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Research on pipelines elements strength with stress raisers in the area of slide

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In classical Griffith problem, the crack in the brittle material in case when there are no plastic deformation effects around crack tip is considered. Therefore, in the system energy balance, the crack growth is reduced to the effective surface of body energy at the moment of shift. But this model is not suitable for metals, because there are plastic deformation marks in the form of cleavage steps and rivers in the fracture surface even at a temperature lower than brittle ductile change [1-8]. This is especially typical for cracks in the metal. It is almost impossible to avoid emerging of field of plasticity in the crack tip at the moment of its start; and therefore, Griffith model is not implemented in its pure form. But submicrocrack is quite another matter. Because of its size smallness, the submicrocracks possess the following characte- ristic feature: they are not able to violate the plastic relaxation in crystals of α-iron and also in steels.

The crack initiation mechanism for atomic-scale (≈ 10^{-4} mm) is similar in case of both brittle and ductile fracture.

Usually, in pipe steels the cracks appear around the top of dislocations pileup near any barriers:
boundaries of crystals, twins, in the slip band, carbides nucleus and so forth.

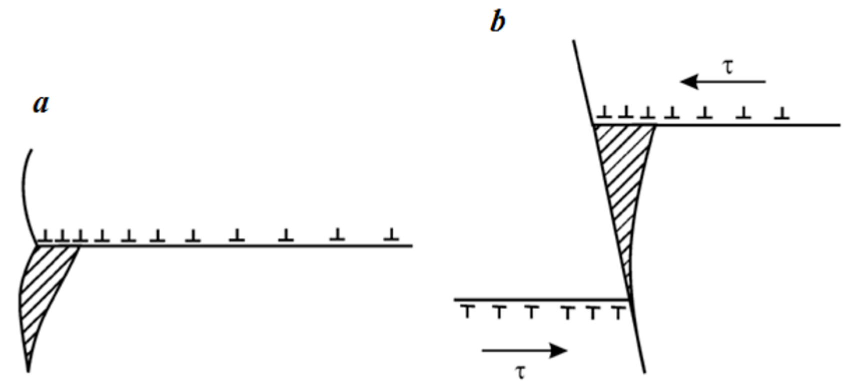

Figure 1. The diagram of crack initiation in dislocations

Actually, under the stresses action, the pileup edge dislocations in close proximity to barriers may be found to be so appressed to each other that their extraplanes will run into one another, and incipient microcrack will emerge. This pattern is implemented if there is plastic deformation sufficient for dislocation pileup formation. The crack shown in Fig. 1a is formed in plane perpendicular to the plane of dislocations slip under tensile stresses as a result of shear stresses concentration in the main part of pileup. The diagram of another type of crack initiation near barrier is shown in Fig. 1b in case of dislocations pileup emerging in the parallel slip planes.

In metals with body-centered lattice (they include pipe steels), the crack can be formed according to the model shown in Fig. 2.

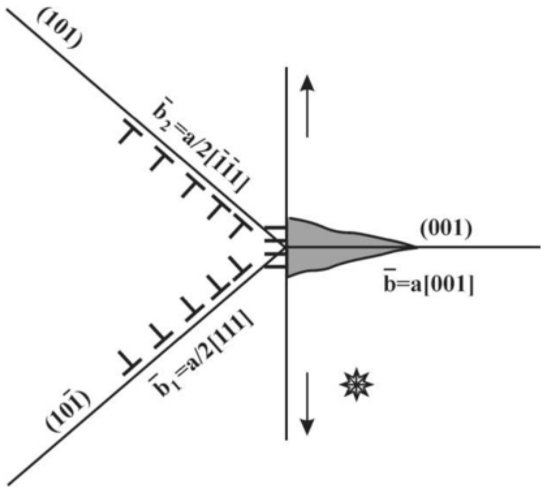

Figure 2. Diagram of cracks initiation in the body-centered cubic lattice of metals

Multiple repeating of this interaction process leads to association of new dislocations. In course of time, this causes the formation of crack nucleus. In this case, there is no need for barriers for dislocations in the initial condition. It should be noted that barriers and also dislocation pileups and cracks are formed by plastic deformation.

In metal, the crack is formed not around the top of pileup but inside it. The gap on the slip plane is due to parallel stresses. It appears due to deformation of slip planes of dislocation place in other planes. Deformation of slip surface at lengthwise shift initiates the normal stress. This pattern is usually implemented after significant plastic deformation.

During interaction of pipe metal with explosive energy, the twinning is observed near the edge. The crack initiation is observed (Fig. 2 a) in the meeting point of these twins of deformation with any barrier (crystal boundary, another twin).

As it is known, twins are distributed at a high rate, and those, which emerge when meeting of the stress barrier, have no time for relaxation.

Favorable conditions for cracks initiation are created when meeting of the growing twin of deformation with the previously formed one, which had another direction of twinning (Fig. 2b).

The crack also emerges when moving of some crystals towards other ones. The probability of such cracks initiation is usually increased under conditions of highly developed intercrystalline deformation. The boundary intersection of three crystals in elongated conditions is shown in Fig. 3a. The intercrystalline shift occurs along the boundaries between crystals A-C and B-C, where there are large shear stresses. As a result, the crack is initiated near the joint and distributed along the boundaries S-A-B-C (Fig. 3, b).

The analysed patterns of cracks formation depend on metal fracture resistance; and fractions nature is determined by conditions, under which the microcrack has appeared.

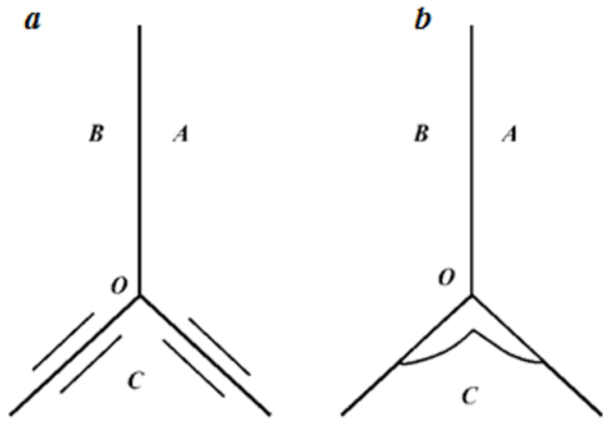

Figure 3. The pattern of crack initiation in the boundary intersection of three crystals due to intercrystalline deformation

At the moment of microspalling, the incipient crack becomes Griffithable, i.e. is distributed automatically with increase in rate [6]. The situation, when the microcrack reaches the size comparable to crystalline grain size, is an important step in the fracture process.

This may be due to the fact that for iron and its alloys, tensile stresses long before shear ones reach a level of theoretical tearing strength. This eliminates the alternative possibility of dislocations generation in the crack tip [5], and therefore, plastic deformation of metal. This particular initial stage of microcrack growth under the action of external stress is implemented by simple cleavage of atomic linkages and constitutes the phenomenon of microspalling. In the crack tip, the stress reaches the theoretical strength of the crystal. This stress is related to the steel structure, namely grain size, carbides shape and size, and whether there are brittle zones of metal in the old pipes.

The repeated observations in the most dangerous sections make it possible to follow the dynamics of stress field, forecast the development of geological processes, and take the emergency measures for stress relief.

The method of determination of allowable level of arbitrarily oriented load on the pipe in the area of ground was developed. The real value of the additional loads, which load the pipeline, and its dependence on the slide direction are to be found on the basis of natural observations or structural theory.

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