Thickness measurement of thin powder layers

To prevent rejects, retouching and to reduce cost of conservatively more than enough applied powder in powder coating processes a handy measurement system allowing to determine the final coating thickness before burning in the coating is an enormous help. To not destroy the quality of the surface a contactless measurement technique is needed.

Based on experience with the measurement of thin layers and related deconvolution techniques [1], [2] air-borne ultrasonics and a new deconvolution algorithme have been investigated [3]. Focussed and optimized composite probes have been used and were excited with a square wave pulser in pulse-echo mode. The signals have been acquired, digitized and after preprocessing (filtering) the difference of Time of Flight (TOF) of two overlapping reflection pulses have been deconvolved. The time resolution of the deconvolution is independant of the sampling and can be much better than the actual sampling rate. Of course the Nyquist theorem has to be fullfilled. This is no restriction since it just says that the samplerate has to be at least twice the maximum frequency (bandlimit, filter) present in the signal itself.

Fig. 1a) shows a characteristic narrow banded signal (860 kHz center frequency) from a flat steel surface (reference signal). A steel block was milled in a way that the distance of the upper and graved surface varied from 0 to about 1300 microns (Fig. 2) . Moving the probe along the edge (see Fig. 2) about 30 signals have been acquired equidistantly (all 4 mm). Fig 1 b), 1 c) show 2 characteristic signals (position 6 and 12). The 30 measured signals have been preprocessed and deconvolved. Fig. 3) shows the evident correlation between measured TOF difference and signal position (depth of milled grave).

The evaluation of the deconvolution results show that time resolution is better or equal to 1 with the chosen processing time unit of 0.08 microseconds (respectively a rate of 12.5 Mhz). First signals processed conservatively have been acquired with a samplerate of 12.5 Mhz. A Fourier analysis shows that the signals spectras do not have energy above 2.0 Mhz. This means that a sampling rate of 4.0 Mhz would have done the job as well. Due to the time base of the ADC an experimental check with a sample rate of 5.25 MHz has been carried out successfully.

Although the processing time unit basically could be further improved table 1 gives some ideas what the achieved results and axial resolution mean in several interesting applications and low center frequencies. With low frequencies a lot of attenuation problems available in new engineered materials could be solved.

Of our special interest is the thickness measurement of powder coatings. While the soundvelocity of the electrostatic applied powder / air mixture is estimated to be 2 times the velocity in air [1)] it is also an estimation that thickness powder / air layer is reduced by a factor of 5 [2)] by smelting (burning in process, hardening).

distance in	f_{center} (MHz)	$f_{upperb.}$ (MHz)	samplerate min (MHz)	proc. unit (µs, MHz)	velocity (mm/µs)	λ (µm)	ax. resol. by deconv (µm)
air	0.860	2.0	4.0 (5.25)	0.08, 12.5	0.34	395	16
powder coating	0.860	2.0	4.0 (5.25)	0.08, 12.5	0.68[1)]	198	6 [2)]
ceramic coating	8.6	20	40	0.008, 125	6.00	700	24
concrete	0.086	0.2	0.4	0.8, 1.25	4.00	46500	1600

table 1: several applications, frequencies and thickness / depth resolution

The required resolution for the powder coating thickness measurement problem is about 5 microns. Therefore a processing time unit of 0.08 µs (12.5 Mhz) seemed to be ok (compare line 2 in table 1). First results based on real measurement are documented in Fig. 4. and are very promising result. Today corresponding patent is pending [3].

[1] R. Gut, P. Kreier, G.S. Moschytz; Trellis Based Deconvolution of Ultrasonic Echoes; Proc. of IEEE International Symposium on Circuits and Systems, Vol. 2, Seattle, May 1995

[2] P. Kreier, R. Gut, G.S. Moschytz; Genaue und automatisierbare Schichtdickenmessung mittels Entfaltung von Ultraschall-Laufzeitsignalen; Berichtsband Jahrestagung DGZfP, 22.-24.5.1995, Aachen

[3] patent pending

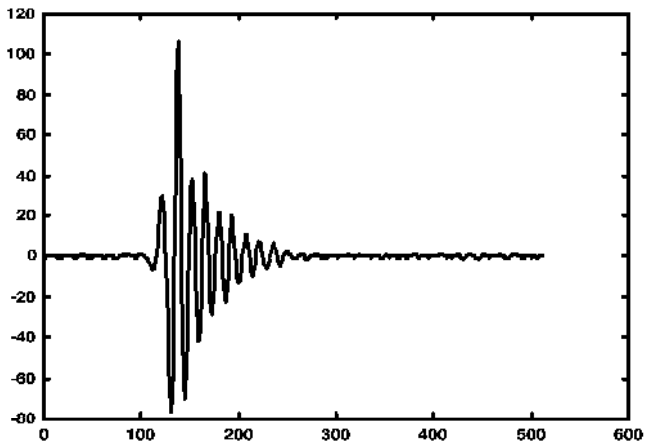

Fig. 1a) reference signal on flat steel surface

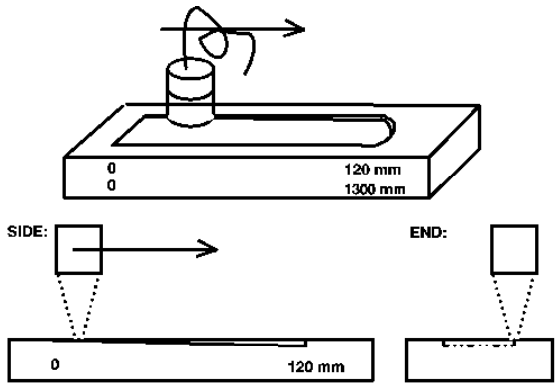

Fig. 2 steel edge and measurement setup

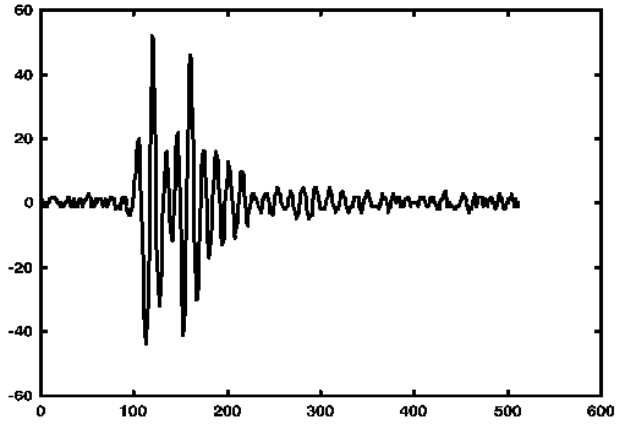

Fig. 1b) signal on steel edge (position 12 see Fig.3

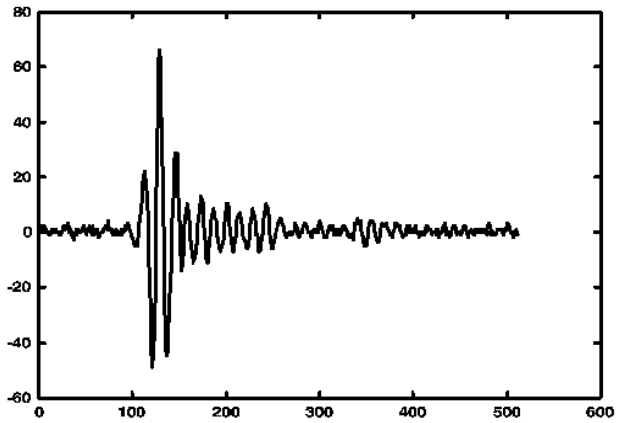

Fig. 1c) signal on steel edge (position 6 see Fig.3

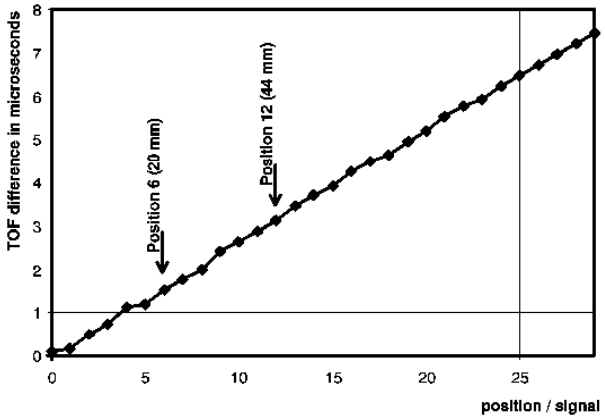

Fig. 3 results on depth measurement on steel edge

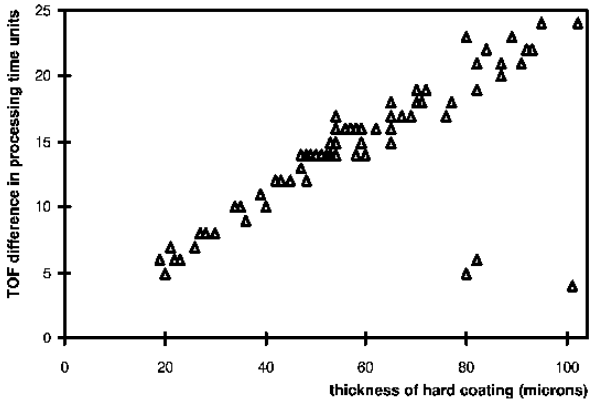

Fig. 4 thicknessmeasurement of powder coating