

### 3.3 Potential properties of the superficial layer

#### 3.3.2 Stereometric-physico-chemical parameters

1) **Emissivity** - constitutes the main parameter, characterizing the quality of the superficial layer as a thermal radiator

**Total emissivity**  $\epsilon_T$  describes what portion of radiant energy  $M$  is emitted by a unit surface, relative to a unit surface  $M_{bb}$  of a hypothetical blackbody in same temperature conditions.

**Monochromatic emissivity**  $\epsilon_\lambda$  describes the appropriate ratios of monochromatic radiant power densities of the tested body and blackbody at the same temperature for any chosen radiation wavelength

$$\epsilon_T = \frac{I_{\lambda, \text{obj}}}{I_{\lambda, \text{bb}}} \quad \epsilon_{\lambda 1} = \frac{m_{\lambda 1}}{m_{\lambda 1, \text{bb}}}; \quad \epsilon_{\lambda 2} = \frac{m_{\lambda 2}}{m_{\lambda 2, \text{bb}}}; \quad \epsilon_{\lambda n} = \frac{m_{\lambda n}}{m_{\lambda n, \text{bb}}}$$

For the case where the character of the unevenness profile can be simplified to a series of wedge-shaped 楔形的, V形的 cavities, the cavities as shown on the profile plot are represented by **triangular-shaped teeth**, regardless of the direction in which the profile is measured. The value determined is the mean emissivity of the cavity material, can be expressed by the formula:

$$\epsilon_{T(n)} = \epsilon_{T(nR)} \frac{W}{1+(W-1)\epsilon_{T(nR)}}; \quad W = \frac{n_{w(n)}}{n_{w(nR)}}$$

- where  $W$  - relative cavity, expressed by the formula
- where:  $n_{w(n)}$  - cavity at temperature  $t$ ;  $n_{w(nR)}$  - initial cavity
- also  $n_w = \sqrt{1 + 4\left(\frac{R}{S}\right)^2}$
- where:  $R_c$  - height of unevenness;  $S$  - surface roughness spacing.

### 3.3 Potential properties of the superficial layer

#### 3.3.3 Physico-chemical parameters

The most important physico-chemical property is the solid **microstructure** on which other properties of the superficial layer depend. These are

- mechanical (hardness, plasticity, residual stresses, fatigue strength, wear resistance),
- chemical (absorption, chemisorption, resistance to chemical corrosion),
- electrochemical (resistance to electrochemical corrosion),
- thermo-physical (conductivity, expansion, physiosorption, adhesion 粘着),
- electrical (resistivity, conductivity),
- magnetic (coercion, permeability 磁导率)

$$\epsilon = F \{ \varphi(m), f [ \epsilon_\sigma, \tau_\sigma, t_m, v_p, \xi (u, p, h) ], \psi(n) \}$$

where:

$m$  - parameter dependent on the type of material,;

$t_\sigma$  - oxidation temperature,

$\tau_\sigma$  - oxidation time,

$t_m$  - temperature at which emissivity is measured,

$v_p$  - rate of temperature change,

$u$  - environment in which the temperature corrosion process (scaling) takes place;

$p$  - pressure of corrosive environment,

$h$  - humidity of corrosive environment at service or ambient temperature;

$n$  - parameter taking into account unevenness(roughness) of the radiating surface.

From among the nine variables, the biggest effect on emissivity is exhibited by:

- surface roughness, to a lesser degree surface flaws and to a minute degree waviness,
- physico-chemical condition of the emitting material (non-oxidized material, material covered by a film of oxides or other chemical compounds)

### 3.3 Potential properties of the superficial layer

Generally, the emissivity of the superficial layer of every material increases

with a rise of the unevenness of the surface,

the degree of corrosiveness of the environment (e.g., a rise of its humidity)

and the degree of corrosion (most often the degree of oxidation).

All of these factors intensify with a rise of temperature.

- Greatest emissivity is exhibited by surfaces which are rough, matte(不光滑的), dark, oxidized and corroded.
- 2) Reflectivity ( $R$ ) - depends on the same parameters as emissivity.
  - Since for non-transparent bodies,  $\epsilon_T + R = 1$
  - Highest reflectivity for heat radiation is exhibited by surfaces which are smooth (polished), shiny and bright.

### 3.3 Potential properties of the superficial layer

#### 3.3.3 Physico-chemical parameters

(1) Hardness

The basic property of all solids, by which the solid offers resistance to plastic deformation or cracking破裂.

In a narrowed-down sense, it is the resistance of the material to plastic deformation by concentrated forces, acting on a small surface area.

Usually, the higher the stress loading to which the part is subjected, the higher should be the hardness of the surface.

#### Example:

**The relation of the emissivity of the metal to the roughness**  
The total emissivity of the metallic material, working in an atmosphere composed of air, is expressed by

$$\epsilon_T = \epsilon_{T(m)} + \Delta \epsilon_T$$

where:  $\epsilon_{T(m)}$  is the initial emissivity of the non-oxidized material, dependent only on the type of emitting material and its smoothness;  $\Delta \epsilon_T$  - is the increment of emissivity, resultant from surface oxidation and surface unevenness.

$$\Delta \epsilon_T = \epsilon_{T(n)} + \epsilon_{T(m)}$$

where:  $\epsilon_{T(n)}$  is the rise in emissivity, stemming from the rise in surface unevenness, being the result of oxidation;

$\epsilon_{T(m)}$  is the rise in emissivity stemming from the change in chemical and phase composition of the emitting material (metal - metal oxides)

### 3.3 Potential properties of the superficial layer

#### 3.3.3 Physico-chemical parameters

Physico-chemical properties of the superficial layer vary from one zone to the next within the superficial layer.

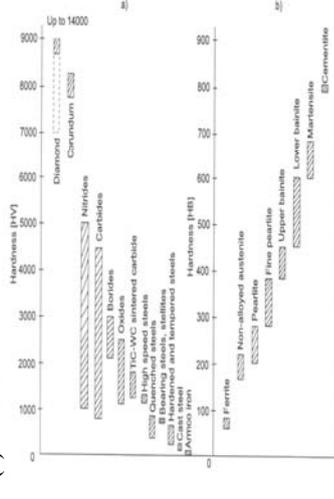
The existence, location and thickness of these zones are the resultant of core material properties and extraneous effects.

They are, therefore, strongly dependent on the type of treatment operation but independent only to a minor degree on surface geometry.

### 3.3 Potential properties of the superficial layer

#### 3.3.3 Physico-chemical parameters

(1) Hardness



### 3.3 Potential properties of the superficial layer

#### 3.3.3 Physico-chemical parameters

##### (1) Hardness

Hardness (microhardness) is one of the most basic, universally accepted properties of materials, easily measured by various methods, and connected with many other properties of the superficial layer.

Hardness depends on the type of material and its structure which, in turn, depends on treatment, especially strain-hardening (加工硬化), and thermochemical treatment.

The microhardness of superficial layer zones may change during service, especially during wear, as the result of microstructural changes.

The hardness of crystalline bodies depends on the limit of elasticity under compressive loading and on the modulus of elasticity.

### 3.3 Potential properties of the superficial layer

#### 3.3.3 Physico-chemical parameters

##### (3) Residual stresses

In all materials subjected to extraneous effects, there occur non-uniform volume changes, both reversible and irreversible, causing the formation of stresses.

Stresses describe the state of internal forces and moments of forces, brought about by the interaction, in a given locality, of two parts of the material, situated on either side of an apparent crosssection.

After the removal of external effects, reversible changes (elastic deformations) undergo atrophy. However, some irreversible changes (plastic deformation) remain in the material, along with stresses caused by them which are referred to as residual stresses

#### 3.3.3 Physico-chemical parameters

##### (3) Residual stresses

Residual stresses are characterized by their sign ("+" compressive and "-" tensile), their value, distribution, gradient and depth of penetration.

In the superficial layer there exist three kinds of residual stresses; they are manifest predominantly as macrostresses.

Micro and submicrostresses affect the limit of elasticity of the material but have only a small influence on its strength.

Factors causing the formation of residual stresses:

- mechanical,
- thermal,
- structural

### 3.3 Potential properties of the superficial layer

#### 3.3.3 Physico-chemical parameters

##### (2) Brittleness

is a material property, consisting of permanent partition of material under the influence of internal or external forces.

Usually, brittleness occurs in solids within certain temperature ranges. Metals may exhibit different types of brittleness, e.g., cold shortness, hot shortness, hydrogen(oxygen) embrittlement, etc.

In the case of superficial layers and coatings, brittleness is an undesirable effect.

Often, although not always, brittleness is connected with

hardness: the higher the hardness, the greater the brittleness of the layer.

#### 3.3.3 Physico-chemical parameters

##### (3) Residual stresses

###### Type of the residual stress

According to the classification by N.N. Davidenkov

- stresses of the 1<sup>st</sup> kind, termed macrostresses (body stresses), caused by the mutual interaction of macroscopic-size zones of the material. Macro stresses are caused directly by non-uniform plastic deformation, temperature changes, changes in the material structure or a combination of the above.

They may be regarded as the result of the total average interaction of microstresses, assuming homogeneity of the material microstructure, i.e. isotropic properties: 各向同性.

These stresses cause changes of dimensions, deformation or cracking of the object or its superficial layer.

##### (3) Residual stresses

General functional expression.  $\sigma_{ij} = f(m, t, k, o)$

where:  $m = f_i(c, w, f, ch, s)$  - is the function of the primary material (core; superficial layer, coating), described mainly by its properties:  $c$  - thermal (especially: thermal conductivity, thermal expansion, specific heat);  $w$  - mechanical (especially strength: Young's modulus, Poisson ratio);  $f$  - physical (e.g., ion implantation);  $ch$  - chemical (especially: chemical composition, formation of chemical compounds of diffusing atoms with substrate atoms);  $s$  - structural (especially: roughness and valley bottom radius) and metallographic 金相学 (especially grain type, size and orientation, defects);

$t$  - technology of formation of superficial layer or coating (type, number, sequence and parameters of treatment operations; temperature, temperature variation rate, temperature gradient, pressure, loading, feed rate, energy, element concentration, etc.);

$k$  - shape and size of component 成分 in which residual stresses are measured;

$o$  - interaction of core with superficial layer or coating

### 3.3 Potential properties of the superficial layer

#### 3.3.3 Physico-chemical parameters

##### (2) Brittleness- Ductility

A property opposite to brittleness is ductility - the susceptibility of metals to permanent plastic deformation without the formation of cracks.

Ductility is one of the basic characteristics of the metallic state. Often the term "ductility" is used as a synonym of plasticity but it means a qualitative(定性的) , non-measurable characteristic, strongly dependent on structure, processes occurring at the atomic level and on the type of slip .

##### (3) Residual stresses

- stresses of the II<sup>nd</sup> kind, termed microstresses, formed as the result of non-homogeneity of metallic structure, consisting of grains and grain blocks.

Microstresses are formed between separate components of the microstructure and act upon various microstructure elements which already are subjected to different microstresses. Their chief source is different crystal orientation and the associated anisotropy 各向异性 of elastic and plastic properties of the various crystals.

-microstresses of the III<sup>rd</sup> kind, termed submicrostresses . They are treated as stresses of the material's crystal lattice, especially in zones with defects.

In such zones the proper structure is disrupted by the occurrence of own or foreign atoms in improper interstitial and nodal sites 替位点 or the existence of voids 空位.

#### 3.3.3 Physico-chemical parameters

##### (3) Residual stresses

In the absolute sense, a given value of residual stresses when all other parameters are equal depends heavily on the method of measurement. Numerical values of residual stresses, obtained by different measurement methods, may differ.

Residual stresses in a superficial layer directly affect the layer's cohesion , but their action may also be of an indirect nature - by forcing the migration of atoms with small diameters through the crystal lattice of the host material. Less than 原子扩散和温度引起的高温 concentration and heat diffusion.

However, local stresses may cause migrations of interstitial 空位 atoms to sites preferred by geometry or thermodynamics (vacancy clusters, dislocation lines, grain boundaries and stacking faults).

### 3.3 Potential properties of the superficial layer

#### 3.3.3 Physico-chemical parameters

##### (3) Residual stresses

Generally, with a rise in the strength of the mechanically strain-hardened material and in the strain-hardening parameters (mainly, the loading force), residual stresses in the superficial layer increase.

Their value, depth of penetration and character of distribution may all be controlled by treatment operation parameters.

In almost all cases the formation of compressive stresses in the superficial layer causes a rise of fatigue strength (with tensile stresses the effect is opposite) and hardness, wear resistance and corrosion resistance.

### 3.3 Potential properties of the superficial layer

#### 3.3.3 Physico-chemical parameters

##### (5) Adsorption

is the process of attraction of substances (gases, vapors, solids in solution, ions and liquids) and their collection at the surface of solids and liquids, at the interface between solid and gas or liquid and gas.

Adsorption is manifest in changes of concentration of a substance in the boundary layer between two neighboring phases and depends both on the properties of the adsorbing body (adsorbent/吸附剂), as well as the adsorbed body (adsorbate).

Greater adsorption is exhibited by bodies with a developed surface (e.g., rough and porous) than by bodies with smooth surfaces.

### 3.3 Potential properties of the superficial layer

#### 3.3.3 Physico-chemical parameters

##### (5) Adsorption

Adsorption at the surface of crystalline substances usually lowers their strength properties.

Adsorption is utilized in processes of machining, by the introduction of adsorbable/能吸附的 components to lubricants and coolants; in service, by using lubricants containing adsorbable components for machine lubrication in order to prevent dry friction;

AL<sub>2</sub>O<sub>3</sub> in thermo-chemical processes and in plating metal substrates

#### 3.3.3 Physico-chemical parameters

##### (3) Residual stresses

The value and distribution affect strength properties, especially fatigue strength, resistance to dynamic loading and to brittle cracking, as well as tribological properties, especially contact fatigue.

A particularly significant effect of residual stresses on mechanical properties, especially fatigue, is revealed in the case of superficial layers containing technological or structural flaws, surrounded by stress concentrations.

Residual stresses may be caused by treatment operations or service (e.g. through friction). In the first case, treatment or technological residual stresses are formed, while in the latter, service residual stresses. Service conditions may cause the relaxation and redistribution of technological residual stresses.

### 3.3 Potential properties of the superficial layer

#### 3.3.3 Physico-chemical parameters

##### (5) Adsorption (type)

Physical adsorption (also termed: molecular, surface, specific or physisorption) consists of densification/增密作用 of a substance at the surface of the adsorbent under the influence of intermolecular forces of attraction, so-called Vander Waals forces.

Condensation adsorption (also called capillary) consists of such a high densification of gases and vapors of the adsorbent that after covering the surface with a monomolecular layer they undergo condensation to the liquid state. This type of adsorption takes a somewhat longer time than the physical, it is partially reversible. The desorption curve differs from that of adsorption (this is the so-called sorption hysteresis).

Chemical adsorption (chemisorption) is also often called activated adsorption because it calls for a much higher activation energy than physical adsorption and is of the order of 20 to 80 kJ/mole.

### 3.3 Potential properties of the superficial layer

#### 3.3.3 Physico-chemical parameters

##### (6) Solubility/溶解度

The ability of a substance in the solid, liquid or gaseous state to form, together with other substances, mixtures which are homogenous from a physical and chemical point of view.

At a given temperature and under a given pressure, solubility depends on the state of aggregation of the dissolved substance and of the solvent.

Physical solubility consists of the formation of interstitial/间隙式 solutions

Chemical solubility means the formation of a special type of chemical compounds.

#### 3.3.3 Physico-chemical parameters

##### (4) Adsorption

A physico-chemical process of permeation/渗透 of mass, consisting of the taking up of a constituent, usually a gas mixture called absorbate, by a liquid or a solid (called adsorbent) and uniform dissolution of the former in the entire mass of the latter.

The effect of absorption is widely used in the chemical and related industries in order to separate a harmful or a valuable component out of a gas mixture or to combine the gas with an absorbent to obtain a compound, an extraction/提取 of a substance dissolved in a liquid, etc.

In surface engineering, absorption of gases by solids is utilized chiefly in order to saturate the superficial layer by the diffusing element. The course of absorption is, in this case, dependent on the difference of chemical potentials in solids and the surrounding environment.

Absorption also plays an important role in tribology

### 3.3 Potential properties of the superficial layer

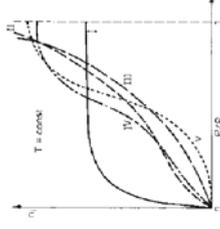
#### 3.3.3 Physico-chemical parameters

##### (5) Adsorption

Types of adsorption isotherms of gases and vapors, according to Brunauer;

$n_i$  - total amount of adsorbed substance i;

$p$  - pressure;  $p_0$  - pressure of saturated gas.



Type I - typical curve for chemical adsorption, less frequent for physical adsorption;

Types II to V - various curves for physical adsorption; the most frequent is type II, least frequent - type V

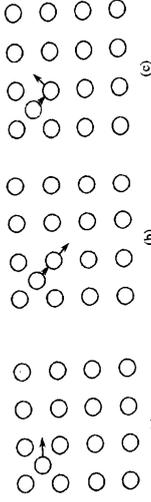
### 3.3 Potential properties of the superficial layer

#### 3.3.3 Physico-chemical parameters

##### (7) Diffusion

###### basic diffusion mechanisms (crystal) :

– **interstitial**- occurring mainly in interstitial solutions, when, by means of jumps, atoms smaller than those of the matrix move from one interstitial (interatomic) void to the next. Such voids occur always, even in lattices with closest packing and their size depends on the type of lattice.

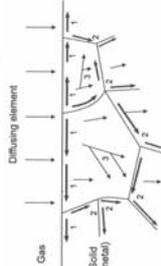


Direct interstitial diffusion (a) small lattice deformation, Indirect interstitial diffusion (b), (c) large lattice deformation

– **diffusion along interfaces (surface diffusion)** - occurring with high intensity both across interfaces between the solid phase and gas or liquid, as well as inside multi-phase bodies.

Boundaries between phases are structurally defective areas, thus they constitute paths of easy diffusion.

Effects of diffusion along interface boundaries depend on surface tension between the particular phases: when tension values are close there is a tendency to form globular phase particles; when a new phase with a lower surface tension than that of already existent phases is created, due to diffusion, there is a tendency to penetrate the new phase along interphase boundaries of the primary phases



- 1 - easiest diffusion - along surface;
- 2 - more difficult diffusion - along grain boundaries;
- 3 - most difficult diffusion - across grains (inside grains)

### 3.3 Potential properties of the superficial layer

#### © 1.3.3 Physico-chemical parameters

- (9) Catalysis
  - Depending on the physical state of the catalyst, we distinguish the following types of catalyses:
    - **homogenous and heterogeneous**
    - **heterogeneous**
  - The reaction of heterogeneous catalysis comprises five stages: diffusion of substrates to the catalyst, adsorption, chemical transformations at the surface, desorption, and diffusion of reaction products from the catalyst surface.
  - **heterogeneous catalytic activity is influenced by the size and character of the surface, chemical composition of superficial layer, its structure, inclusions of foreign substances**, in short, all those factors which affect the energy of the superficial layer.

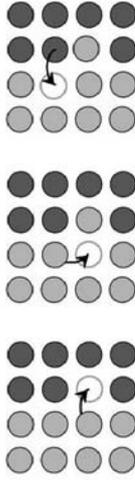
### 3.3 Potential properties of the superficial layer

#### 3.3.3 Physico-chemical parameters

##### (7) Diffusion

###### basic diffusion mechanisms (crystal) :

– **vacancy** - 指以空位为媒介而进行的扩散, occurring mainly in substitution-type solutions, when the displacement of atoms takes place by way of vacancies, i.e. point defects of the lattice, created by the absence of an atom in a lattice node.



### 3.3 Potential properties of the superficial layer

#### 3.3.3 Physico-chemical parameters

##### (7) Diffusion

In all cases, a rise of temperature significantly intensifies diffusion processes and extension of time causes an increase in the amount of the diffused element.

**Intensification** of diffusion is also aided by the existence of residual stresses and, to a lesser extent, by electric and magnetic fields. In all cases, of capital importance are element concentration and chemical potential.

In surface engineering, the most important role is that played by the diffusion of particles of gases and metals or non-metals into metal alloys, resulting in the formation of chromized, borided, silicized, sulfurized and other layers (including combinations).

### 3.3 Potential properties of the superficial layer

#### 3.3.3 Physico-chemical parameters

##### (9) Catalysis

The condition for a catalytic reaction of particles at the metal surface is their prior chemisorption.

Metals according to their tendency to chemisorption

Metals	N <sub>2</sub>	CO <sub>2</sub>	H <sub>2</sub>	CO	C <sub>2</sub> H <sub>4</sub>	O <sub>2</sub>
Ti, Zr, Hf, V, Nb, Ta, Cr, Mo, W, Fe, Ru, Os, Ni, Co	+	+	+	+	+	+
Rh, Pd, Pt, Ir, Mo			+	+	+	+
Al, Cu				+	+	+
Li, Na, K					+	+
Mg, Ag, Zn, Cd, In, Sn, Pb, Bi, Sb, Sn						+

Besides basic diffusion mechanisms, in specific conditions, especially in the case where a tendency exists to form intermetallic compounds or specific lattice defects (dislocations), special mechanisms may occur – **reactive diffusion** - consisting of the formation, at phase boundaries in the matrix, as the result of reaction between the guest element and the matrix or precipitations and the formation of new phases with different lattice structures

– **dislocation diffusion** (diffusion through dislocations) - occurring in the case of linear defects in crystals, which constitute passages of easy diffusion at lower temperatures.

Diffusion is facilitated more by edge-type than by screw-type dislocations.

Dislocation diffusion plays a significant role in thermo-mechanical burnishing 抛光, 抛光, 抛光 where plastic deformations raise the density of dislocations. Heating causes them to atrophy 萎缩, 衰退 but aids diffusion (recrystallization, homogenization and recovery occur)

### 3.3 Potential properties of the superficial layer

#### © 1.3.3 Physico-chemical parameters

##### 8) Adhesion

is a phenomenon of permanent and strong joining of superficial layers of two different (solid or liquid) bodies (phases) brought into mutual contact.

A specific case of adhesion is cohesion (凝聚力) which occurs when the bodies in contact are of the same material

In the case of strong adhesion of solids, with time and due to diffusion, there comes about a progressively stronger bond. This so-called “intergrowth 共生” or “in-growth” may lead to an atrophy of the interface as the result of an unlimited solubility in the solid state, i.e., the transformation of two joined phases into a single phase. This process occurs mainly in the adhesion of same materials

### 3.4 Practically usable properties of superficial layer

#### © 3.4.1 Strength properties--fatigue

##### 1) The formation of fatigue fracture

- A fatigue fracture develops gradually.
- As the number of changes of loading increases, successively, there come about local plastic deformation in particular grains, formation of slip bands, division of grains into blocks and submicroscopic fissures.
- Local micro cracks propagate and join up with one another. The process of cracking is initiated in a site of strong concentration of stresses.
- Next, the crack develops gradually up to the moment when the remaining portion of the cross-section becomes too weak to support the load and suffers catastrophic decohesion 脆性破坏.

### 3.4.2 Tribological properties

#### 1) Types of friction

- Friction is a physical phenomenon, always involving mutual displacement of particles of matter in different states of aggregation. It may be termed:
  - external, when it involves the relative displacement of surfaces of two solids in contact with each other. This type of friction is characterized by mutual interaction of bodies on their touching surfaces, manifest by resistance to relative displacement in a direction tangent to the surface of contact;
  - internal, when it involves the relative displacement of particles of the same body: of a liquid separating the surfaces of solids (e.g., in fluid friction) or particles of a solid (e.g., in deformation).

### 3.4.2 Tribological properties

#### 1) Types of friction

From the point of view of the presence of a lubricant between rubbing surfaces, the following types of kinetic friction may be distinguished

- physically dry friction** - when no other bodies (solid, liquid or gaseous) are present between the rubbing surfaces while the rubbing surfaces themselves are not coated by any adsorbed chemical compounds; in practice, this type of friction occurs extremely seldom in vacuum;
- technically dry friction** - when the rubbing surfaces may be coated with oxides and layers of adsorbed gases or vapors. Presently, science accepts a dualistic character of the origin of friction forces, based on Kragelski's molecular-mechanical theory, according to which the total force of dry friction  $T = T_{adhesion} + T_{cohesion}$

where:  $T_{adhesion}$  - component of friction force, originating from the overcoming of adhesion forces 粘附力 which are caused by molecular interaction in the contact zone;  $T_{cohesion}$  - component of friction force, originating from the overcoming of cohesion forces 聚力, caused by elastic and plastic mechanical deformation

### 3.4.3 Anti-corrosion properties

#### The relation of anti-corrosion property to the superficial layer

- (1) The chemical composition of the superficial layer has a decisive influence on the extent of corrosion.
- (2) Surface roughness significantly affects corrosion resistance. The lower the roughness, the higher the resistance.
- (3) The structure of the superficial layer also affects the extent of corrosion
- (4) Deformation disturbs the crystalline structure, favor the susceptibility of alloys to corrosion.
- (5) Compressive residual stresses do not exhibit a detrimental effect and even slightly improve corrosion resistance of metal alloys. Tensile residual stresses cause a deterioration of corrosion resistance

- 2) Effect of properties of superficial layer on fatigue strength
- the increase of the hardness, significantly improve fatigue properties.
  - the highest improvement of fatigue strength may be achieved through an increase in surface smoothness, and the decrease in surface roughness and flaws

– a lesser degree of improvement of fatigue strength, 40 to 45% on an average, is achieved by changes in the chemical composition of the superficial layer (diffusion alloying with carbon, nitrogen, chromium, boron, etc. or their combinations)

Residual stresses have a significant effect on fatigue strength. These stresses superimpose themselves (i.e., add algebraically) on those stemming from external loading and cause either a rise or a drop of the fatigue limit of an object, depending on whether the net result will be an increase or decrease of the sum total of stresses at concentration sites

Corrosive environments such as moist air, tap water, sea water, and electrolyte solutions all lower fatigue strength.

### 3.4.2 Tribological properties

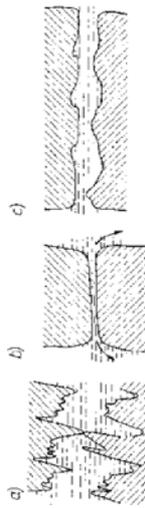
#### 1) Types of friction

- Depending on the relative velocity of rubbing materials, friction may be divided thus:
  - static - this is the friction between two bodies in mutual contact which do not change their relative positions, expressing a force which must be overcome to initiate relative movement of these bodies;
  - kinetic - this is the friction between two bodies in relative movement, expressing force which must be overcome to maintain the movement of these bodies

### 3.4.2 Tribological properties

#### 2) The relation of friction and wear to the superficial layer

- (1) Roughness
  - a) excessively high roughness;
  - b) excessively low roughness;
  - c) optimum roughness

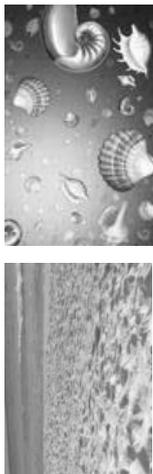


(2) Hardness significantly affects. Particularly good tribological wear resistance is exhibited by superficial layers obtained by heat and thermo-chemical treatment.

- (3) Residual stresses in the superficial layer affect tribological properties only slightly. Usually compressive stresses increase resistance to abrasive wear.

- Destruction of material as a result of fatigue exhibits a different character than the one caused by static loading and occurs without major plastic deformations.

- On the fracture surface thus formed, which in the macroscopic scale bears the character of a brittle fracture, it is clearly possible to distinguish the fatigue zones of the developing fracture. It has a characteristic, so-called "beachmark" or "seashell" appearance



### 3.4.2 Tribological properties

#### 1) Types of friction

- From the point of view of wear intensity, friction may be divided as below:
  - wear, occurring in the majority of practical cases, associated with a smaller or greater degree of destruction of the rubbing surfaces, accompanied by high intensity of wear;
  - non-wear, occurring only in special conditions and associated with the spontaneous constitution, during service, of new rubbing surfaces, as the result of so-called selective translocation of soft material. In these cases the intensity of wear is several orders of magnitude smaller than in wear type friction.

### 3.4.2 Tribological properties

#### 1) Types of friction

- boundary friction - when the rubbing surfaces of both bodies are separated in the contact zone by the so-called boundary layer, formed by components of the lubricating substance (lubricant).

A boundary layer is formed due to adsorption and chemisorption of particles of active substances, their densification 增稠 and ordering 排序 of polarization under the influence of the surface's electrical field, leading to a rise in density and viscosity of the substance in the surface zone

- fluid friction - when between the surfaces of rubbing bodies there is a continuous, unbroken layer of liquid or gaseous substance, under pressure which balances out 相抵, 平衡 forces of normal load pressure from both bodies to such an extent that surface asperities do not come into mutual contact.

- mixed friction - which is an intermediate case between dry and fluid friction.