Selected Examples on the Topography of Shot Peened Metal Surfaces

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Introduction

Shot peening of metal surfaces produces different topographies according to the application. The structure is essentially determined by the kind of peening media. However, the hardness of the peened metal and the peening parameters such as velocity of peening media and number of surface collisions are of important influence.
These relations are demonstrated in the following survey by series of selected examples. In addition the limits of shot peening treatment are discussed.
The different surface patterns after shot peening can be shown up distinctly by scanning electron microscopy.
Application of round uniform peening media produces an uniform looking surface. However, if the bead velocity is choosen too high or the quantity of shot per area and therefore the coverage is too high, differently destroyed surfaces are produced. Broken parts of the shot yield an irregular furrowed peened surface which is not desired. If sharp edged rests of shot are present it is possible that small particles of the shot remain in the peened metal surface.

Peening media and sample material used

From a larger number of peening media and peened material used, the following examples were selected:

Peening media	Hardness [kp/mm^2]	Density [g/cm^3]
ZrO_2 (Zr)	800 - 1000 HV	3.7-3.95
Al_2O_3 (MKE)	1800 - 2200 Knoop	3.95
Glass beads (MGL)	515 Knoop	2.45-2.5
C-Steel (GSR)	450 - 510 HV	7.4-7.8
Aust. Steel, granulated	415 HV	7.4-7.8
Al, granulated	100 - 120 HV	2.75

Peened material:

Aluminium alloy	130 - 150 HV
Copper alloy	80 - 100 HV
Austenitic steel	200 - 220 HV

Surfaces of aluminium-alloys

The surface of an AlZnMg-alloy shot peened by small new glass beads is shown in Fig. 1, and a similar surface peened by larger new glass beads in Fig. 2. If the same alloy is peened by glass beads, which were in operation for a longer period, so the "realistic" surface, Fig. 3, is produced. If the coverage and the peening pressure is increased the surface becomes much rougher and more irregular and material layers become separated from the matrix material, Fig. 4. When the coverage and the energy of the glass beads is further increased, separation of material particles becomes more distinct, Fig. 5. The

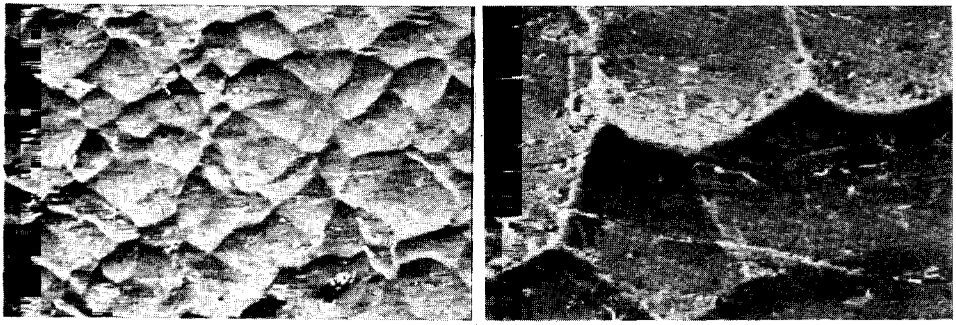


Fig. 1: 103:1 412:1
Peening media: MGL 0.18 - 0.3 mm, coverage: A* = 1 x 98 %, air pressure: p = 1.1 bar, Almen intensity: 0.2 N

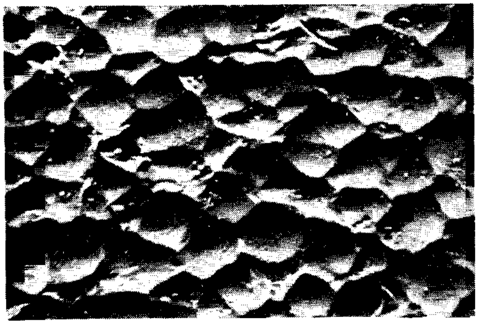


Fig. 2: 55:1
Peening media MGL 0.42 - 0.84 mm coverage: A* = 2 x 98 %, air pressure: p = 0.5 bar, Almen intensity: 0.18 A

surface peened by clean steel shot is shown in Fig. 6. By increasing the quantity of shot per area, here again a more irregular surface appears, produced by repeated plastic deformation, Fig. 7. If the same alloy is peened by steel shot and subsequently by glass beads (round and broken beads in water), a surface with regular impressions appears caused by the steel shot and smaller impressions in it produced by the glass beads, Fig. 8. This peening combination was choosen to clean the aluminium surface from remainders of ferritic steel. It was not investigated whether inclusions of the glass remained. A new peening media which is coming into use consists of ceramic beads (ZrO_2). Fig. 9 and 10 show surfaces peened by virginal Zirconia. The surface in Fig. 10 was peened with higher velocity and intensity, and thus shows larger impressions. To demonstrate the limits of peening treatment with Zirconia, a series was performed similar to the glass treatment. By increasing velocity and coverage, thus the shot quantity per area was varied. The experiments were carried through with virginal shot, because no shot with longer operating time was available. Fig. 11 and 12 show regular impressions, but if the velocity and the shot quantity is increased separation of material; Fig. 13, becomes visible again. If the velocity and the quantity is increased the size of the impressions increases, Fig. 14, but the material separations are not more distinct than as in Fig. 13. Here it should be investigated, if increasing energies produce deeper plastic deformation and prevent an early surface damage.

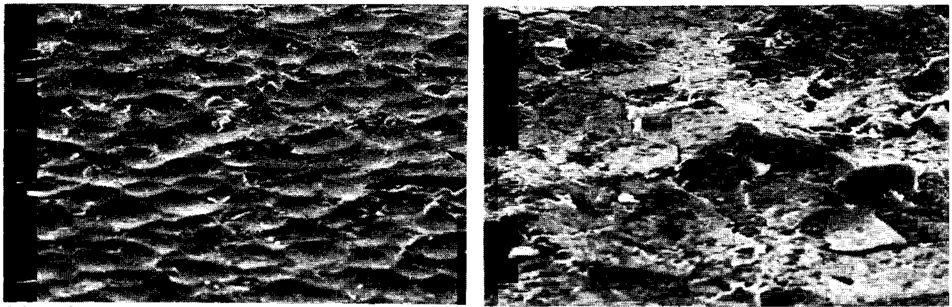


Fig. 3: 54:1 300:1

Peening media : MGL 0,42 - 0,84 mm air pressure : p = 0,5 bar

coverage : A* = 6 x 98%

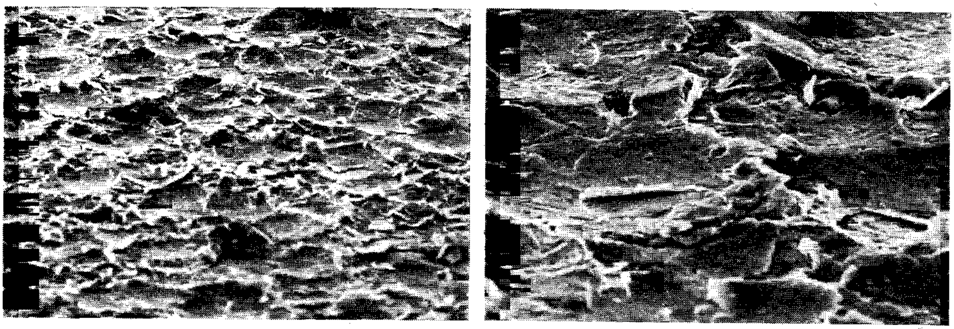


Fig. 4: 54:1 300:1

Peening media : MGL 0,42 - 0,84 mm air pressure : p = 1,0 bar

coverage : A* = 10 x 98%

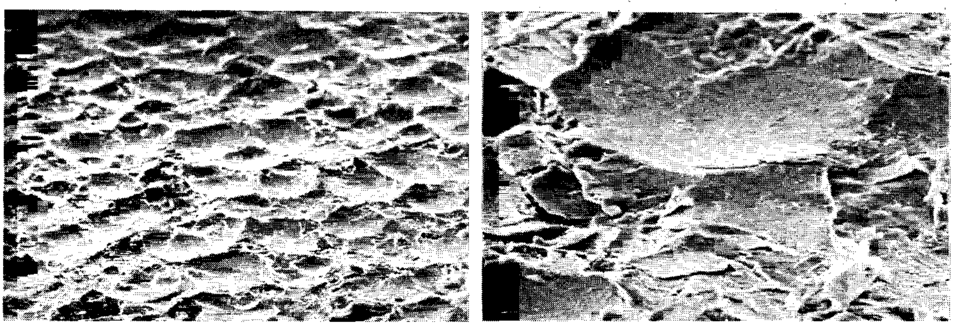


Fig. 5: 54:1 300:1

Peening media : MGL 0,42 - 0,84 mm air pressure : p = 2,0 bar

coverage : A* = 12 x 98%

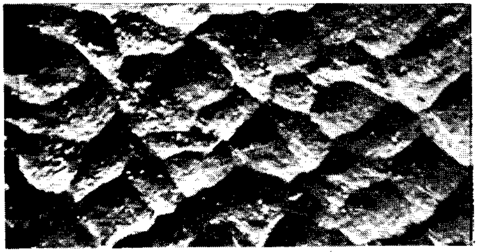
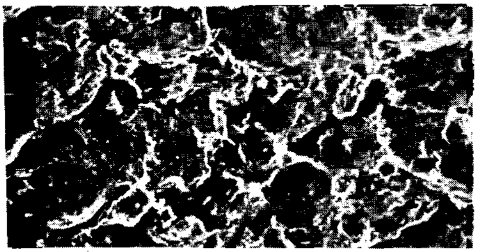


Fig. 6: 55:1
peening media: GSR 0,7 mm
coverage : A* = 1 x 98%
air pressure : p = 0,7 bar
Almen intensity : 0,21 A



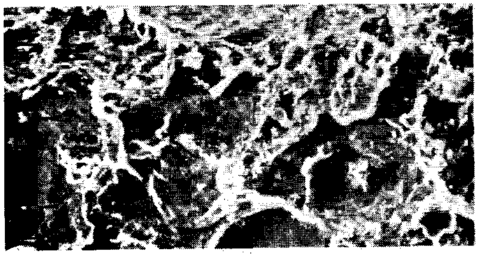


Fig. 7: 54:1 103:1
peening media : GSR 0,6 mm
coverage : A* = 6 x 98%

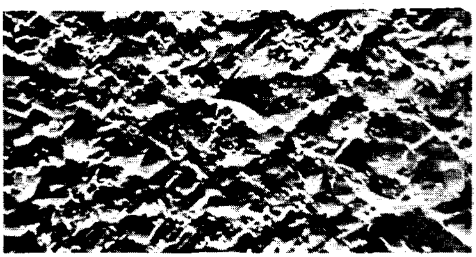


Fig. 8: 55:1
peening media : GSR 0,7 mm
coverage : A* = 1 x 98%
air pressure : p = 0,7 bar
+ MGL 0,25 - 0,42 mm (wet)
Almen intensity : 0,21 A/0,2 N

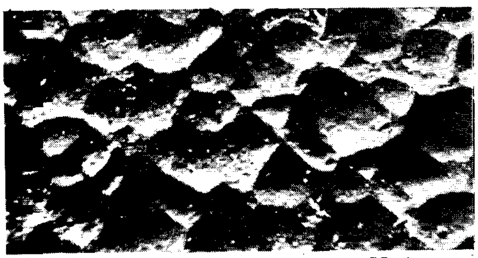


Fig. 9: 55:1
peening media : Zr 0,42 - 0,85 mm
coverage : A* = 2 x 98%
air pressure : p = 0,3 bar
Almen intensity : 0,16 A

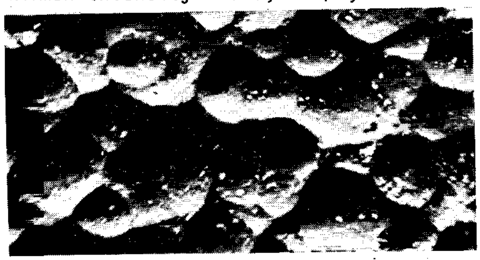


Fig. 10: 55:1
peening media : Zr 0,42 - 0,85 mm
coverage : A* = 2 x 98%
air pressure : p = 0,9 bar
Almen intensity : 0,3 A

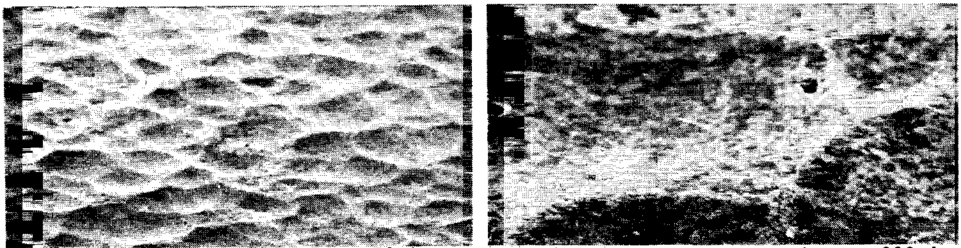


Fig. 11: 54:1 300:1
peening media : Zr 0,6 - 0,85 mm air pressure : p = 0,5 bar
coverage : A* = 6 x 98%

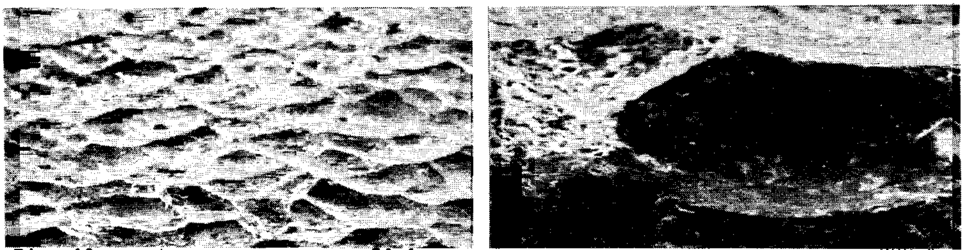


Fig. 12. 54:1 300:1
peening media : Zr 0,6 - 0,85 mm air pressure : p = 1,0 bar
coverage : A* = 8 x 98%

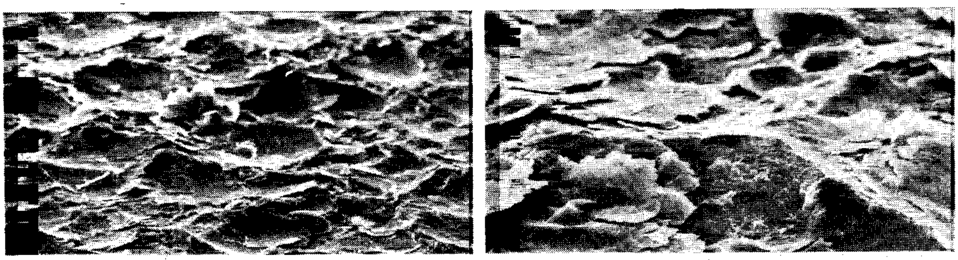


Fig. 13: 54:1 300:1
peening media : Zr 0,6 - 0,85 mm air pressure : p = 2 bar
coverage : A* = 10 x 98%

Fig. 14: 54:1 300:1
peening media : Zr 0,6 - 0,85 mm air pressure : p = 3 bar
coverage : A* = 12 x 98%

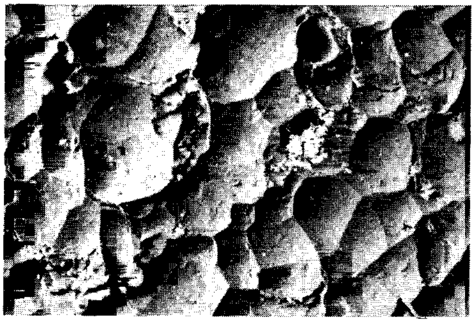


Fig. 15 100:1 300:1
peening media : Zr 0,21 - 0,3 mm air pressure : p = 2 bar
coverage : A* = 1 x 98%

Fig. 15 shows an inclusion of Zirconia particle in an aluminium surface. However, this inclusion was not easy to find and it was an exception with the present parameters.

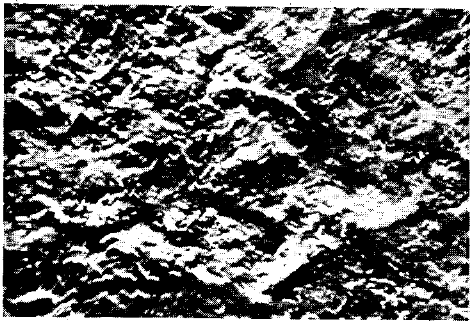
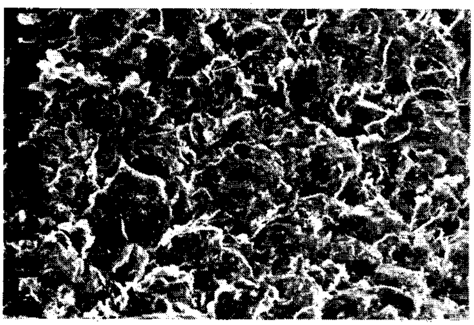


Fig. 16: 55:1
peening media: Al-Gr 1,2 - 1,8 mm
coverage : A* = 2 x 98%
air pressure : p = 1 bar
Almen intensity: 0,25 N



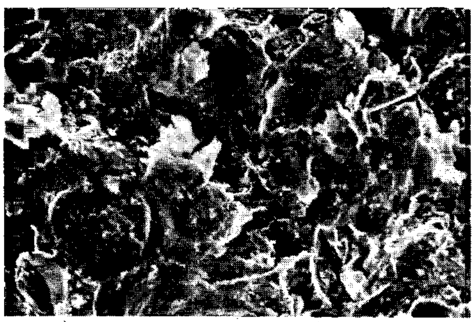


Fig. 17: 100:1 300:1
peening media : St-Gr 0,1 - 0,2 mm air pressure : p = 2 bar
coverage : A* = 2 x 98%

To produce residual compressive stresses and to strain harden surfaces it is not always necessary to use beads as peening media. Fig. 16 shows an aluminium surface peened with granulated aluminium. If the peening parameters are varied in the wrong direction, i.e. in this case higher density of the shot, smaller shot diameter, higher velocity, the surface is destroyed and shows a totally different pattern, Fig. 17, than with correct choice of parameters.

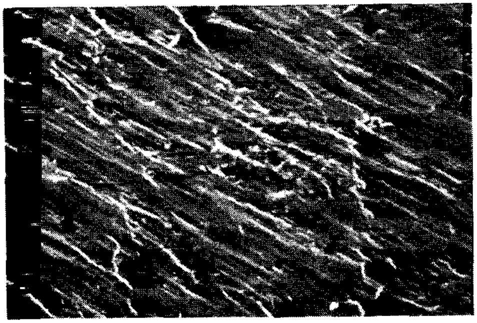


Fig. 18: 100:1 400:1

peening media : C-Steel 1,2 mm
coverage : A* = n x 98%

brush diameter: d = 300 mm
rotation : n = 1000 mm^{-1}

Fig. 18 shows an aluminium surface treated by a peening brush. After a brushing time of one minute no typical impressions of shot peening are visible but the surface shows sliding lines in brushing direction.

Surfaces of copper alloys

Investigations of a copper nickel aluminium alloy led to the accidental result in Fig. 19. In cast copper parts, depending on the size, micro shrink holes are not avoidable. In such shrink holes Zirconia beads have settled and were hammered in by the following beads. Fig. 20 shows a copper surface after peening with granulated austenitic steel. Similar to the situation described in Fig. 17 the peening parameters were choosen too high and the surface becomes damaged.

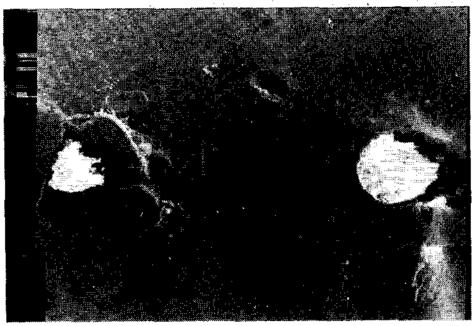


Fig. 19: 100:1 200:1

peening media : Zr 0,85 - 1,18 mm
air pressure : p = 1 bar
Almen intensity : 0,38 N

coverage : A* = 1,2 x 98%
air pressure : p = 3 bar

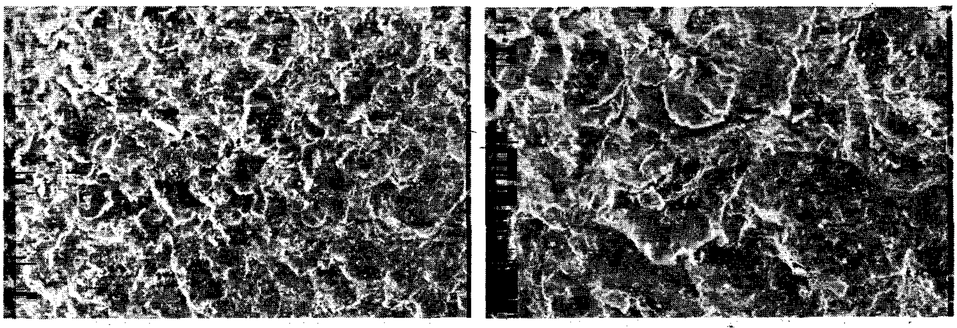


Fig. 20: 100:1 300:1
Peening media : St-Gr 0,1-0,2 mm air pressure : p = 2 bar
coverage : A* = 1,5 x 98%

Surface of austenitic steel

At last some examples from a peening treatment of austenitic steel are shown. Fig. 21 shows the surface of austenitic steel peened by granulated austenitic steel. The surface, like the aluminium surface peened by granulated aluminium, looks regular and undamaged. Here the parameter combination was correct.

If the glass shot contains broken parts or if the glass breaks due to higher velocities, glass particles intrude in the austenitic steel. The irregular surface pattern is shown in Fig. 22. By back scatter electrons the dark embeddings of Silicon particles are made visible, Fig. 23, and are confirmed by an energy dispersive x-ray analysis.

Fig. 24 demonstrates the surface of an austenitic steel which was to be cleaned by an abrasive shot (Al_2O_3) and after that should get a typical peening structure by Zirconia shot. With this parameter combination it was found that the former embeddings of sharp corundum remained in the surface and were not removed by the following peening treatment.

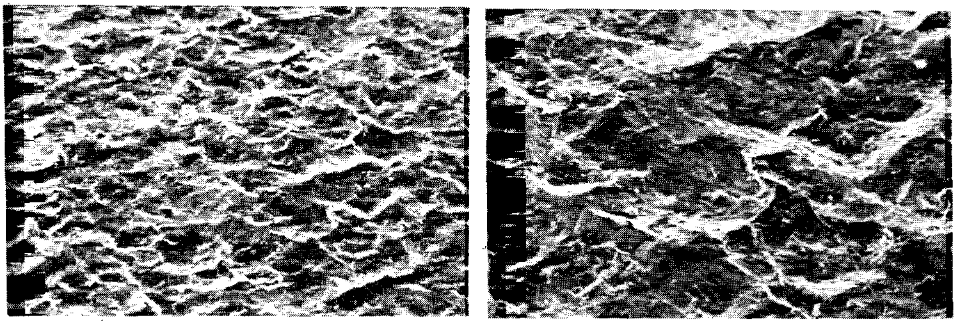
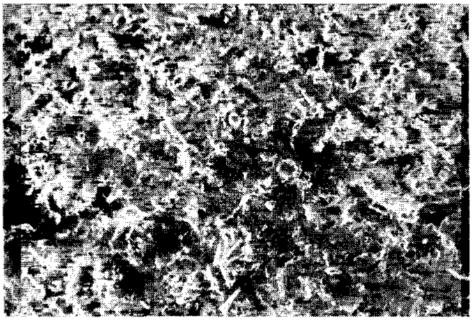


Fig. 21: 100:1 300:1
Peening media : St-Gr 0,2-0,4 mm air pressure : p = 2 bar
coverage : A* = 1,2 x 98%



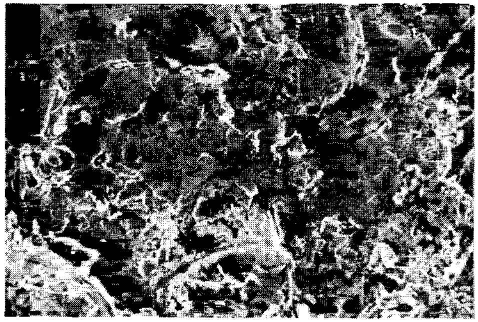
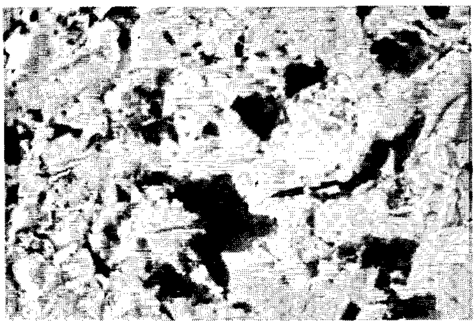


Fig. 22: 100:1 300:1

peening media : MGL 0,1 - 0,3 mm air pressure : p = 2 bar

coverage : A* = 2 x 98%



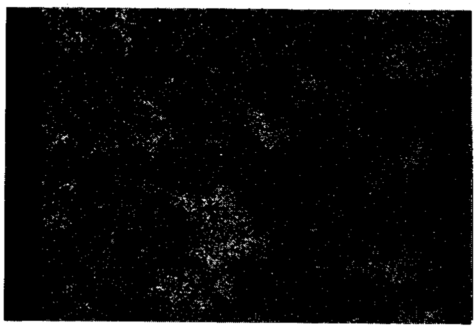
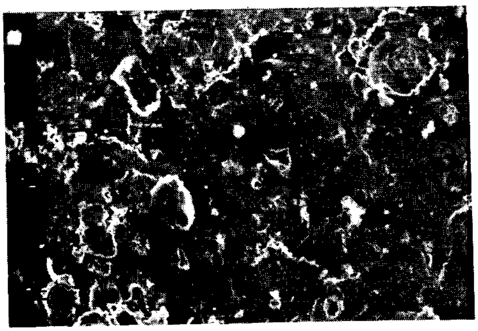


Fig. 23: 600:1 600:1

Silicon inclusions (black) by back scatter electron

Energy dispersive x-ray analysis of Silicon

section of Fig. 22



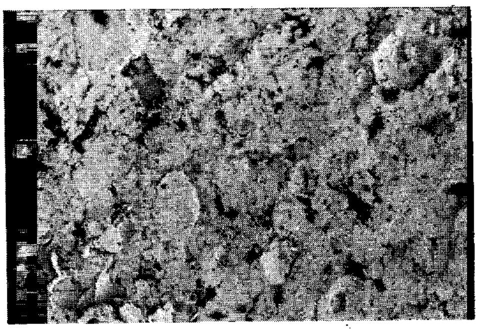


Fig. 24: 300:1 300:1

peening media : MKE 0,06 - 0,1 mm + Zr 0,15 - 0,21 mm

coverage : A* = 1,2 x 98%

Al_2O_3 inclusions by back scatter electrons

air pressure p = 2 bar