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EFFECT OF SHOT PEENING ON STRESS CORROSION CRACKING ON AUSTENITIC STAINLESS STEEL

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ABSTRACT

Shot Peening is usually considered as a sensible method to prevent cracking related to fatigue or stress corrosion. In this paper I present the results of static stress corrosion tests of three austenitic materials. The specimen for tensile test were made from the material 1.4571(X 6 CrNiTi 17-12-2), 1.4541(X 6 CrNiTi 18-10) and 1.4462(X 2 CrNiMoN 22-5-3).
The different shot peening parameters were selected by the Peenstress ^{sm} *Software. The calculated and measured residual stress profiles are very close.*

KEY WORDS

Stress corrosion cracking (SCC), residual stress, compressive stress, stress distribution, $MgCl_2$ *immersion test, controlled shot peening, Peenstress - calculated stress profiles, measured stress profiles*

INTRODUCTION

Controlled shot peening is an established process that is used to increase the resistance of metal parts to fatigue failure in a great variety of industries, including aircraft, aerospace, automobile, heavy equipment, power generation, petrochemical, etc. The residual compressive stresses introduced by shot peening have a major beneficial effect not only upon metal fatigue but upon all the tensile stress related modes of failures such as stress corrosion cracking, corrosion fatigue, thermal fatigue and fretting fatigue. To these can be added the purely mechanical effects of a peened surface that can reduce galling, improve lubricity, close porosity, increase sealing properties, and even form parts or correct their shape.

It is an establihed fact that stress corrosion cracking (SCC) only occurs in the presence of a critical state in the working material caused by enviroment conditions and by sufficiently high tensile stress (Fig. 1). The residual stresses induced by the shot peening procedure will have a positive effect on fatigue, on stress corrosion cracking resulting from any oscillation and on tensile crack corrosion in the components.

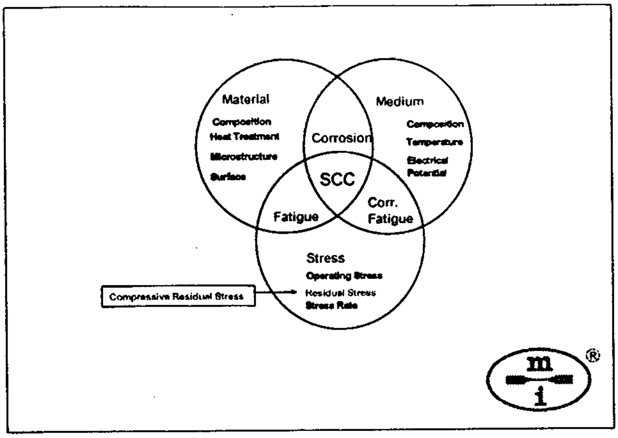


Fig. 1 Influence of critical states on material failures

In chemical plants it is not possible to exert influence on the medium and thereby prevent stress corrosion cracking. For this reason the materials and the distribution of residual stress were varied in the tests conducted.

MATERIALS AND EXPERIMENTAL PROCEDURES

Three typical materials, all used in chemical plants, were selected for the tests under laboratory conditions.

1.4571	X6 CrNiMoTi 17-12-2
1.4541	X6 CrNiTi 18-10
1.4462	X2 CrNiMoN 22-5-3

From the chosen materials tensile strength specimens (proportional test bars) were made for the stress corrosion cracking test. An unpeened specimen was solution heated to reach a uniform starting states. The remaining specimens were then peened in line with three different shot peening parameters.
The shot peening parameters were selected and optimised with the assistance of the Peenstress ^{sm} Software.

Figure 2, below, shows the relationship between the basic shot peening parameters and the distribution of residual stress [Source: B.Scholtes DGM 1980].

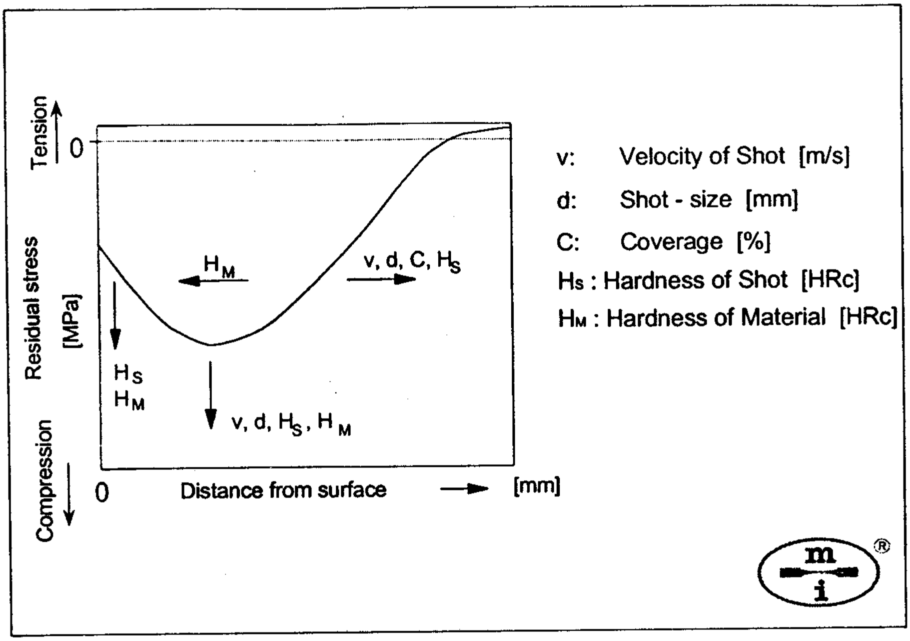
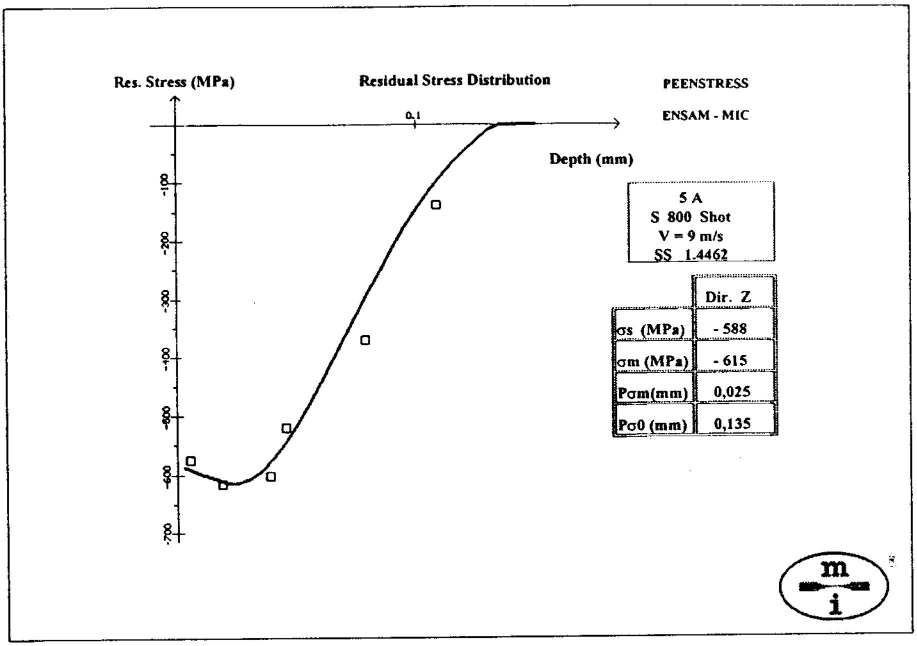


Fig. 2 Shot Peening Parameter vs. Residual Stress Distribution

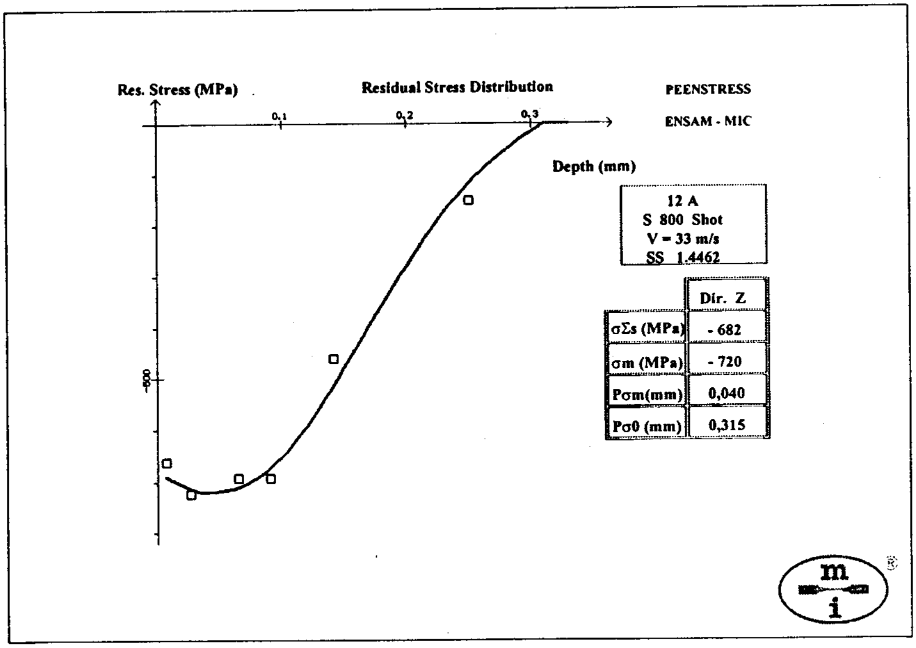
The proportional test bars selected were processed in automated equipment and under full production conditions on the PEENAMATIC shot peening systems.
The shot peening medium for all of the specimens was Stainless Steel Cut Wire (SSCW), size 0.8 mm, material 1.4310, hardness 610 – 670 HV1. The intensities were 5A, 12A and 20A. The degree of coverage was uniform 100% for all specimens, and this was controlled by means of the PEENSCAN procedure.

The following diagrams indicate the calculated distribution of the residual stress of the various materials. The residual stress values were measured with the hole drilling method and they are denoted in each case by a small rectangle.



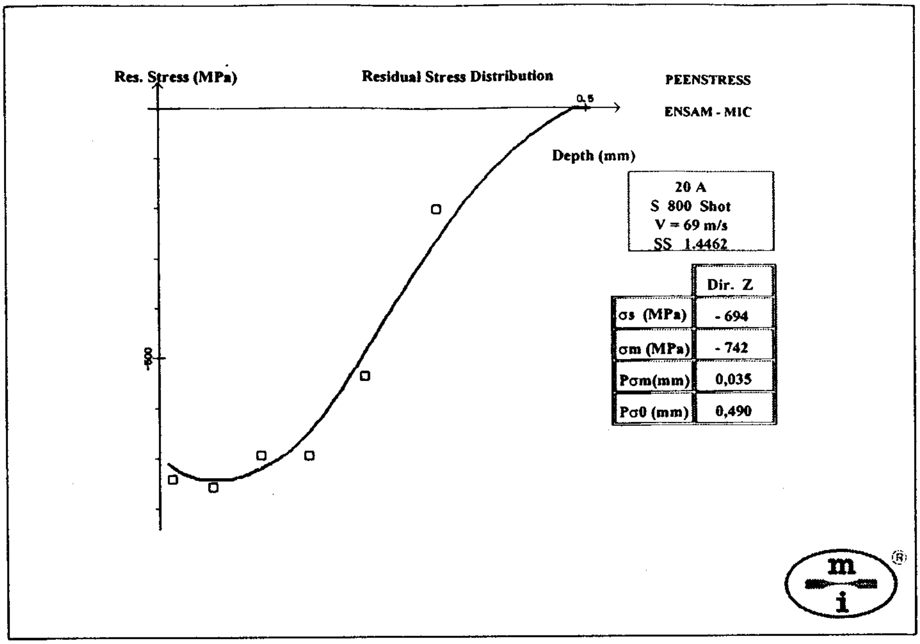
	Dir. Z
σs (MPa)	- 588
σm (MPa)	- 615
Pσm(mm)	0,025
Pσ0 (mm)	0,135

Fig.: 3 Stress distribution of material 1.4462



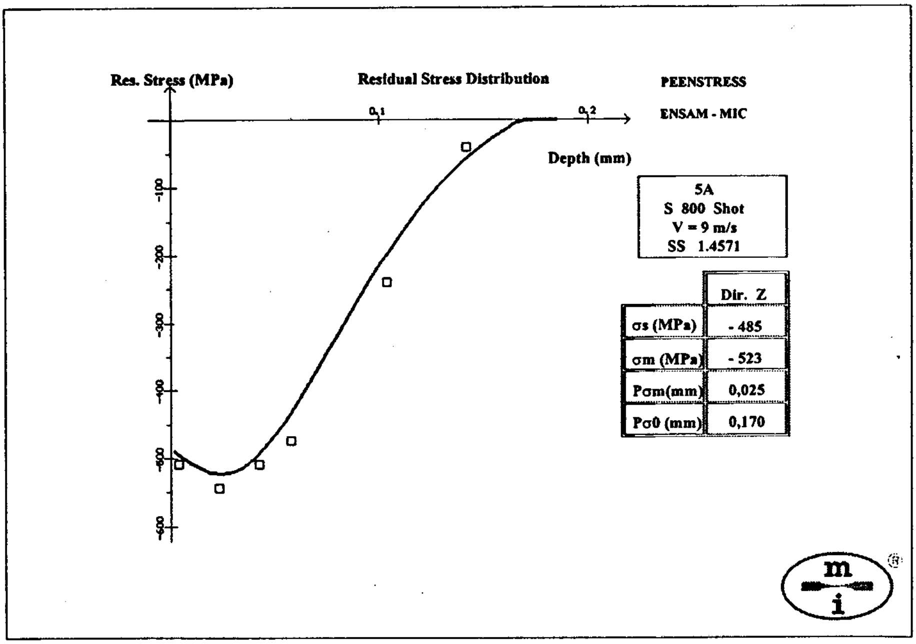
	Dir. Z
σΣs (MPa)	- 682
σm (MPa)	- 720
Pσm(mm)	0,040
Pσ0 (mm)	0,315

Fig.: 4 Stress distribution of material 1.4462



	Dir. Z
σs (MPa)	- 694
σm (MPa)	- 742
Pσm(mm)	0,035
Pσ0 (mm)	0,490

Fig.: 5 Stress distribution of material 1.4462



	Dir. Z
σs (MPa)	- 485
σm (MPa)	- 523
Pσm(mm)	0,025
Pσ0 (mm)	0,170

Fig.: 6 Stress distribution of material 1.4571

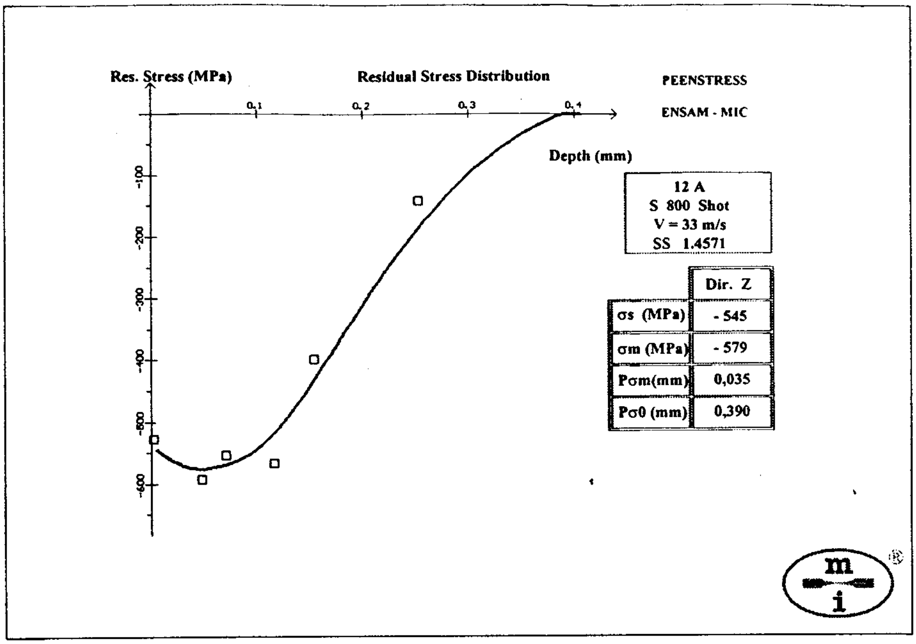


Fig.: 7 Stress distribution of material 1.4571

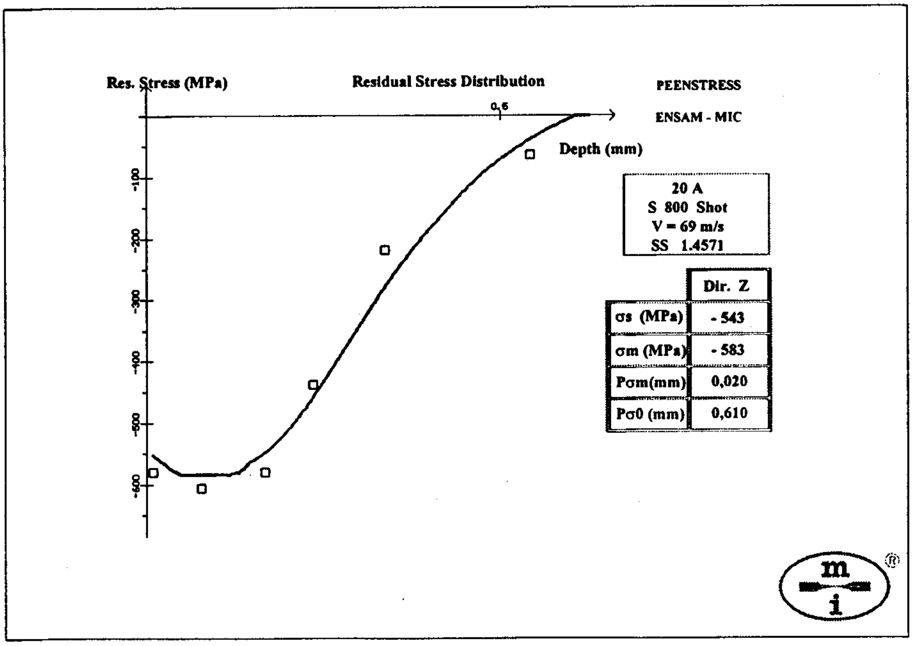
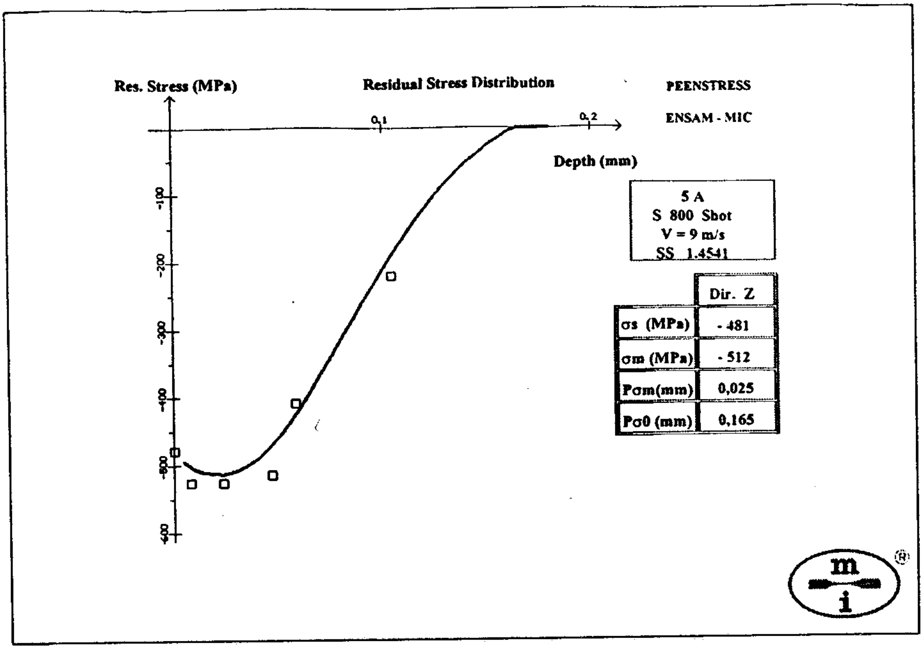
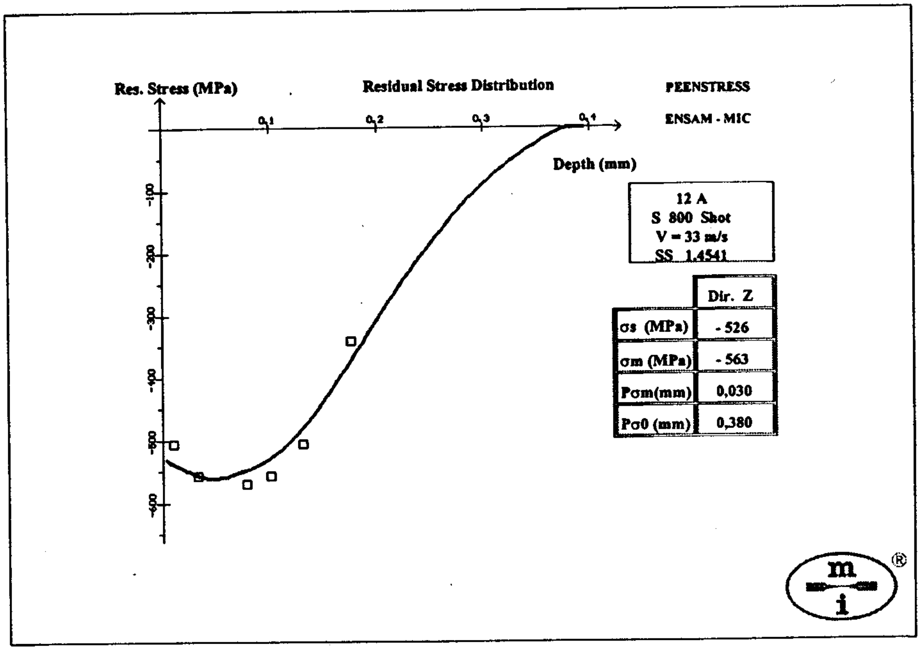


Fig.: 8 Stress distribution of material 1.4571



	Dir. Z
σs (MPa)	- 481
σm (MPa)	- 512
Pσm(mm)	0,025
Pσ0 (mm)	0,165

Fig.: 9 Stress distribution of material 1.4541



	Dir. Z
σs (MPa)	- 526
σm (MPa)	- 563
Pσm(mm)	0,030
Pσ0 (mm)	0,380

Fig.: 10 Stress distribution of material 1.4541

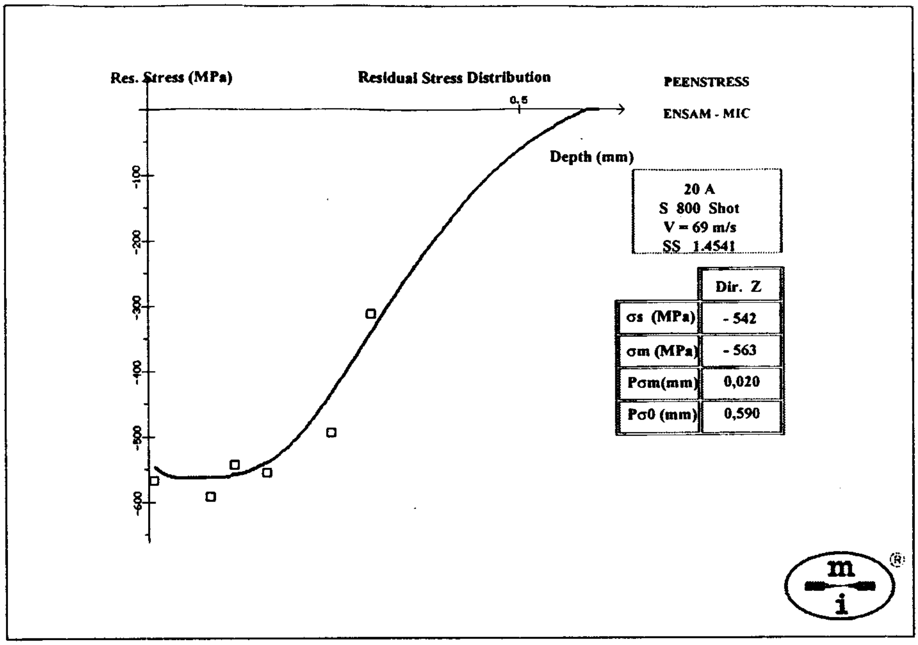


Fig. 11 Stress distribution of material 1.4541

The proportional test bars were fixed firmly in a holding device and tested statically for tensile strength. In total, four load conditions at 50%, 70%, 80% and 90% of the yield points of the respective material were applied. The specimen were exposed to a 42%$MgCl_2$ solution at a constant temperature of 145° Celsius.

RESULTS AND DISCUSSION

The following table displays the exposure times elapsing until the onset of the stress corrosion cracking. Due to the limited time available for the tests not all permutations were tested. The tests were aborted after an exposure period in excess of 1,000 hours without any findings.

Material	Shot Peening Parameter	Load			
		50%	70%	80%	90%
1.4541	not peened	11h	5h	----	3,2h
	SSCW 0,8, 5A, 100%	----	----	----	----
	SSCW 0,8, 12A, 100%	----	----	----	----
	SSCW 0,8, 20A, 100%	----	>1000h	----	>1000h
1.4571	not peened	17h	11,3h	----	7,5h
	SSCW 0,8, 5A, 100%	----	----	----	----
	SSCW 0,8, 12A, 100%	----	>1000h	----	>1000h
	SSCW 0,8, 20A, 100%	----	>1000h	----	>1000h
1.4462	not peened	5,3h	3,3h	----	1,3h
	SSCW 0,8, 5A, 100%	----	----	----	----
	SSCW 0,8, 12A, 100%	----	>1000h	>1000h	2h
	SSCW 0,8, 20A, 100%	----	>1000h	>1000h	5,3h
1.4529	not peened	----	500h	----	37h

The results given here demonstrate clearly that controlled shot peening the materials significantly increases their resistance to stress corrosion cracking in all three cases.

On inspection of the exposure times of the unpeened specimens it is noted that the material 1.4462 has the lowest resistance to stress corrosion cracking. The application of controlled shot peening at a load of 70% the exposure time can be increased from 3.3 hours to over 1,000 hours. At 90% load the improvement is not so significant.

The results for the material 1.4529 in a peened state are not yet available. The exposure times of 500 hours and of 37 hours permit the conclusion that the shot peened version will generate also no findings.

Even under high static loads the materials 1.4541 and 1.4571 display a marked improvement against stress corrosion cracking. Because of the high testing times required only a few alternatives were investigated. Not even under high static loads did any damage occur, therefor it may be assumed that no premature damage needs to be anticipated at a reduced load earlier stage.
The application of controlled shot peening acquires special importance in the context of the production costs.

The production costs for a 5,000 litre storage tank made of the material 1.4541 and including the cost of shot peening would be approximately EUR 48,000. In case of making it from the material 1.4571, the production costs including shot peening would amount to EUR 50,000. The application of the material 1.4462 would increase the production costs to EUR 90,000 without including controlled shot peening.

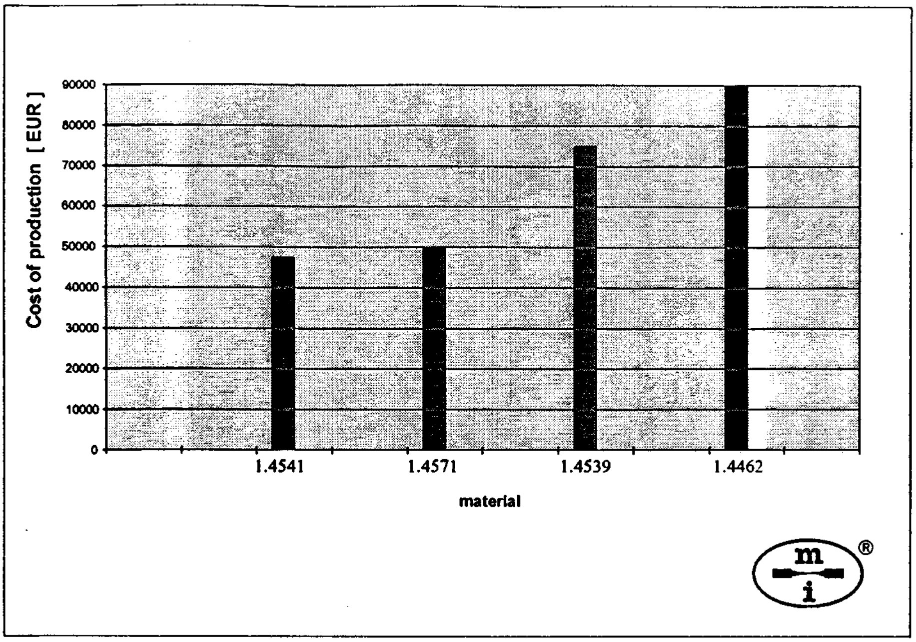


Fig.: 12 Cost Comparison of 5000 liter tank

CONCLUSION

Up to now tests have only been completed under static load.
In plant construction most components are under dynamic stress. In the future tests for corrosion fatigue will be carried out.
On the basis of the results obtained the findings will be put into practice.

The investigation into the production costs of a 5,000 litre storage tank revealed significant differences. For producing the tank from material 1.4541 or 1.4571 the cost for the controlled local shot peening at the site is already included.

Controlled shot peening will significantly increase the resistance to stress corrosion cracking. Earlier research confirms the above findings in respect of ferritic base materials and in NH_3 media.

On the basis of the present results less expensive materials may be used in plant the construction or in chemical plant without impairing the resistance to corrosion.