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SCALE LEVELS OF DYNAMIC TRANSLATIONAL FRACTURE MECHANISMS

S.A. Atroshenko

IPME RAS, Bolshoy 61, V.O., Saint Petersburg, 199178, Russia

e-mail: satroshe@mail.ru

Abstract. An experimental study of the morphology of the spall split of the pearlite steels was carried out. The distribution of elements of spall fracture on the scale for the longitudinal and transverse components was shown.

1. Scale Levels of Dynamic Translational Fracture

In carrying out the work, experiments were conducted on spall fracture on a number of pearlite steels [1, 2]. All samples were cut after the shock loading on one of the planes in the direction of wave propagation and examined the morphology of the spall split. Spall fracture is a combination of two interrelated processes - (a) the normal split and (b) shift. Localization of deformation is the main channel of deformation and fracture of materials under dynamic loading. A characteristic feature is the fact that the formation of spall split has stepped form, which indicates the movement of material in the form of discrete micro-currents whose wave parameters (the mass velocity, the velocity of propagation of the wave front, etc.) differ from each other. As a result, of interference between direct and reflected from the free surface unloading waves, spalling conditions in each micro-flow are realized at different distances from the free surface of the target. The spall cracks are not only areas of normal tension parallel to the wave front, but also areas of longitudinal localized shear around the edges of normal breaks. Some sections of the longitudinal shear spall cracks have the characteristics of "adiabatic shear bands" - the narrow, about 1 μm band, directed along the particles velocity vector. In steels and titanium alloys, these bands have after etching white color and represent regions of phase transformation.

Metallographic investigation of the samples indicates that the spall fracture is carried out simultaneously at several scale levels. To determine the spatial scales of the longitudinal and transverse spall localization in this work it was carried out statistical analysis of the geometric dimensions of micro-fracture in the spall area for steels Cr-4Ni-Mo, 2Cr-2Ni-Mo-V, Cr-Ni-Mo-V etc.. To this aim, they were performed detailed measurements of all longitudinal and transverse micro-fractures on the samples loaded at different rates. 4000-5000 measurements were conducted of the longitudinal and the same number of transverse bands localization of fracture. Results of statistical treatment revealed grouping of micro-cracks for four scale levels - two for longitudinal shear and two for normal breaks, they are shown in Table 1.

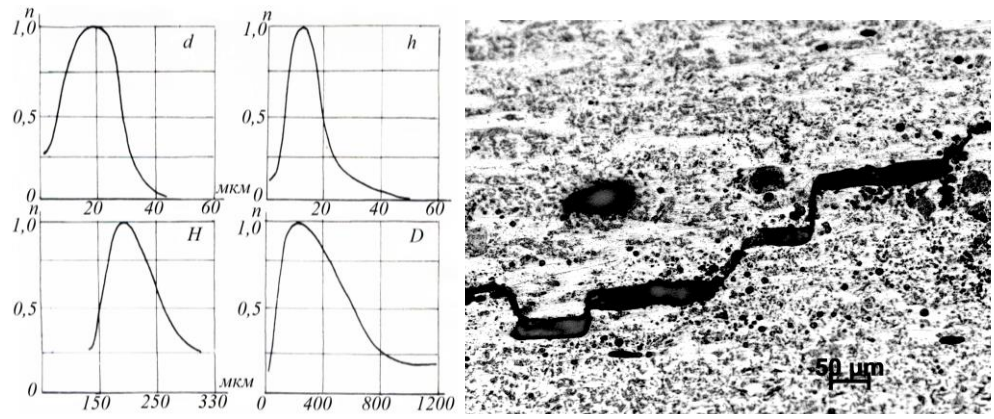
The data in Table 1 shows that, depending on the rate of load dimensions of the longitudinal elements of spall cracks behave non-monotonically - at a certain loading speed longitudinal micro-cracks reach some maximum size, and then reduced.

Figure 1 shows the normalized curves of distribution for longitudinal and transverse micro-fracture for steel 2Cr-2Ni-Mo-V at a loading rate 400 m/s.

As can be seen from Fig. 1, there is a clear distribution of the structural elements of the spall split in scale for the longitudinal components of the spall crack, and transverse components. At high loading rates sufficient for complete separation of the spall plates, lower scale levels of localization, both for longitudinal shear and the normal break not occurs.

Table 1. Characteristics of micro-fracture in the steels of the spall zone.

Steel	Loading velocity V, m/s	Micro-fracture characteristics			
		d	h	D	H
Cr-2Ni-Mo-V	245	15			
	320	20	15	175	220
	470	40	48	200	
	480	20	27	85	65
2Cr-2Ni-Mo-V	300	11	10		
	340	25	12	190	
	400	11	9	180	165
Cr-Ni-Mo-V	278	10	20		
	352	10			
	408	11	5	75	280
Cr-4Ni-Mo	320	48	16	145	
	330	24	16	300	310
	350	115	32		450



a b

Fig. 1. Normalized curves (a) of the longitudinal (shifts) (h and H) and transverse (breaks) (d and D) micro-fractures of 2Cr-2Ni-Mo-V steel at a loading rate of 400 m/s and (b) micrograph of spall crack of step form.

2. Reorientation of non-crystallographic shifts under changing the speed of loading

With increasing loading rate picture of the spatial orientation of micro-fractures in the area of spalling substantially modified - there is a significant proportion of micro-shears oriented at an angle of 45° with respect to the direction of wave propagation. Dynamic deformation of the material becomes more isotropic, so it will be carried out mainly on the planes of maximum shear stresses that in an isotropic body are oriented at an angle of 45° with respect to the direction of wave propagation. Spall crack in this case, consists mainly of portions oriented at an angle of 45° to the direction of wave propagation. It was performed a statistical analysis of quantitative data on the orientation of micro-fractures in the area of spalling. The results of this analysis are presented in Fig. 2.

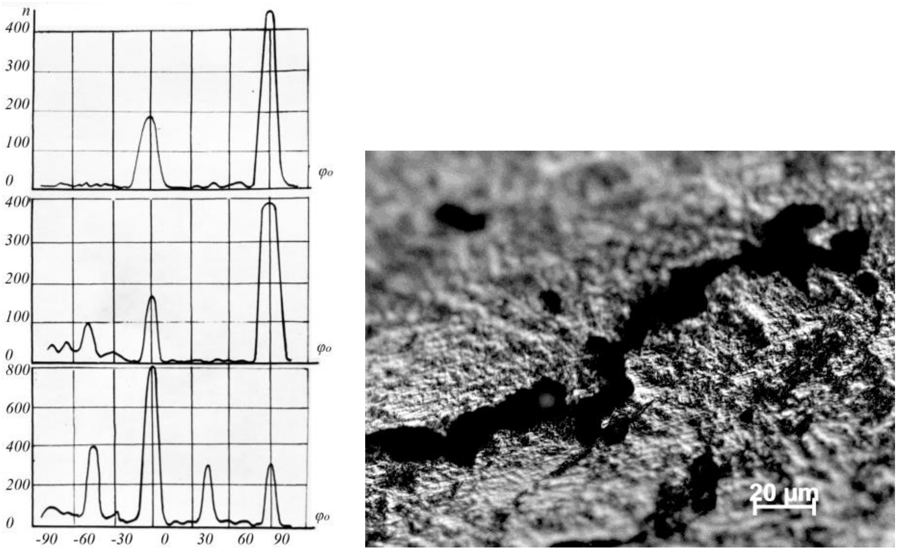


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Fig. 2. Distribution of micro-fracture in spall zone in steel Cr-Ni-Mo-V on their orientation under speed increases from 300 to 400 m/s (downward) (a) and the spall split regions located at an angle to the wave propagation direction (b).

This figure shows that at a speed of 300 m/s in steel Cr-Ni-Mo-V basic share of spall slit is micro-fractures parallel to the wave front (in Figure 0° - is the wave front, and 90° - its direction of propagation). By increasing, the projectile velocity up to 350 m/s is gradually increased distribution corresponding longitudinal shear. The number of normal tension persists. A further increase in the speed of the projectile up to 400 m/s leads to the fact that, while maintaining the number of normal breaks a significant proportion of shear damage, oriented at an angle of ±45° appears, indicating a more homogeneous nature of the deformation of the material at the plane of maximum shear stresses.

3. Conclusions

1. Scale levels of the fracture in the rear spall zone of steel Cr-4Ni-Mo both longitudinal shear and normal break differ for 1-1.5 order within each type of localization - both longitudinal and transverse.
2. With increasing loading rate range of spatial localization decreases and the average size increases as for the longitudinal shear and normal micro-breaks.

Acknowledgements
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