ANALYSIS OF SURFACE LAYERS MECHANICAL STRENGHTENING BY DYNAMICAL SHOT PEENING

Jozef BÍLIK, Jozef BAČA

Authors: ***Jozef Bílik, PhD, Prof., Jozef Bača, PhD, Prof.***
Workplace: ***Department of Forming, Faculty of Materials Science and Technology SUT***
Address: ***Bottova 23, 917 24 Trnava, Slovakia***
Tel: ***00421 33 5521105*** *E – mail:* ***bilik@mtf.stuba.sk, baca@mtf.stuba.sk***

Key words

shot peening, surface layer, hardening, mechanical strenghtening

guľôčkovanie, vrstva povrchová, spevnenie, spevňovanie mechanické

Introduction

The lifetime, especially of dynamically stressed parts and tools, is influenced by surface layer. The surface layer is the most stressed by internal stress and there are various stress concentrators. Thus it is important, especially at dynamically stressed parts and tools to take increased attention on surface layer. From the surface can start the propagation of fatigue fracture or other failure which disables the part or tool. It was proved and verificated that mechanical strenghtening of surface layers has positive influence on parts and tools lifetime.

Efects of Surface Layers Mechanical Strenghtening

Every cold plastic deformation is connected with deformation strenghtening. Dynamical methods based on strenghtening bodies throwing (mostly balls) on processed strenghtening of surface layers with various shade and dimensions. In this cabe it is the cumulation of small plastic deformation in surface layer during the impact of strenghtening bodies (balls) on strenghtened surface. At strenghtening the change of surface layers properties takes place, but the most important from lifetime is point of view is the change of mechanical properties such as increasing of tensile strenght, hardness and fatigue resistance. Mechanical strenghtening of surface layers is connected with creation of pressure residual stress in surface layers, which eliminates the unfavourable tensile stress created during machining. Also the influence of stress concentrators as technological or construction notches is eliminated. At thermally treated parts and tools the unfavourable effects and decarburization of surface layer.
The surface layers mechanical strenghtening causes:

a) the change of the static and fatigue resistance, because of the pressure residual stress in the surface layer,
b) the change of the abrasion resistance, because of the increased strenght and hardness of tre surface layer
c) the creation of the shell structure in the surface layer,
d) the change of the surface roughness,
e) the change of the electrical and physical properties of surface layer.

The Effect of the Strenghtening Bodies Impact on the Strenghtened Surface

Mathematical model of the effect of the impact procees from the bodies impact theory. At first when the omission of the elastic deformation of the surface and the body (ball) is supposed, the law of momentum can be used

$$m.v = F.t \ ,$$

where m – the mass of the strenghtening body (ball),
F – the force at the ball penetration into the surface,
t – the time of the ball penetration into the surface.

With further adjustment the following formula can be obtained

$$m.a = F \ . \qquad (1)$$

If in the formula (1) the deceleration „a“ is substituted by $a = -\frac{d^2x}{dt^2}$ and the force „F“ by $F = 2.\pi.R.x.\sigma_{km}$ the following formula can be obtained

$$m.-\frac{d^2x}{dt^2} = 2.\pi.R.x.\sigma_{km} \ , \qquad (2)$$

where R – the radius of the ball,
σ_{km} – the deformatin resistance of the strenghtened material,
x – the instantaneous depth of the ball penetration into the surface.

The conditions at the ball penetration into surface are showed on fig.1.

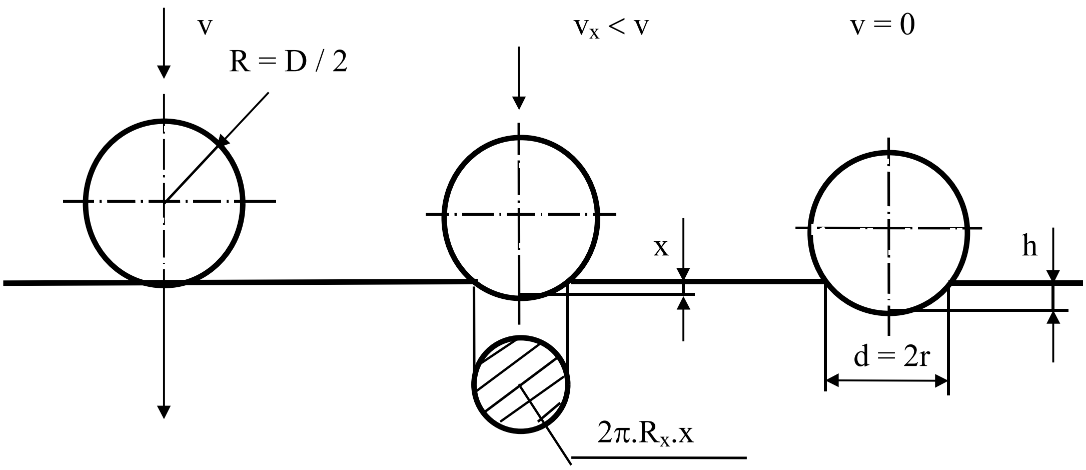

Fig. 1 *The ball pentration into the surface*

By solving the formula (2) the formula for the maximal depth of the ball penetration can be obtained, of course without consideration of elastic deformation

$$x_{\max} = v.R.\sqrt{\frac{2.\rho}{3.\sigma_{km}}} , \qquad (3)$$

where ρ – the density of the ball,

v – the velocity of the ball impact on the strenghtened surface.

At more accurete determination of the real depth of the ball penetration into the surface also the bounce velocity after the impact must be tahen in account.

In that case the depth of penetration can be established by formula

$$x_s = x_{\max} . \left[1 - \left(\frac{v'}{v} \right)^2 \right] , \qquad (4)$$

where v' is the bounce velocity of the ball after the impact.

The velocity racio $\frac{v'}{v}$ presents the so called coeficient of restitution „k".

So the formula (4) can be presented as

$$x_s = x_{\max} .\left(1 - k^2\right).$$

The coefficient of restitution „k" is not constant and its size decreases with the increasing impact velocity „v".

The experimental Determination of the Penetration Depth of plastic Deformation

For this the most used are:

- the measurent of hardness on surfaces after thin layers gradual grinding (fig.2),
- the measurement of hardness an tapered surface, created by the grinding of the strenghtened surface at $1 \div 2^{o}$ angle (fig.3),
- the measurement of the microhardness from surface to axis on the axial section,
- the observation of the surface layer strukture on the axial section.

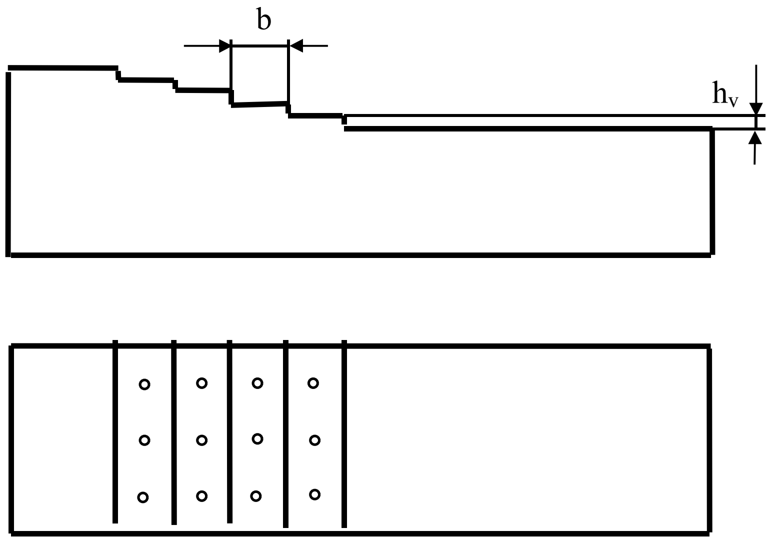

Fig. 2 *The adjustment of the specimen for the measurement of the hardness after thin layers gradual grinding*

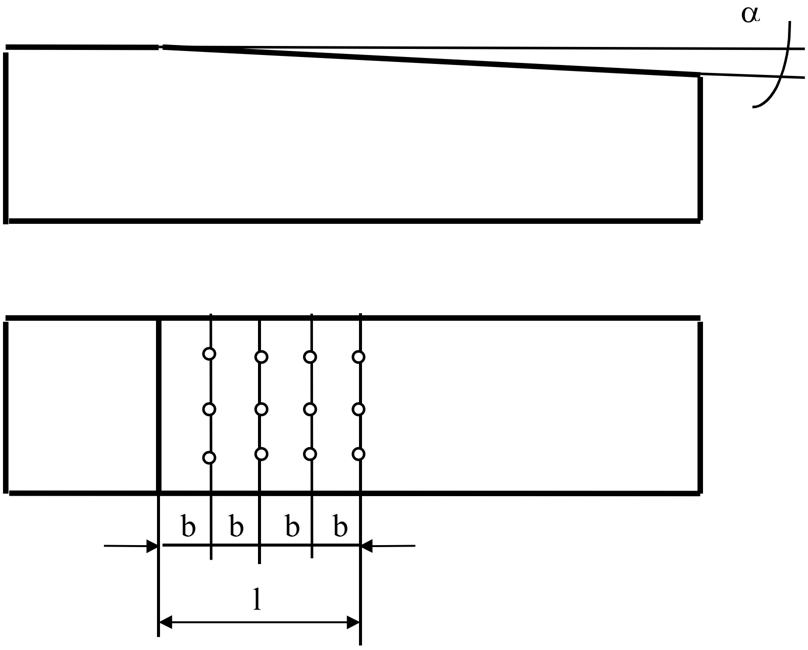

Fig. 3 *The adjustment of the specimen for the measurement of the hardness on the tapered surface*

In this case two methods the measurement of the hardness HRA after thin layers gradual grinding with thickness of 0,05 mm and the measurement of the microhardness HV from surface on the cross section are used for the determination of the plastic deformation penetration depth for STN 419552 tool steel.

The measured values are showed in table 1, 2 and graphs an fig.4 for the shot peening time 6 and 8 minutes, the ball impact velocity on strenghtened surface from 30 to 32 ms^{-1}. The measured values of microhardness are showed in table 3 and graphs on fig.5.

THE VALUES OF HARDNESS FROM SURFACE TO AXIS FOR 19552 STEEL, THE SHOT PEENING TIME 6 MINUTES, THE HARDNESS BEFORE SHOT PEENING 75 HRA, THE SURFACE HARDNESS AFTER SHOT PEENING 78 HRA

Table 1

The measurement place	1	2	3	4	5	6	7
The distance from surface [mm]	0,10	0,15	0,20	0,25	0,30	0,35	0,40
The average hardness from three measurements HRA	77,6	77,3	77,0	76,5	76,5	76,0	75,5

THE VALUES OF HARDNESS FROM SURFACE TO AXES FOR 19552 STEEL, THE SHOT PEENING TIME 8 MINUTES, THE HARDNESS BEFORE SHOT PEENING 75 HRA, THE SURFACE HARDNESS AFTER SHOT PEENING 80 HRA

Table 2

The measurement place	1	2	3	4	5	6	7
The distance from surface [mm]	0,10	0,15	0,20	0,25	0,30	0,35	0,40
The average hardness from three measurements HRA	78,8	78,3	77,8	77,8	77,0	76,7	76,5

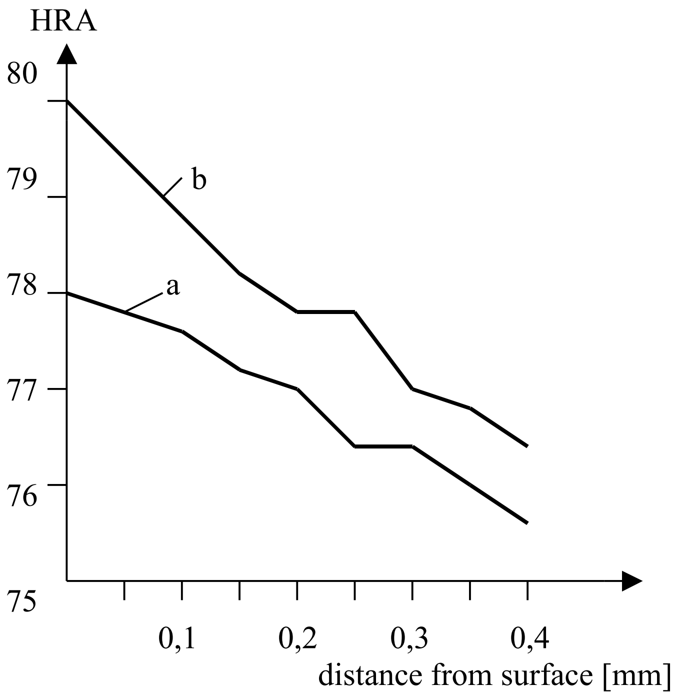

Fig. 4 *Influence of the distance from surface upon hardness for 19552 steel*
a) for table 1, b) for table 2

THE MEASURED VALUES OF MICROHARDNESS HV0,05 FOR 19552 STEEL FOR THE SHOT PEENING TIME 8 MINUTES

Table 3

Hardness of specimen before shot peening	Distance of imprint from surface [mm]	Measurement No.1	Measurement No.2	Average value of microhardness HV
		Hardness HV	Hardness HV	
40 HRC	0,04	478	478	478
	0,06	478	464	471
	0,15	444	396	420
	0,24	409	422	415
	0,36	411	394	402
	0,45	398	398	398
	0,55	404	394	399
48 HRC	0,04	530	540	535
	0,08	527	511	519
	0,14	499	527	513
	0,23	508	496	502
	0,32	502	493	498
	0,44	476	511	494

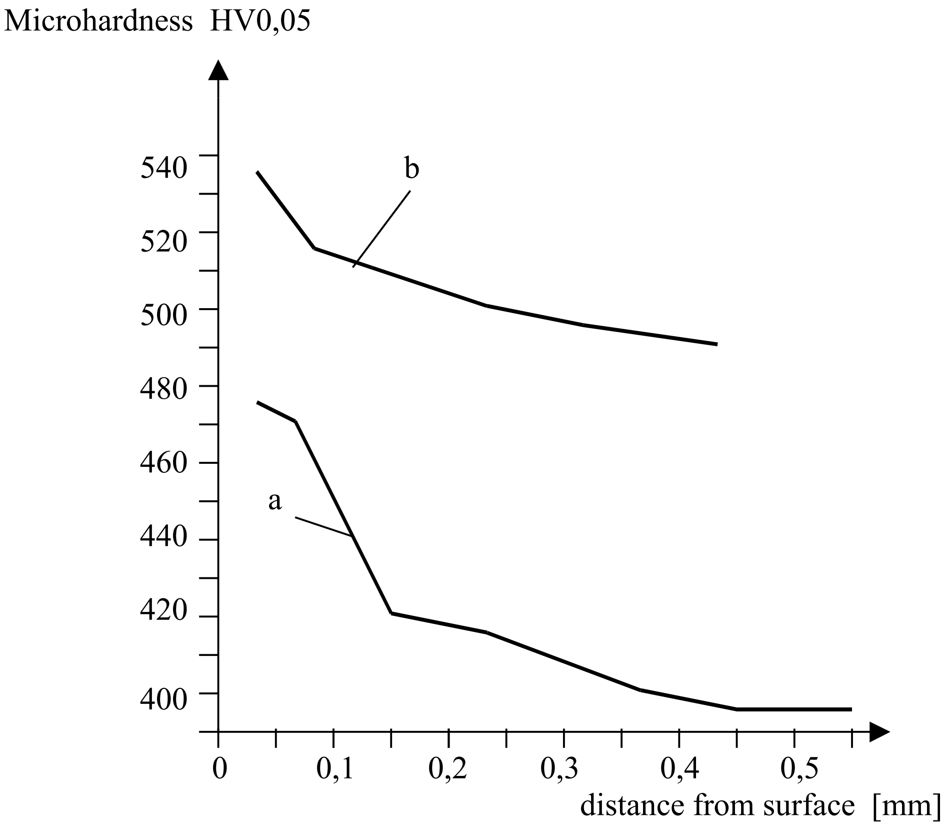

***Fig. 5** Influence of the distance from surface upon average value of microhardness for table 3*
a – hardness of specimen before shot peening 40 HRC,
b – hardness of specimen before shot peening 48 HRC

Conclusion

The determined values of hardness HRA at 588 N total load also values of microhardness HV at 0,4 N total load eudience that the mode of shot peening is suitable because of the maximum hardness on the surface and its gradual decreasing on the value before shot peening.

It was established by measurement of hardness HRA and also microhardness, that the depth of plastic deformation penetration at 19552 tool steel heat treated to hardness 40÷48 HRC was from 0,3 to 0,5 mm, which is suitable from the application point of view.

References:

[1] BÍLIK, J. *Forging dies lifetime increasing by surface layers strenghtening*. Dissertation. Trnava: MtF STU, 2003.
[2] BAČA, J. *Contribution on problem of cavity tools production by forming*. Habilitation. Trnava: MtF STU, 1995.
[3] BAČA, J. - BÍLIK, J. - ŽATKOVIČ, J. *Experimental Methods of Forming.* Bratislava: ES STU, 2000.
[4] BAČA, J. - BÍLIK, J. *Technology of Forming*. Bratislava: ES STU, 2000.