

The Optimum Proposal Research of the Gas Well's Flat Buckle Oil Pipe About the Size of the Gland

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Abstract

Gland can be effective to improve the air sealing of the flat buckle oil pipe, the size of the gland have great impact on the effect of the air sealing. But the optimal size of the flat buckle oil pipe is influence on the parameters of the pipe and the condition of underground. At present, it has not yet formed the optimum proposal. For this purpose, this paper establish the model of the stress-strain with the condition of underground and conclude the size of gland of gas well's flat buckle oil pipe optimum proposal. The result of the research indicates that within certain limits, the smaller of the gland's external diameter, the more thickness of the gland, the larger of the contact pressure, the better of the sealing property.

Key words: Gas-injection well; Flat buckle oil pipe; Gland; Optimum proposal

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INTRODUCTION

In the flat buckle oil pipe of gas-injection well, the connect of pipes' vice sealing property is meaningful to inject gas smoothly. Discovering in the spot, the leak of the flat buckle oil pipe of gas-injection well almost happens in the joint of the pipes which leads to the gas leakage^[1-3]. The bad sealing property material of the gland

and the unreasonable size is the reason of the sealing property losing efficacy of the gland^[4-7].

For the purpose, this paper makes force analysis to gland in the process of the stage of free deformation and establishes the stress-strain model of the spring stage of the gland. In the stage of the free deformation of the gland, we can know the relation of the contact pressure and the gland's external diameter and the relation of the thickness and the external diameter of the gland. And we can make optimum proposal about the thickness and the external diameter of the gland by change the contact pressure, axial strain and the stage of free deformation.

1. THE MECHANICS MODEL OF THE GLAND OF FLAT BUCKLE OIL PIPE

See the gland as a cylinder, so use the cylinder coordinate to show. Get any infinitesimal hexahedron *ABCDEF* from PTFE gland (as shown in Figure 1). Get tiny increment from *r, φ, z* as *dr, dφ, dz*, among these *dr* is the distance of the two cylindrical surface inside and outside; *dφ* is the angle of the two vertical surfaces; *dz* is the distance of the two level surfaces.

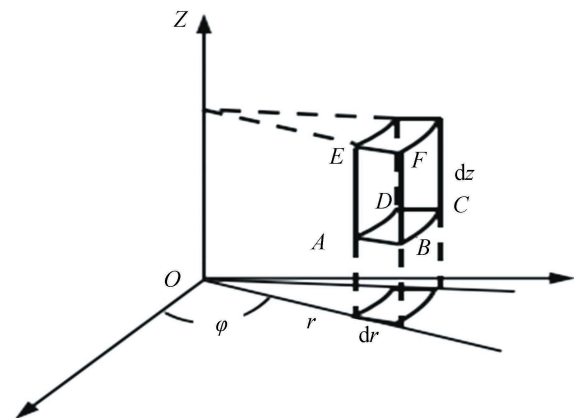


Figure 1
The Sketch Map of the Infinitesimal Gland

In the cylinder coordinate of Figure 1, U_r expresses the vertical displacement of the hexahedron. U_ϕ expresses the circular displacement of infinitesimal. U_z expresses the axial displacement of infinitesimal. Because the gland is a cylinder rotator embracing z axis, which is the symmetry axis. Because the circular displacement of the gland is zero which means U_ϕ is zero. Among these U_r and U_z are the function of r and z .

In the cylinder coordinate, ε_r , ε_ϕ , ε_z expresses the vertical strain, the circular strain and the axial strain.

According to the expression of the article, the circular displacement is zero when producing deformation. By Figure 1, we can know the vertical strain of the gland:

$$\varepsilon_r = \frac{A'B' - AB}{AB} = \frac{BB' - AA'}{AB} = \frac{U_r + dU_r - U_r}{dr} = \frac{dU_r}{dr} \quad (1)$$

The circular strain of the gland:

$$\varepsilon_\phi = \frac{A'B' - AB}{AB} = \frac{BB' - AA'}{AB} = \frac{U_r + dU_r - U_r}{dr} = \frac{dU_r}{dr} \quad (2)$$

The axial strain of the gland:

$$\varepsilon_z = \frac{E'A' - EA}{EA} = \frac{AA' - EE'}{EA} = \frac{U_z + dU_z - U_z}{dz} = \frac{dU_z}{dz} \quad (3)$$

The vertical length of the infinitesimal hexahedron $ABCDEF$ is dr , the axial length is dz , which means to $rd\theta$. So the volume of the infinitesimal before deforming is $rdrd\theta dz$, the volume of the gland after being stressed is:

$$(dr + \varepsilon_r dr)(rd\theta + \varepsilon_\theta rd\theta)(dz + \varepsilon_z dz)$$

So the volume strain of the infinitesimal hexahedron $ABCDEF$ is:

$$\begin{aligned} \theta &= \frac{V' - V}{V} = \frac{(dr + \varepsilon_r dr)(rd\theta + \varepsilon_\theta rd\theta)(dz + \varepsilon_z dz) - rdrd\theta dz}{rdrd\theta dz} \\ &= (1 + \varepsilon_r)(1 + \varepsilon_\theta)(1 + \varepsilon_z) - 1 \\ &= \varepsilon_r + \varepsilon_\theta + \varepsilon_z + \varepsilon_r \varepsilon_\theta + \varepsilon_r \varepsilon_\phi + \varepsilon_r \varepsilon_\phi \varepsilon_z \end{aligned} \quad (4)$$

See the $\varepsilon_r \varepsilon_\theta$, $\varepsilon_r \varepsilon_z$, $\varepsilon_\theta \varepsilon_z$, $\varepsilon_r \varepsilon_\theta \varepsilon_z$ as high order negligible in Formulas (1)-(4). Substitute (1), (2) and (3) into (4), and we can know the volume strain of the gland:

$$\theta = \varepsilon_r + \theta_\phi + \theta_z = \frac{dU_r}{dr} + \frac{U_r}{r} + \frac{dU_z}{dz} \quad (5)$$

In the stage of free deformation, the volume of the gland is invariant before and after the deformation, which means $\theta = 0$, then substitute into (5):

$$\theta = \varepsilon_r + \theta_\phi + \theta_z = 0, \quad (6)$$

$$\frac{dU_r}{dr} + \frac{U_r}{r} + \frac{dU_z}{dz} = 0 \quad (7)$$

Because U_z is the function of z , we can assume that $U_z = f(z)$, so the differential coefficient from U_z to z $\frac{dU_z}{dz}$ is a constant. Therefore, we can know that:

$$\frac{d}{dr} \left(\frac{dU_z}{dz} \right) = 0 \quad (8)$$

So,

$$\frac{d\theta}{dr} = \frac{d(\varepsilon_r + \varepsilon_\phi + \varepsilon_z)}{dr} = 0 \quad (9)$$

Substitute (9) into (5), we can know the vertical differential equation is that:

$$\frac{d^2 U_r}{dr^2} + \frac{1}{r} \frac{dU_r}{dr} - \frac{U_r}{r^2} = 0 \quad (10)$$

The above formula is the vertical displacement differential equation in the free deformation of the gland when the outside surface of the gland contacts with the inside surface of the pipe.

2. THE AXIAL POWER OF THE OUTSIDE SURFACE OF THE GLAND

Assume that the outside radius and the inside radius are r_{ri} and r_{ro} , the leak of the pipe's outside radius and inside radius are r_{ci} and r_{co} , the boundary condition of displacement in Formula (10):

$$\begin{cases} U_r |_{r=r_{ri}} = 0 \\ U_r |_{r=r_{ci}} = r_{ci} - r_{ro} \end{cases} \quad (11)$$

The explanation of Formula (10) the boundary condition of displacement in Formula (11) is:

$$U_r = \frac{(r_{ci} - r_{ro})r_{ci}}{r_{ci}^2 - r_{ri}^2} r - \frac{1}{r} \frac{(r_{ci} - r_{ro})r_{ci}r_{ri}}{r_{ci}^2 - r_{ri}^2} \quad (12)$$

So we can know the vertical strain of the gland:

$$\varepsilon_r = \frac{dU_r}{dr} = \frac{(r_{ci} - r_{ro})r_{ci}}{r_{ci}^2 - r_{ri}^2} r + \frac{1}{r^2} \frac{(r_{ci} - r_{ro})r_{ci}r_{ri}}{r_{ci}^2 - r_{ri}^2} \quad (13)$$

We can know the circular strain of the gland from Formula (12):

$$\varepsilon_\phi = \frac{U_r}{r} = \frac{(r_{ci} - r_{ro})r_{ci}}{r_{ci}^2 - r_{ri}^2} + \frac{1}{r^2} \frac{(r_{ci} - r_{ro})r_{ci}r_{ri}}{r_{ci}^2 - r_{ri}^2} \quad (14)$$

From Formulas (12), (13), (14), we can know:

$$\varepsilon_z = -(\varepsilon_\phi + \varepsilon_r) = -\frac{2(r_{ci} - r_{ro})r_{ci}}{r_{ci}^2 - r_{ri}^2} \quad (15)$$

The axial stress of the gland is:

$$\begin{aligned} \sigma_z &= -\frac{E}{(1-2\nu)(1+\mu)} \left[(1-\mu)\varepsilon_z + \mu(\varepsilon_r + \varepsilon_\phi) \right] \\ &= -2 \frac{Er_{ci}}{1+\mu} \left(\frac{r_{ci} - r_{ro}}{r_{ci}^2 - r_{ri}^2} \right) \end{aligned} \quad (16)$$

Among these, E —elasticity modulus of the material of the gland; μ —poisson ratio of the material of the gland, without unit; “minus” means axial stress is pressure.

So the axial power making the outside surface of the gland contact with the inside surface of the pipe is:

$$F_{RZ} = \int_{r_{ro}}^{r_{ci}} \sigma_z (2\pi r dr) = -2 \frac{Er_{ci}}{1+\mu} \frac{(r_{ci} - r_{ro})^2}{r_{ci}^2 - r_{ri}^2} (r_{ci} + r_{ro}) \quad (17)$$

3. THE CONTACT PRESSURE OF THE GLAND

After being stressed the outside surface contact with the inside surface of the leak of the pipe, the area of stressing is:

$$A = \pi(r_{ci}^2 - r_{ri}^2). \quad (18)$$

After finishing make-up, the contact pressure of the gland is:

$$P = \frac{F_{RZ}}{A} = \frac{F_{RZ}}{\pi(r_{ci}^2 - r_{ri}^2)} = -2 \frac{Er_{ci}}{1 + \mu} \frac{(r_{ci} - r_{ro})^2}{\pi(r_{ci}^2 - r_{ri}^2)} (r_{ci} + r_{ro}). \quad (19)$$

After finishing make-up, the distance of the end of the two pipes is $x = 1.5$ mm.

Assume the thickness of the gland is H , so:

$$H = x + L. \quad (20)$$

Among these, L is the axial variable:

$$L = \varepsilon_z H. \quad (21)$$

Simultaneous (15), (20), (21), we can know that:

$$H = \frac{x(r_{ci}^2 - r_{ri}^2)}{2r_{ci}r_{ro} - r_{ci}^2 - r_{ri}^2}. \quad (22)$$

4. OPTIMIZE THE SIZE OF THE GLAND

According to the various height of the gland, after finishing make-up its thickness is $x = 1.5$ mm, and at this moment the axial stress ε_z is:

$$\varepsilon_z = \frac{H - x}{H}. \quad (23)$$

According to the above formula, we can draw the relationship curve between the height of gland H and the axial stress ε_z :

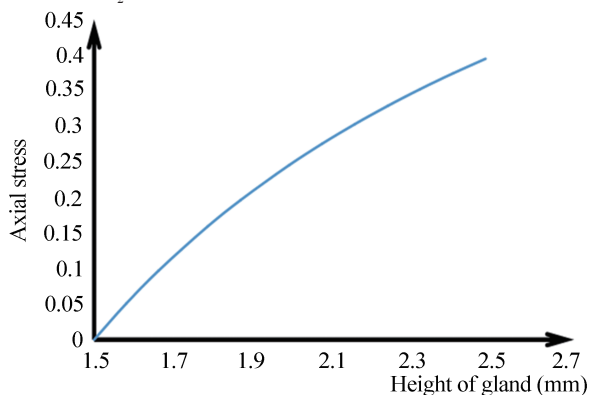


Figure 2
The Relationship Curve Between the Height of Gland H and the Axial Stress ε_z

Draw the relationship curve between the height of gland H and the axial stress ε_z has important significance, to prevent the elastic and plastic deformation or the plastic deformation occur on the gland, we should correct

on the different height glands. Zhang Yuguo^[8] conduct a compressed springback experiment on the material of PTFE, and draw a conclusion to the compressed stress-strain curve on PTFE. And when the axial stress $\varepsilon_z > 0.32$, the gland will occur the elastic deformation.

But from Figure 2, it is obviously that the axial stress ε_z cannot greater than 0.32. In the elastic range, the height of the gland the bigger the better, which means the outside radius the smaller the better, but when the outside radius r_{ro} is too smaller it will lead to the instability phenomenon. And it will most probably cause eccentricity in the process of the installing of the gland, which directly leads to the invalid of the gland. So the outside radius of the gland r_{ro} should greater than or equal to the free end of the outside radius of the pipe $R = 34.6$ mm.

So, to improve the sealing property of the gland, get the $r_{ro} = R = 34.6$ mm, substitute $r_{ro} = 34.6$ mm into (19) and (22), then obtain the height of the gland $H = 2.3$ mm, contact pressure $P = 98.4$ MPa. So, it is obvious that the contact pressure $P \gg$ the gas-injection pressure P_i .

CONCLUSION

(a) By means of the stress model of the gland in the free deformation stage, conclude that the contact pressure and the height of the gland have positive correlation. In the precondition of the compression of the distance of the two end of the pipes, the higher of the gland, the larger of the axial stress, and the larger of the contact pressure.

(b) We can get from the established the model: the height and the outside radius of the gland have certain negative correlation. When the outside of the gland equal to the inside radius of the leak of the pipe, the height of the gland is the distance of the two ends of the pipes after finishing make-up, and at this moment. the contact pressure is zero. In the allowed range, the smaller of the outside radius of the gland, the more thickness of the gland, the larger of the contact pressure, the better of the sealing property.

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