NEW DEVELOPMENTS IN FAST 3D - SURFACE QUALITY CONTROL

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Abstract: Inspection is the process of determining if a product deviates from a given set of specifications. Fast Inspection usually involves measurement of specific part features such as assembly integrity, geometric dimensions and surface finish. It is a quality control task, but is distinguished from testing tasks. The visual inspection of 3D - parts (car body parts) is a special task within manufacturing that has been auto-mated at a comparatively slow pace up to this time. Different optical methods, applied for 3D - Measuring of microscopically and macroscopically sheet metal parts based on the Projected Fringes Method (PFM), the Electronic Speckle Interferometry (ESPI), the Structured-Lighting Reflection Technique (SLRT), White-Light-Interferometry (WLI) and also SEM-, AFM- and Laser Scanning methods (LSM) will be discussed. In addition, stylus instruments and also colorimeter measurements was included. The presentation is closed with advantages and disadvantages of different contemporary intelligent methods for car body inspections: Neural Net based Classification; Fractal Analysis and Wavelet Transformation.

Keywords: Inspection; Surface, Optical methods, Intelligent Interpretation

1 INTRODUCTION

In different companies Quality Assurance policy is established in order to guarantee the best quality products and technical support for its clients. In this way, in-process inspections must cover all levels of production to meet the requirements of ISO 9000.

The surface of a solid is that part of the solid that represents the boundaries between the solid body and its environment. Surfaces as physical entities possess many attributes, geometry being one of them. Surface geometry by nature is three-dimensional and the detailed features are termed topography. In engineering, topography represents the main external features of a surface.

Surface topography is, therefore, significant for surface performance and the importance of surface topography measurement as a means of functional analysis and prediction is indisputable. Engineering surfaces are created in various ways, typically by forming, surface treatment and coating. Surface topography modification is therefore performed by material removal, transformation or addition. Mostly a combination of various forming, treatment and coating operations are employed to produce surfaces with characteristics that are desirable for a particular application. Each surface generation process produces surface topography characteristic of the process and process variables used. Surface topography, therefore, contains signatures of the surface generation process and as such can be used to diagnose, monitor and control the manufacturing process. In an engineering sense, the ultimate objective of surface topography measurement, as a means of control and knowledge, is to establish a correspondence between an engineering surface phenomenon (e.g. wear, chatter, etc.) and its topographical characteristics (e.g. bearing area and oil retention volume, waviness power and periodicity, etc.). Surface topography measurement, therefore; serves as a vital link between manufacturing, functional performance analysis and prediction, and surface design. The relationships between surface design, function, manufacturing and assessment based on the measuring techniques, the physical characterisation and intelligent interpretation are schematically shown in Fig. 1. It is well known, that the geometrical topography of tools and sheet metal parts depend on their manufacturing conditions. On the other hand the functional performance of the 3D-geometry and the quality is strongly related to the geometrical characteristics of the surface topography. Additionally the

demands of high-productivity manufacturing require that advanced process control balance between functional properties, 3D-topography and the surface characterisation.
There are different optical, non-contact methods to investigate surface structures and morphologies.

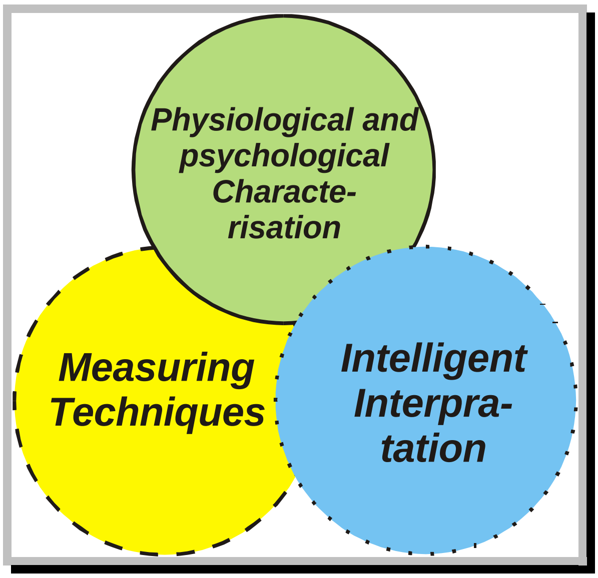


Figure 1. Three basics of a Surface Characterisation [1]

2 PHYSIO- AND PSYCHOLOGICAL ASPECTS OF SURFACE DEFECTS

Basic studies of the detect ability of dents, dimples and creases in car bodies were done at the DaimlerChrysler Research Centre in Ulm. In order to define the requirements, which the resolution of an optical 3D-sensor should meet, first of all the customer's measure had to be known. Therefore, a study [2] of the perception of geometric faults in car bodies was carried out in co-operation with ophthalmologists from Ulm University. A subsequent psychological study showed that the customers' acceptance of faults mainly depends on psychological factors [18].

3 TYPES OF DEFECTS

A-Class surfaces of car body parts are increasing. One example is space frame cabins and special parts, given in the next figures.

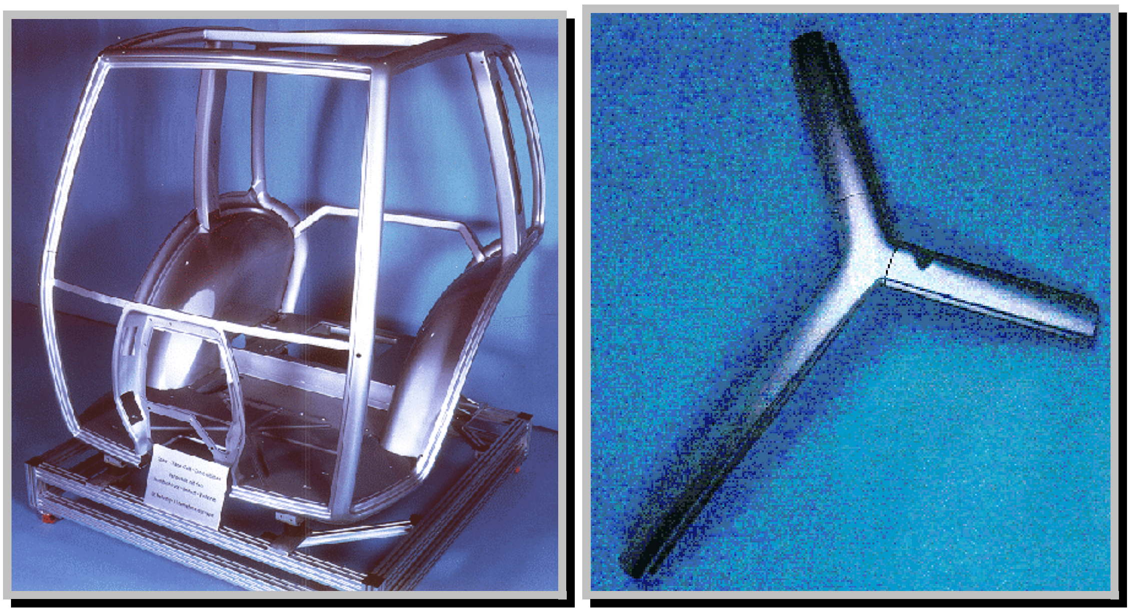


Figure 3. Space frame cabin and a detail (Source: Dr. Meleghy Hydroforming)

From the metrology point of view the defects may be classified in the following main types (Figure 4 and 5) [7].

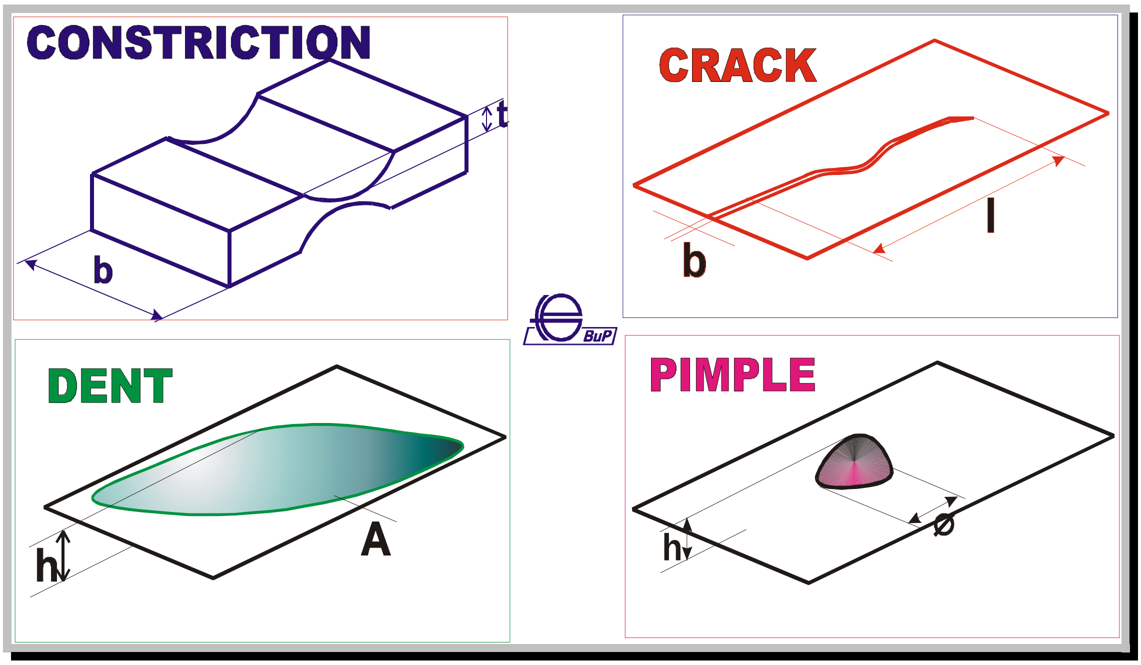


Figure 4. Some of the main cosmetic defects on car body parts [7]

TYPES OF DEFECTS	SIZES AND MEASURES
Constriction	$t \geq 20\mu m$; $b \geq 3mm$
Crack	$l \geq 500\mu m$
Dent	$h \geq 20\mu m$; $A \approx 40cm^2$
Pimple	$h \geq 8{,}5\mu m$; $A \approx 0{,}038cm^2$
Waviness	$Depth \geq 20\mu m$; $A \approx 80cm^2$

Figure 5. Types of defects in relation with size and measures [7]

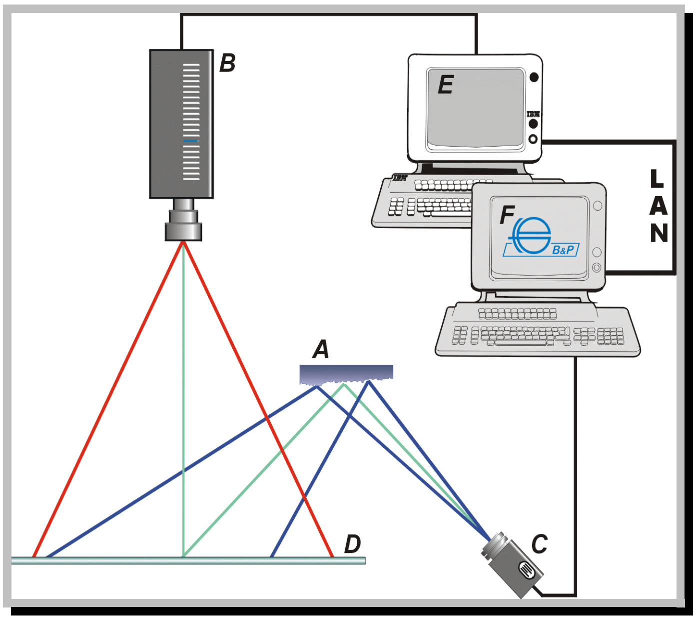
4 MEASURING PRINCIPLE AND RESULTS FOR A-CLASS SURFACE QUALITY CONTROL

A *structured-lighting reflection technique* was developed in order to detect and measure small waviness and curvature defects on specular free-form surfaces. It can reconstruct the 3D relief of specular free-form surfaces and display the curvature at each point.

A calibrated camera observes the reflection of a retro-illuminated LCD panel through the free-form surface. The use of a coded lighting technique and the knowledge of the set-up geometry allow to locate each observed point on the LCD panel. Using the principle of inverse ray tracing, a surface modelled with Bezier polynomials is fitted to the observed data. Unlike structured-lighting projection techniques which are directly sensitive to the topography of the surface to be inspected, the structured-lighting reflection techniques are essentially sensitive to the gradient and thus enable the detection and measurement of curvature defects which are imperceptible using the projection techniques.

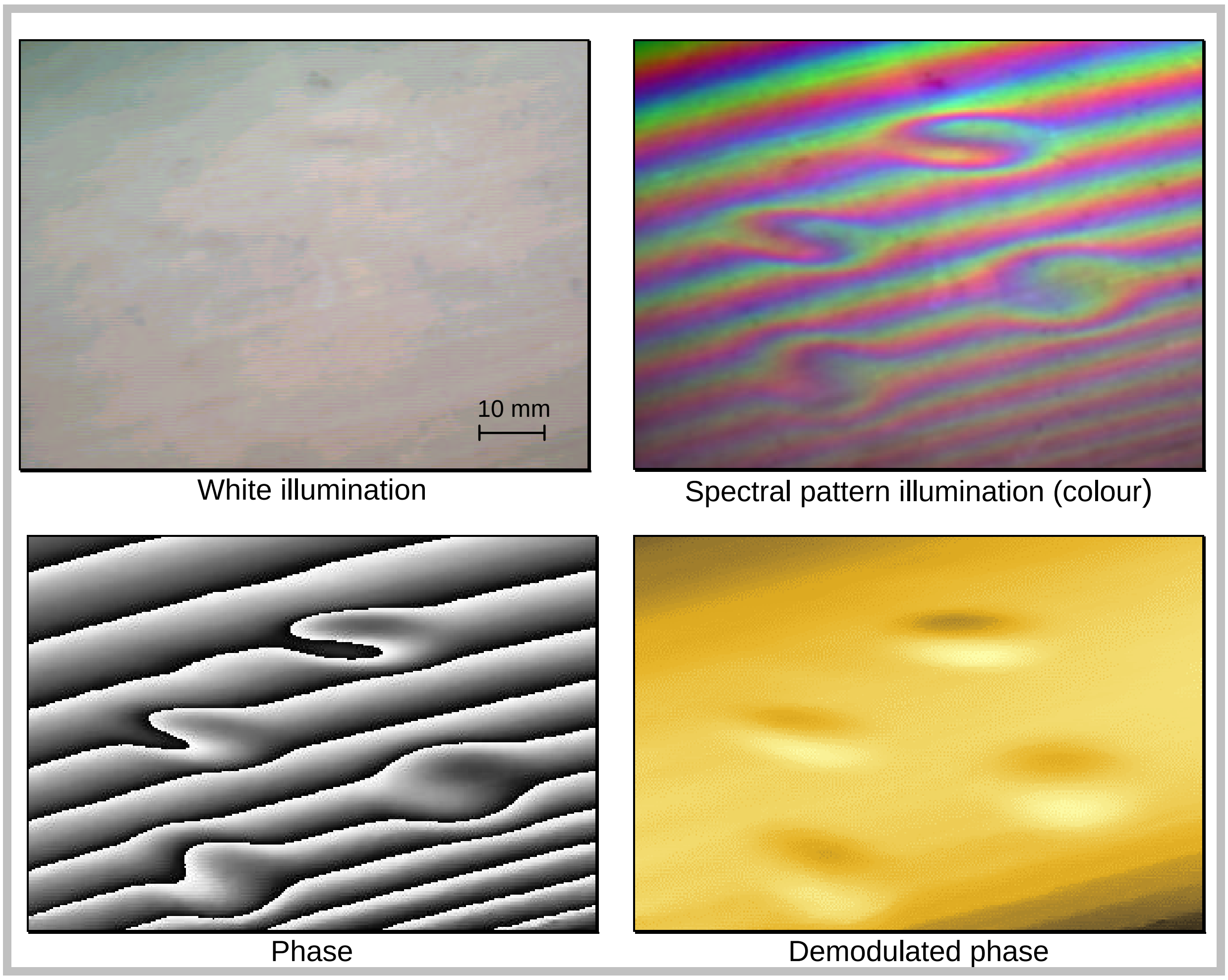
Based on previous investigations [3-7] for relations between the 3D-topography of sheet metal parts and the surface characterisation, the following principle for the detection of different types of cosmetic defects given in Figure 6 has been applied.

One application (Fig. 7) was directed to fold detection on class A surfaces using a single colour image (Car body part; blank aluminium; measuring area 100x70 mm^2).



A - specimen
B - projection unit
C - CCD-Camera
D - projection area
E - pattern generation
F - pattern recognition

Figure 6. Measuring principle [8]



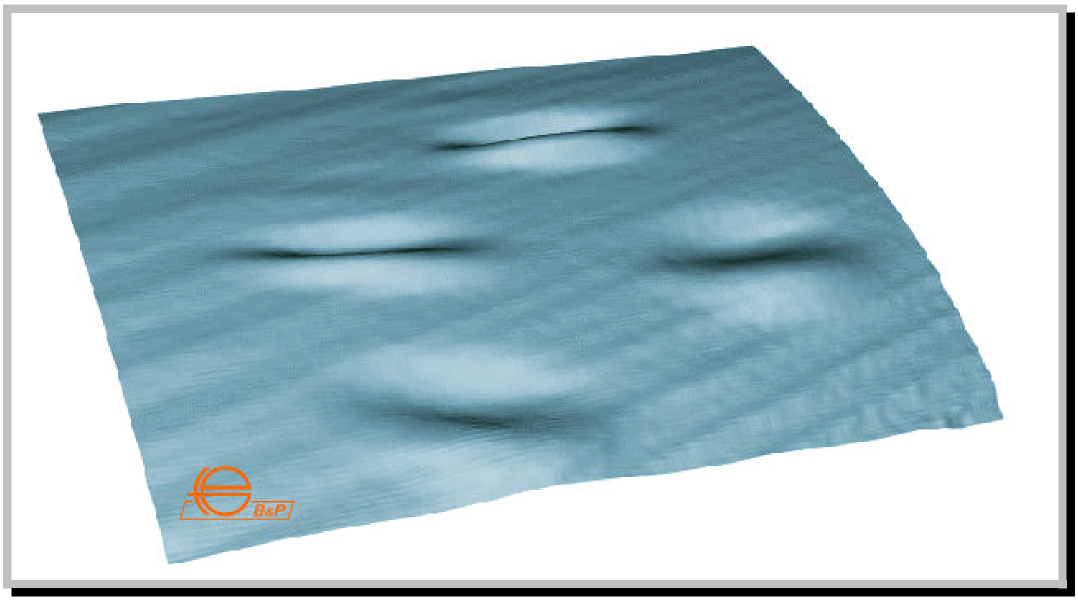
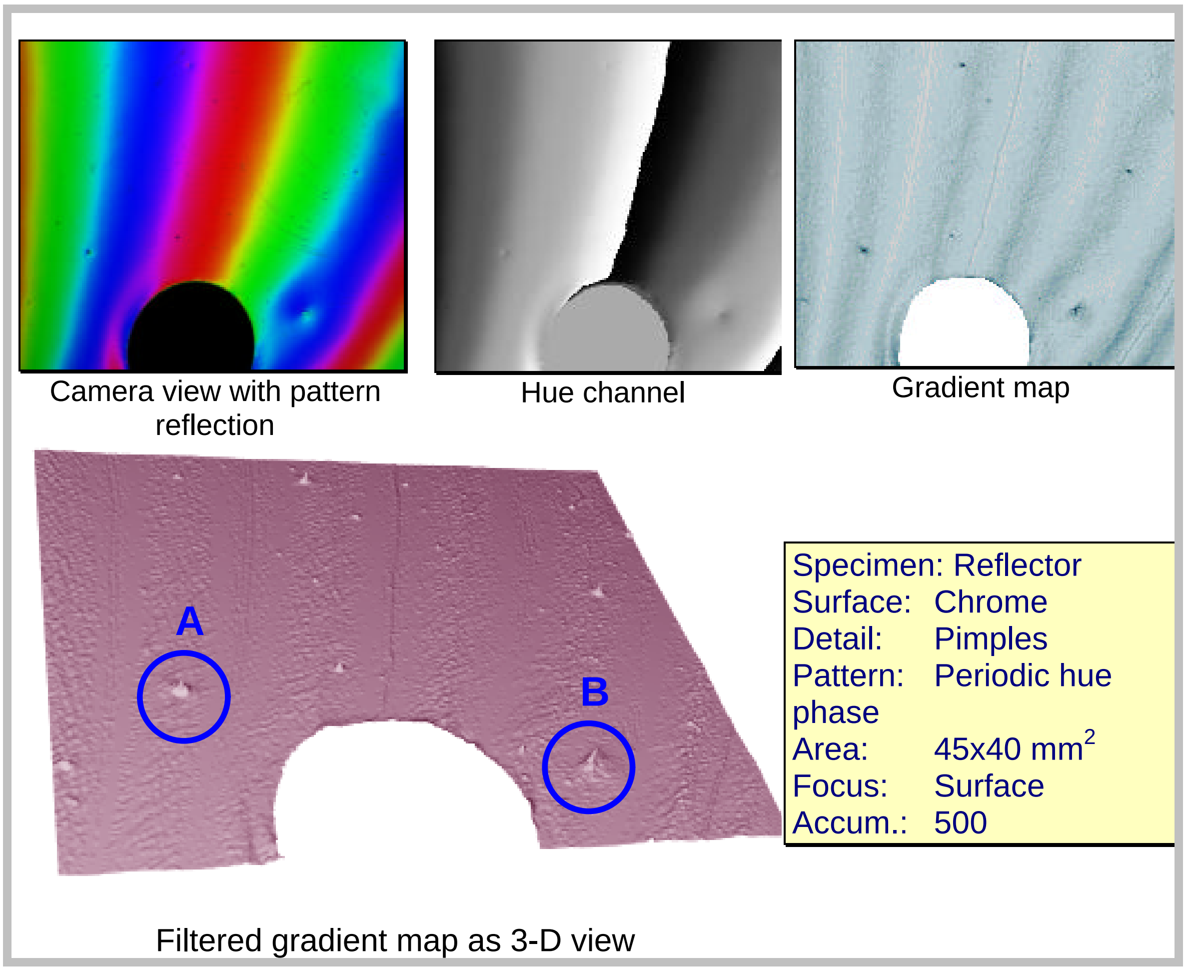
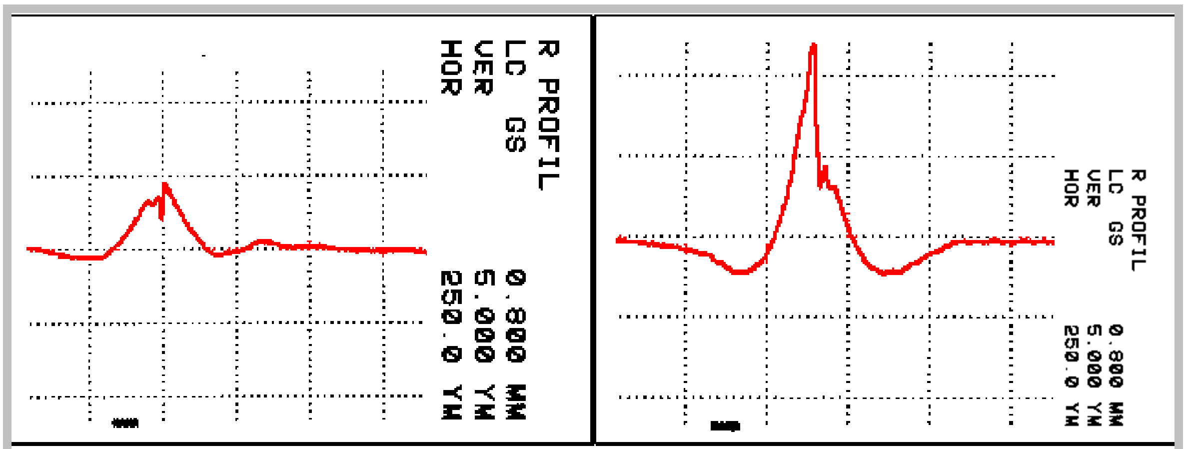


Figure 7. Fold detection

Next application is a fast pimple detection on a reflector surface using a HSB colour model.





Stylus traced profile of Pimple A: Height 5.2 µm; Diameter 0.7 mm	Stylus traced profile of Pimple B: Height 14.2 µm; Diameter 0.9 mm

Figure 8. Fast pimple detection (HSB colour model)

One of the main complicates problem is the detection of waviness on sheet metal surfaces. To get a sufficient quality of the detected defects and reducing the noise of the image, a special software module for accumulation of single images has been developed. A series of test images gives the following information (Table 1).

Table 1. Test series for different accumulation rates

Used images	*Time for image acquisition (theoretical) [s]*	*Real time for image acquisition [s]*	*Mean deviation [Grey levels]*	*Maximum Deviation [Grey levels]*	*Variant*	*Standard deviation*
1	0,04	0,04	1,73	8	1,5905	1,2612
2	0,08	0,12	1,03	5	0,6187	0,7866
3	0,12	0,24	1,47	5	0,6233	0,7895
4	0,16	0,28	1,17	5	0,6601	0,8125
5	0,20	0,36	1,29	4	0,5059	0,7113
10	0,40	0,76	1,33	3	0,3462	0,5884
25	1,00	1,92	1,24	3	0,3124	0,5589
100	4,00	7,48	1,20	3	0,2933	0,5416
500	20,00	38,40	0,50	1	0,2500	0,5000

The application of different other optical methods for 3D-surface detection of sheet metal parts (Projected Fringes Method, Electronic Speckle Interferometry, White-Light-Interferometry, SEM, AFM and Laser Scanning Methods) has been reported in [9-13] and methods of intelligent interpretation (FFT; Neural Nets and Fuzzy-Clustering, Wavelet Transformation and Power Spectra) has been reported in [1,13-17].

5 SUMMARY

Surface Quality Control of car body parts is a topic of different disciplines. Up to this time, this is a visual inspection task. There are strong demands for a complete automatisation of the inspection process. Starting with physiological and psychological test series of costumers and experts to analyse defects under special conditions and the selection of the main cosmetic defects, we give some examples for a fast inspection of car body parts with class-A surfaces.

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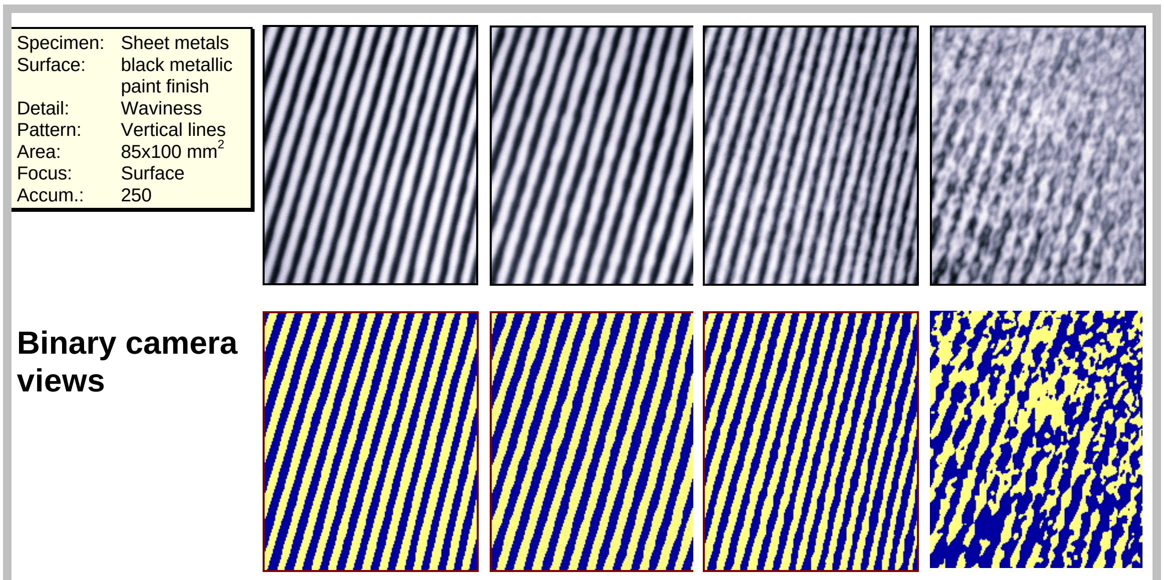

Specimen	A	B	C	D
Visual waviness rating	none	slightly	striking	very strong
Average structure size	7.01 pixels	7.19 pixels	5.97 pixels	6.14 pixels
Standard deviation	0.576	0.825	1.058	3.858

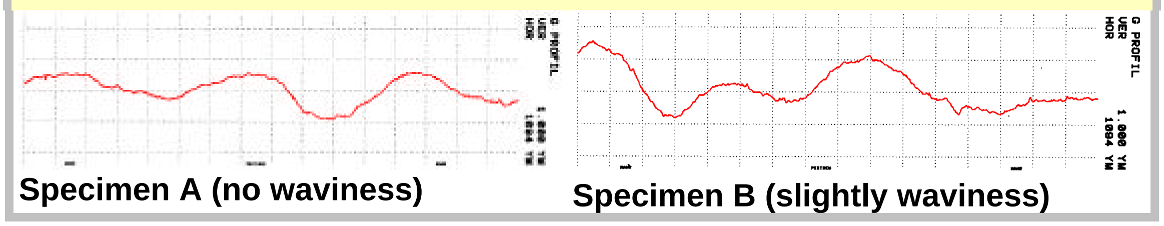

Figure 8. Fast estimation of paint finish waviness on car body parts by structure size analysis

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