The development of tool materials and methods of hardening of them is normally done in a certain sequence [1]. Depending upon the type of tool, the parameters of optimization are specified, the optimum structure of the material providing the necessary physicomехanical properties for obtaining the highest level of the selected optimization parameter is established, the optimum composition or method of hardening is selected, and based on the service parameters the areas of rational use of the material are designated.

In modern machine building production tool life most frequently controls the effectiveness of a metal working operation. Therefore a detailed study of failures becomes a necessary link in the development of tool materials. This makes it possible to come close to one of the pressing problems of metallurgy, the formation of materials with specified properties. This fact changes the very approach to the problem of development of tool materials.

The investigation of failures includes two stages. The first stage includes the analysis of service damages and the second stage, resulting from the first and based on its data, is the laboratory study of the failures. The result of such investigations is the creation of models making it possible to reliably determine the parameters characterizing tool life. Knowing these parameters it is possible to switch to a structure of the materials which may provide the required level of them and from it to selection of the optimum composition or methods of hardening. It is basically important that the primary consideration is the properties (that is, the parameters controlling tile) and they, in turn, propose obtaining of a specific structural condition. The material created in this manner (production operation) has an especially differentiated designation by purpose.

As an example we will give the results of investigations devoted to the problem of decreasing the spalling (that is, failure) of the working edges of punching dies of Kh12M steel. This form of failure of punching dies quite frequently encountered in practice causes very low life, on the order of $10^4$ and in some cases $10^5$ load cycles, with an average life of the dies losing effectiveness for wear on the order of $10^5-10^6$ load cycles. At the same time it is necessary to differentiate spalls caused by organizational and technical reasons (low accuracy and rigidity of the press or of the die itself, negligence of the set-up man or the punch operator, etc.) and systematic spalls caused by production factors. An analysis of service failures and statistical investigations of the life of production dies made it possible to establish that a systematic spall normally sets in after a certain number of load cycles and is related to the production parameters of the stamping process, particularly to such as geometry of the contour being punched and mechanical properties of the piece being punched. This provided a basis for proposing the fatigue nature of spalling. Spalling is characteristic of dies with significant stress raisers. Systematic spalling is observed with a certain combination of geometric parameters of the part being punched [2]. For dies subjected to spalling the moment of the start of failure is controlled by the tensile strength of the sheet being punched. A stronger material spalls with a smaller number of load cycles.

Spalling of the most heavily loaded element of the die, the cutting punches, was studied on models. On a test stand (die) completely imitating service conditions parts were punched with a hole in the form of an equilateral triangle. To create extremely rigid service conditions the punch of high-strength troostitic (σt = 1660 MPa) U8A steel [3] was prepared with minimum production gaps. The condition of the surface of the edge of the punches after $10^4$ load cycles was studied on an S4-10 scanning electron microscope. The intensity was evaluated quantitatively from the amount (dimensions) of spalling of the working edge of the punch.

It was established that spalling of the working edge is caused by low-cycle fatigue. This is confirmed by:

- Intense plastic deformation of the working edge itself. On some portions even slip bands may be distinguished (Fig. 1a). Plastic deformation is especially developed in the zone of stress concentration (Fig. 2b);
Fig. 1. Scanogram of the origin of failure of the edge of a punch: a) slip bands at the origin of failure (3000 ×); b) general view (850 ×).

Fig. 2. Kinetics of spalling of punches (1200 ×): a) original condition; b) after 3000 loadings; c) after 5000 loadings.

Fig. 3. Scanogram of an area of fatigue on the edge of a punch (1200 ×).

the character of the origins of failure, which have a striated microrelief characteristic of fatigue fractures (Fig. 3);

the kinetics of the spalling process (Fig. 2), a study of which showed that first intense accumulation of plastic deformation occurs in the zone near the edge (Fig. 2a, b). During this period in the zone of deformation there originate and grow microcracks, which after a certain number of load cycles merge into the main crack, then forming the origin of failure (Fig. 2c).

As a rule the fatigue cracks propagate along the working edge (Fig. 1a). In the zone of load concentration the main crack may develop from the surface into the depth of the metal, leading to spalling of broad portions of the edge (Fig. 2c).

Therefore the parameter controlling the life of punching dies is the resistance to low-cycle fatigue failure. Since in low-cycle fatigue the origin of cracks occurs very rapidly [4], it is clear that the parameter of optimization will be the cyclic crack resistance of the material. It is known that this increases with an increase in the critical stress intensity factor of the material $K_{IC}$, especially in the low-cycle area [5], and therefore this value is taken as the parameter of optimization.

It was experimentally established that the parameter $K_{IC}$ of Kh12M steel is determined to the greatest degree by the residual austenite content (Table 1). An increased crack resistance (33 MPa $\sqrt{m}$) is obtained with the presence of a significant (~ 40%) amount of it, limited from above by considerations of life of the edge. Plastic deformation of the punching die (Figs. 1a and 2c) must not cause crumpling of it in macroscopic volumes,