The results of numerous studies show that surfaces treated by different methods deviate from the specified shape and degree of roughness, regardless of the manufacturing technology employed. These errors have a significant effect on the wear of the contact surfaces of parts that comprise friction couples. Thus, they also have a significant effect on the durability of machines in general. The actual area of contact of surfaces depends mainly on their microscopic and macroscopic geometry and the loads applied to them. To a large extent, the wear that the surfaces of parts undergo is caused by the cutting of microscopic scalp shaped projections that remain on the surface after the treatment. The quantitative values obtained to characterize wear are a reflection of a volumetric change in the surfaces of parts. The results of the studies in [1] show that metallic surfaces have roughness at the atomic level and that their highest protuberances are the parts of the roughness that make contact with other surfaces. For metals in air at room temperature, those protuberances may be dust particles. Dust particles can take up most or all of the loads on the surface when those loads are small.

An examination of parts that had been machined established that small particles of the material of the tool are almost always transferred to the surface of the workpiece and can result in its intensive scratching. This creates additional sources of stress concentration, which leads to intensive wear and corrosion. For example, when the surface of a part is machined by abrasive methods (grinding, honing, lapping, treatment with a free abrasive, etc.), abrasive particles stick to the surface and abrade it, creating a friction couple together with the surface. Thus, one prerequisite in choosing parts that are to be part of friction couples is to also choose the proper type of treatment for the contacting surfaces. Abrasive machining is often the only type of treatment that will produce the required surface quality and dimensional accuracy. However, the phenomena described above apply to machining done with a metallic tool as well as to abrasive machining, since material from the cutting tool is transferred to the surface of the workpiece and adversely affects its wear resistance. Thus, it is necessary to consider not only the amount of material that is transferred, but also the character of its distribution on the surface of the part being machined. As shafts or bushings move relative to one another, some abrasive particles become stuck to their surfaces. Friction increases, while wear decreases somewhat. After a stable state has been reached, wear takes place mainly due to cutting of the metal. Here, part of the load is taken up by the abrasive particles, which results in the formation of channels on the friction surfaces. The degree of wear amounts to roughly 8–12% of the volume of the channels.

A similar effect is seen during the operation of oil-field equipment, except that the phenomenon occurs within relatively large volumes. Wear is intensified because the abrasive particles that accompany the petroleum products fall into the gap between the plunger and the bushing (Fig. 1) of the equipment.

Thus, in order to obtain the required service life from machines and mechanisms, it is necessary to choose the appropriate methods for treatment of the surfaces of the parts that comprise friction couples and to combine those methods in an optimum manner that ensures a high degree of surface quality and dimensional accuracy and minimizes the size of the gap between the parts of joints.

The results of numerous studies have proven that it is impossible to obtain a wear-resistant surface layer by using just one method of treatment (however progressive and effective that method might be). It has been established that worn surfaces treated by different methods used in different sequences differ significantly from one another (Fig. 2). However, microscopic
cutting is not always the predominant mechanism of wear during friction (it is so only at low slip speeds), and plastic deformation does not always take place. Conversely, at high slip speeds, the surface layer is softened due to plastic flow of the metal, and the character of wear of the surface of the given part depends on the laws that govern its occurrence. Whereas the surfaces of parts are characterized by abrasive-mechanical wear in the first case, adhesional-phase wear predominates in the second case. On the whole, the rate and character of wear of a surface layer are very complex issues. Here, the most important factor is the condition of the surface layer of the part – the roughness and the shape error produced by the treatment given the part. By controlling the manufacturing operations used, it is possible to obtain the necessary microroughness – a microroughness that increases the oil capacity and load-bearing area of the surface. The optimum combination of manufacturing operations makes it possible to form the main accuracy parameters of surfaces during the preliminary operations and form accuracy and quality indices during the final operations.

Experience in the use of oil-field equipment shows that the micro-geometry of the surfaces of parts and their accuracy are the main indices that characterize the durability of a friction couple. These two factors determine the service characteristics of the equipment: the thickness of the oil film, the gap between plunger and the cylinder, hydraulic resistance, etc.

As is known, the quality indices of a surface change from processing indices to service indices during the run-in period. The largest protuberances are evened out, and the shape errors of the surfaces change somewhat during this period. The condition of the surfaces of parts after run-in differs appreciably from the condition which exists during machining.

If the indices characterizing the condition of a surface layer after machining were to correspond to the indices after the run-in period, it would be possible to shorten that period, increase the wear resistance of the layer, and thus significantly increase the durability of the corresponding friction couple.

The study results not only validate this proposition, but they can – if the parameters of the manufacturing operations have been optimized and the operations have been efficiently combined with one another – significantly improve the wear resistance of the surfaces of parts and predict the wear-resistance characteristics (capabilities) of parts made by combining the manufacturing operations in different ways.

It is known that wear changes the micro-geometry of contacting surfaces and results in the formation of an equilibrium roughness. That roughness depends on the specific service conditions of the rubbing parts. According to [2], when equi-

Fig. 1. Condition of the outside (a) and inside (b) surfaces of parts after their use in an abrasive medium.

Fig. 2. Wear of the surfaces after the use of parts of a deep-well insert pump: a) plunger; b) bushing.