2. The structure and hardness of the nitrided layer of the core depends on the conditions of preliminary heat treatment and ion nitriding. The wear resistance of the layer does not vary in this case.

LITERATURE CITED


REDUCTION IN THE DEFORMATION OF CYLINDRICAL SHAPED ARTICLES DURING NITRIDING

I. S. Dukarevich

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The deformation of nitrided articles caused by a change in specific volume of the diffusion layer and formation of nitride phases is an integral process which accompanies hardening of articles by this method. The amount and nature of deformation depend on a considerable number of factors: article configuration and dimensions, the ratio of the nitrided layer thickness to the cross-sectional area, location of the nitrided layer on individual surfaces, nitriding and prior heat treatment technology, steel chemical composition, etc. [1, 2]. A number of methods have been developed in industry directed towards reducing deformation such as reduction in the area of the nitrided surfaces, introduction of allowances, stiffening an article cross section, symmetrical placing of the nitrided layer, development of rational prior heat treatment schedules and introduction of stabilizing tempering, etc. [1]. In each specific case an individual approach is required to developing a structure and the technology for preparing nitrided articles.

As a rule in nitriding articles of cylindrical shape used extensively in engineering (cylindrical sleeves, shrouds, rings, bushes) there are rigid specifications for the geometry of the inner working surface: the ellipse, cone waist, and barrel of finished articles are limited to micron tolerance. In order to provide these tolerances deformation after nitriding before finish machining should not be more than several hundredths of a millimeter since allowances do not exceed 0.05-0.10 mm; deeper removal of metal leads to a sharp reduction in surface hardness. Permissible values of deformation for cylindrical shaped articles are achieved by placing the nitrided layer only on the working surface (for example the surface of cylindrical sheaths), by an increase in the thickness of the cross section (allowance over the loaded surface), by rational alteration of thermal and mechanical treatment operations with the aim of the minimum redistribution of internal stresses on removing volumes of the metal. Here it is very important to include in the production cycle operations for preparing complex structural elements (holes, grooves, slots).

Uniformity of nitrided layer thickness has a considerable effect on the nature and amount of deformation for cylindrical articles. For articles of steel 38Kh2MYuA of comparatively simple shape with a height of 150 and diameter of 135 mm unstable and high ovality (0-0.5 mm with an ovality tolerance of not more than 0.08 mm) were obtained during nitriding, which appeared to be the result of nonuniform nitride layer thickness. A 'wave' 0.1-0.5 mm thick in the layer at the inner surface with a stable layer thickness (0.5 ± 0.05 mm) at the outer surface was established by macrostructural analysis. The reason for this phenomenon is presence of still zones within the article with adequate circulation of the gas atmosphere in the furnace. Introduction into the production process of phosphating before nitriding made it possible to stabilize the uniformity of inner surface impregnation.
Fig. 1. Effect of phosphating on nitrogen concentration in the diffusion layer on steel 40Kh: 1 (Δ) - without phosphating; 2 (×) - with phosphating

TABLE 1

<table>
<thead>
<tr>
<th>Position of tinned areas on the inner surface of a tube blank</th>
<th>Position of impressions</th>
<th>Position of measurements</th>
<th>h</th>
<th>Δh</th>
<th>St.s, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole surface</td>
<td>In any area</td>
<td>Top</td>
<td>14.86/14.84</td>
<td>11.38/11.31</td>
<td>-0.02/0.07</td>
</tr>
<tr>
<td>Without tinning</td>
<td>In any area</td>
<td>Top</td>
<td>13.61/13.41</td>
<td>12.20/12.75</td>
<td>+5.80/4.55</td>
</tr>
<tr>
<td>Three bands in two diametrically opposite areas</td>
<td>Opposite the central tinned band</td>
<td>Top</td>
<td>11.89/11.86</td>
<td>10.23/10.19</td>
<td>+2.97/3.96</td>
</tr>
<tr>
<td>Ditto</td>
<td>At an angle of 90° to the central tinned band</td>
<td>Top</td>
<td>11.85/11.83</td>
<td>10.62/10.96</td>
<td>+6.18/1.37</td>
</tr>
<tr>
<td>Bands uniformly over the whole circumference</td>
<td>Opposite any tinned band</td>
<td>Top</td>
<td>10.65/12.85</td>
<td>10.53/13.40</td>
<td>+2.20/2.45</td>
</tr>
</tbody>
</table>

Notation. h and Δh are distance between impressions and the change in it after slitting; St.s is area of tinned surface.

Note. In the numerator is the distance between impressions before slitting and in the denominator is the distance after slitting.

with a variation in layer thickness of 0.05 mm, which provided ovality within the required limits (≤0.08 mm) not only for these articles with a height of 150 mm, but also in articles of greater height (500 mm) of the same diameter.

However, in using phosphating it is necessary to consider its intensifying effect on impregnation with nitrogen as a result of activating the surface. As a result of using phosphating the thickness of the surface zone with a high nitrogen content (>5%) on nitrided steel 40Kh increased by a factor of two (see Fig. 1). An increase in nitrogen content leads to an increase in specific volume, which causes an increase in deformation. In view of this the phosphating operation, which is desirable to order to obtain a uniform layer thickness at the inner surface of cylindrical articles, is limited to short-term exposure, i.e., 10-15 min.

Particular attention is drawn to the deformation of cylindrical articles machined in making complex structural elements (holes, slots) after nitriding. In cutting slots at the ends before nitriding there is a reduction in stiffness of the end band, and bridges between slots are 'raised' outwards with an increase in diameter to 0.6 mm. Cutting a slot after nitriding also leads to deformation up to 0.3 mm as a result of internal residual stress redistribution. In addition, this operation is difficult due to the high hardness of the nitriding layer.

In order to obtain articles with an acceptable amount of deformation a study was made of the effect on it of "breaks" in the nitrided layer. Annular tube blanks with an outer diameter of 130 mm, a wall thickness of 15 mm, and a height of 50 mm made of steel 38Kh2-MYuA quenched (940°C, oil) and tempered (640°C, air) to a hardness of 302 HB were protected from nitriding over the outer surface and the ends by a layer of tin 10-12 μm thick. The