ESSENTIAL THEORETICAL CHARACTERISTICS OF PIPING SHOT PEENING

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ABSTRACT

Shot peening on the piping systems should be considered as a procedure to increase mechanical properties. During such process it is essential to collect all relevant factors. Classical way is to have enough energy for supply to all devices providing all conditions necessary to have predestinated procedure; in the pictures is visible what is shot peening on the piping systems and piping bundles. Caution is to be taken in considering the rim parts of surfaces. Tangential portion of shot blasting can cause very harmful and damaging effects on the pipe body. In the picture we see shot blasting properly hammering rim part of pipe. On this shocking some steel parts will be removed by tangential shot forces. This shearing force can decrease the thickness of piping. The shots blast this rim part and instead of betterment we get what is not the aim of shot peening.

KEYWORDS
Rimming parts, shot blasting, removing by shearing, pipe bundles, volume forces, equilibrium forces.

1. SHOT PEENING OF PIPING

As reported in previous International Conferences and Publications the importance of Shot peening of piping is very well known. After such treatment piping systems become more valuable. It is quite well known what advantages Shot Peening contribute. Here it is not necessary to repeat them. Enough is to say that increased surface roughness increases heat transfer. In heat exchangers and boilers the heat exchange become effective after Shot Peening. That means heat exchanger or boiler can exchange more heat and therefore the whole plant can become more efficient. As previously stated there are many papers describing and bringing the importance of this procedure. Shot peening personnel in charge for such activities can be called as people for nobling such piping system. After shot peening the piping system has more quality and more value. Purpose of this consideration is how can they be "nobled" outside and inside the piping surfaces. Many factors come into consideration. It is necessary to see which type of deformations appear during shot peening. In some cases plastic and elastic deformation occur. In accordance with our classical mechanical education - Hooks Law helps us to understand behaviour of different steels. Different steels have different behaviour under different loadings and stresses. Fatigue of material must be
observed as a point for such examination.

2. OUTSIDE PIPE SURFACE

Fig. 1. Shot peening of outside and inside surfaces of piping system

Fig. 2. Pressure between two spheroidal bodies and Hertzian diagram
In accordance with planned process, outside surfaces are to be under shot shocking or blasting. These shots must be fabricated as is as per desired procedure (size, hardness, material and shape). Blasting of shots are done by NOZZLES or turbine wheels. Shot with controlled velocity results in shocking on surface of piping. This surface therefore becomes more rough than it was previously. Many Shots cause deformations, shape change and finally become unsuitable. If electromagnetic filters are used that may separate these shots going into the process, and thereby allow only proper shots into the system. Two
spheroidal bodies touch in a point if they are of true geometrical shape. This is in accordance with theory. Two spheroidal bodies pressing each other in one point is indicated in Fig. 2. But the pressing of one another results in deformation. In this way it comes to localized moving and deformation. Here it is necessary to observe if these two bodies are of same material and have same modulus of elasticity.

![Diagram](image)

**Fig. 5. Shot peening by outside shots pressure**

As continuously pressure increases it results in face of touching and becoming one ZONE with radius 'A' according to The Hertzian theory discovered by German scientist H. Hertz 1881.

These two spheroidal bodies with diameters D1 and D2 can be considered as pressurising on the straight plate if one of these diameters becoming form D1 endless.

Fig. 1. shows shot peening of internal and external surfaces of piping. It is necessary to emphasize that in both cases pipes must be in rotation to have uniformity of shots falling with certain velocity. Main aim of such treatment is to ensure whole pipe surface to be uniformly shot peened. In accordance to acting pressure it is possible now to develop and precisely calculate all stresses.

One nozzle has been used for shot peening of one pipe at a time. It is therefore necessary to rotate the pipe to avoid any damage of pipe face by falling shots. Usually proper device for placement of pipes is designed so as to enable equal and continuous rotation of all pipes to be shot peened. In this way shots with certain velocities are going from nozzles or from turbine wheel. In Fig. 4 it may be seen that some portions of pipe face are damaged. This is obvious from what is already said. If it is not continuous rotation of pipe during shot peening then damages on surfaces occur which is visible in the figure.

This damage decreases quality of pipe. Thickness is decreased and pipe with such defects cannot go into any project or construction, and it is to be very carefully checked before use.
3. DEFORMATION CALCULATION

In Fig. 5 a part of pipe under pressure causes extension $dx$, $dy$ and $ex$, and $ez$ and some sliding $gx$, $gy$ and $gz$. This mechanical work deformation is in three directions $x$, $y$ and $z$.

Sum of all mechanical deformations.

$$\text{d}U = \frac{1}{2}(G_xex + G_yey + G_zez + \tau_xgx + \tau_ygy + \tau_zgz) \, dxdydz \quad (1)$$

The $U_0$ is energy of the small portion in consideration. Total potential energy of this portion is expressed by:

$$U = \iiint U_0 \, dxdydz \quad (2)$$

In this expression for potential energy we distribute the stresses for deformation on classical way:

$$W_0(G_x, G_y, G_z, \tau_x, \tau_y, \tau_z) = \frac{1}{2} \left( G_x^2 + G_y^2 + G_z^2 \right) - \mu (G_x G_y + G_y G_z + G_z G_x) + \frac{1}{E} \left( \tau_x^2 + \tau_y^2 + \tau_z^2 \right)$$

where is $G$ modulo of sliding and $G_x G_y G_z$ shear stress in the volume part. Now we can calculate deformation in three directions

$$\frac{\partial W_0}{\partial G_x} = G_x - \mu G_y + G_z = ex$$
$$\frac{\partial W_0}{\partial G_y} = G_y + \mu G_x - G_z = ey$$
$$\frac{\partial W_0}{\partial G_z} = G_z - \mu G_y - G_x = ez$$

Stresses in three directions are:

$$\Delta U_0 = \lambda E + 2Gex = Gx$$

Principle of virtual movement is known from theory and it is used for solving problem of Elasticity. All volume forces are zero if there is no deformation. If we mark $U, V$ and $W$ essential moving of some body points then $\partial U, \partial V$ and $\partial W$ are virtual moving. They are very small values in functions with axes $x, y, z$. These movement during shot peening must be equal to zero in some body points.

Some components of deformation on the axes are as follows:

$$\delta ex = \frac{\partial \delta u}{\partial x}, \quad \delta gx = \frac{\partial \delta w}{\partial y} + \frac{\partial \delta v}{\partial z}$$

$$\delta ey = \frac{\partial \delta v}{\partial y}, \quad \delta gy = \frac{\partial \delta u}{\partial z} + \frac{\partial \delta w}{\partial x}$$

$$\delta ez = \frac{\partial \delta w}{\partial z}, \quad \delta gz = \frac{\partial \delta v}{\partial x} + \frac{\partial \delta u}{\partial y}$$

The potential energy is changed as follows:
\[ \delta U_0 = \delta U_0 \delta ex + \delta U_0 \delta ey + \delta U_0 \delta ez + \delta U_0 \delta ex + \delta U_0 \delta gy + \delta U_0 \delta gz \]
\[ \delta ex \delta ey \delta ez \delta ex \delta gy \delta gz \]  

or abbreviated:
\[ \delta U_0 = Gx \delta ex + Gy \delta ey + Gz \delta ez + tx \delta gx + ty \delta gy + tz \delta gz \]

Mechanical work of shot peening on the virtual moving can be expressed separately for volume and surface forces.

Effect of volume forces or activity is:
\[ \int \int \int (xu + yv + zw) \, dV \]  

where \( dV \) is one small part of such volume

Effect of surface forces of Shot Peening is expressed as:
\[ \int \int (pxu + pyv + pzv) \, dS \]  

where \( dS \) is small part of surface on the shot peened surface. In this way in principle of virtual movements the application on the elastic body can be expressed in next equation as:
\[ \int \int \int (xu + yv + zw) \, dV = \int \int \delta UdV \]  

If procedure follows normal schedule cannot bring any change out of programme of Shot Peening. Difference must be equal zero.
\[ \delta \{ \int \int \int UdV - \int \int \int (Xu + Yv + Zw) \, dV - \int \int (pxu + pyv + pzv) \, dS \} = 0 \]

This is one condition of Shot Peening that during process no deformation can occur on pipe. Whole virtual movements on the outside pipe surface have one characteristic, that potential energy has extreme values.

These extreme values are minimum. Another side of this problem is how can shot peening produce compressive residual stress distribution with maximum magnitude on the pipe surface. It is important to observe hard, intermediate and soft material with localised plastic deformation and how can residual stress generate under such condition. The value of plastic deformation, of piping surface layers is predominant for the magnitude of surface residual stresses. Comparison between surface piping roughness before and after shot peening of piping should be one indicator to be respected. It is clear that the plastic deformation on surface layers caused by shot peening to be considered and studied between many factors. Following such concept should be one assistance to find those peening conditions which come in optimum residual stress distribution for the different purpose of shot peening in such application.

Previous mathematical presentation of those 12 equations serve us better to see this problem. Plastic deformation by shot peening of piping system must increase mechanical properties and never do the contrary. That means avoiding such procedure as Fig. 4 and something similar. In this way shot peening of piping will be beneficial.
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