined independent from the scanner, f.e. with an electronic tacheometer. The use of electronic tacheometers introduces a number of advantages:

- The whole scene can be transformed in a gravity-related system
- The scanner coordinates are externally controlled
- The geometrical quality of entire scans can be improved by a over-determined transformation onto a tacheometric system
- Overlapping areas in adjacent scans are no longer necessary

3. THE MEASUREMENT CONDITIONS IN THE STEEL PRODUCTION ENVIRONMENT

The environmental conditions during the measurements are not very favorable for the operators and the equipment. The main limitations are:

- steam
- toxic gases
- heat
- vibrations

Steam is very critical for the measurement itself, especially when it appears in high concentration. Water drops on the front-glass should be avoided in any cases. Heat and vibrations influence the measured object as well as the scanner equipment. A lot of measurement tasks can only be accomplished during short shut-down or inspection periods.
The measurement equipment including the Laptop for the measurement Software is not designed for rough condition, as they can be found in this field. It would be appreciated, if the equipment got more robust in the future .

4. EXAMPLES

Figure 6a and b show the second level of the hot strip processing facilities in Beeckerwerth. The model consists of 4 levels created out of more than 20 single scans. The registration was established by 40 Tie-points. They were all coordinated with the means of an electronic tacheometer. This as-built-documentation is the digital base for the planning of a modernization resp. modification of the production line in Beeckerwerth (Feuerbeschichtungsanlage 1).

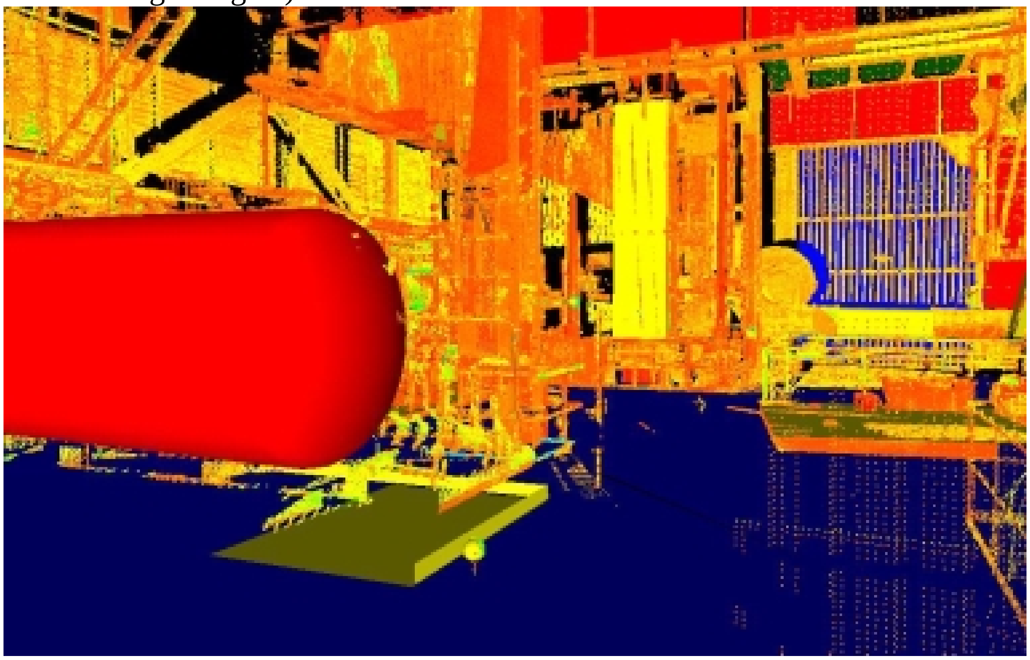


Figure 6a. Hot strip processing plant (level 2, Beeckerwerth, Duisburg)

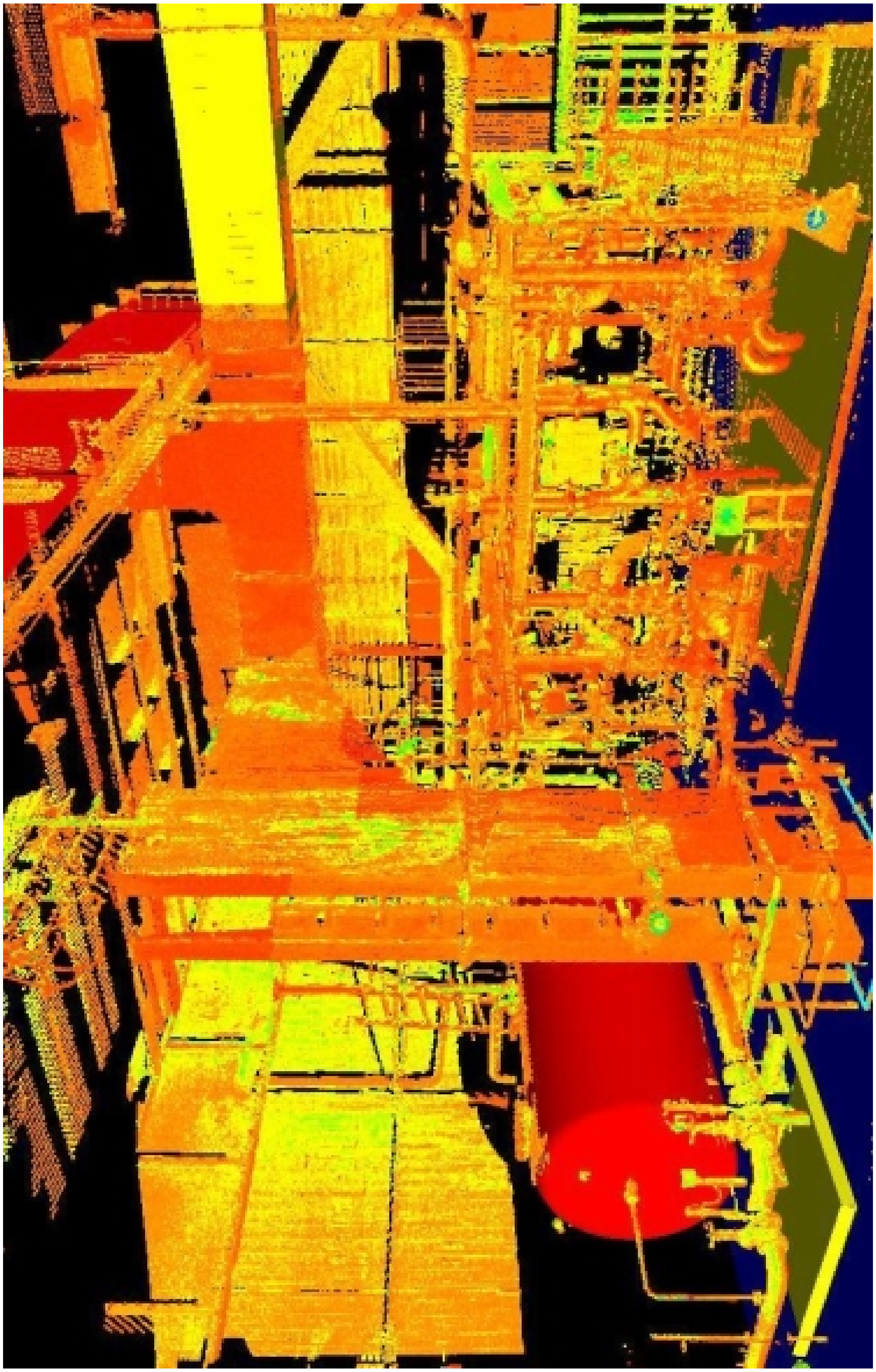


Figure 6b. Hot strip processing plant (level 2, Beeckerwerth, Duisburg)

5. MODELING AND DOCUMENTATION

The acquired point clouds are treated either in the CYCLONE-Software or in AUTOCAD 2000.

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BIOGRAPHICAL NOTES

Prof. Rudolf Staiger

1976–1982:	Studies of geodesy at the University of Karlsruhe (TU) and Paris (IGN)
1983–1987:	Assistant at the geodetic Institute (University of Kalrsruhe)
1988:	PhD on the theory of on-line-Triangulation for Theodolite Measuring Systems
1988–1994:	Kern & Co AG, Aarau (later Leica Geosystems), different functions in the Dept. of Industrial Measurement Systems in Marketing and R&D.
Since 1994:	Professor at the University of Essen (Universität Gesamthochschule Essen) in the Dept. of Surveying Engineering.
Membership:	Deutscher Verein für Vermessungswesen (DVW) Member of Arbeitskreis 5 (AK5) – Instruments and Methods
	Member of FIG Working Group 5.1 –Electronic Tacheometers