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ON SOME MISUNDERSTANDING OF FRACTURE ROUGHNESS PARAMETERS

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ABSTRACT

A corrected equation describing the upper bound for RL-RS relation was derived as

$$R_S = \frac{\pi}{2} R_L - \frac{\pi^2 - 8}{4} .$$

Due to some misunderstanding the above equation was called incorrect. The nature of this misunderstanding is explained and an experimental proof of correctness is presented.

Keywords: fractography, roughness parameters, stereometric equations, surface rougness.

INTRODUCTION

Roughness characterization of fracture surfaces is very important for fracture mechanism analysis. As the measurements in quantitative fractography are performed either on projections or on sections, two types of roughness parameters, related to surfaces and profiles are applied, respectively. The most commonly used are the surface roughness RS and linear roughness RL parameters. The surface roughness RS can be defined as the ratio between true fracture surface area St and its projected area AT (Underwood and Banerji 1987):

$$R_S = \frac{S_t}{A_T} \tag{1}$$

In a similar way linear roughness RL equals the true profile length Lt divided by the apparent projected length L' (Underwood and Banerji 1987):

$$R_L = \frac{L_t}{L'} \tag{2}$$

All the quantities used in equations (1) and (2) are illustrated in Fig.1.

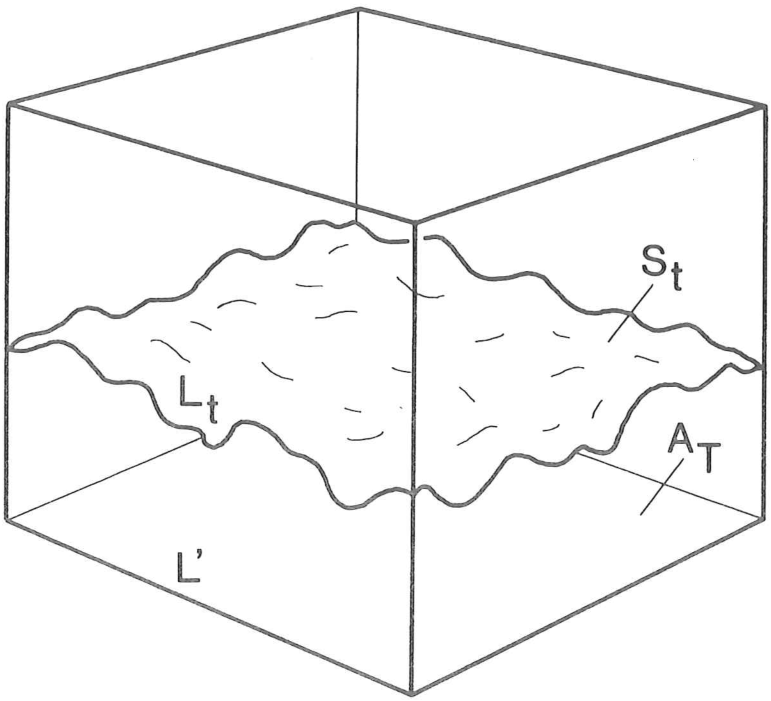

Fig.1. Test cube, fracture surface and fracture profile.

The existence of a close relation between the defined RL and RS parameters enables to derive stereometric equations which express RS as a function of R_L (El Soudani 1978, Wright and Karlsson 1983, Underwood 1989, Wojnar and Kumosa 1990). It can be shown, however, that fracture surfaces of the same linear roughness have not necessarily the same surface roughness. So, within the theoretical foundations of quantitative fractography, the lower and upper bounds for RL-RS relationships have to be derived.

The theoretical bounds have been derived by Underwood (1987). His equations are:

$$R_S = R_L \qquad (3)$$

as the lower bound (line "a" in Fig.2) and

$$R_S = (4/\Pi)\ R_L \qquad (4)$$

as the upper bound (line "b" in Fig.2). It was shown (Wojnar 1988, Wojnar and Kumosa 1990) that equation (4) underestimates the upper bound and a new, corrected equation was derived (line "c" in Fig.2):

$$R_S = \frac{\Pi}{2} R_L - \frac{\Pi^2 - 8}{4} \qquad (5)$$

This corrected equation was criticized by Underwood (1990) in an arbitrary way: "This is obviously impossible, of course". This highly critical opinion do not contain any remarks concerning possible errors in assumptions or derivations, which are published (Wojnar 1988). The opinion presented (Underwood 1990) is erroneous and caused by misunderstanding of the roughness parameters. The aim of this work is to explain this misunderstanding and prove the corrected upper bound is valid.

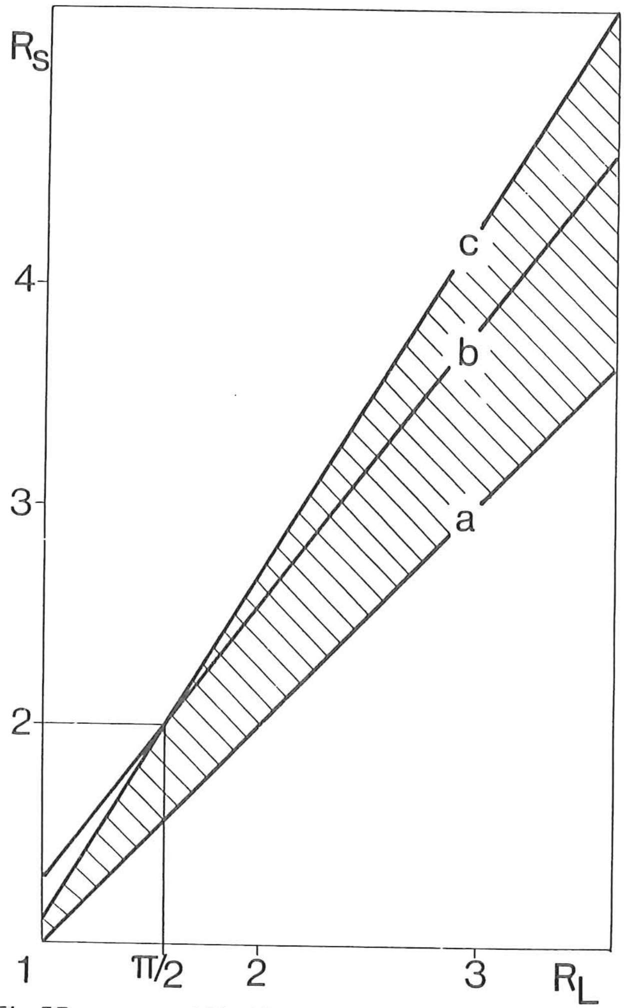

Fig.2. The RL-RS space with theoretical bounds: a - lower bound, b and c - upper bounds according to Underwood and Wojnar.

NATURE OF MISUNDERSTANDING

Let us read some comments on equation (4) (Underwood 1990): "This important equation is valid for any surface, if sampling is performed randomly. However, we would like to restrict (...) to directed measurements only, because of the roughness parameters. Fortunately, directed measurements can be used with random surfaces, because a random surface should give the same value (statistically speaking) for measurements from any direction".

From the above analysis it is clear that, according to Underwood, a randomly curved surface gives the upper limit for RL-RS relations. In fact, the majority of fracture surfaces has their configuration between planarly oriented and random surfaces. This experimental observation cannot be used, however, for establishing theoretical bounds. It is extremely easy to model (see Fig.3) and find real deep fracture surface (see Fig.4) which gives the RL-RS coupled values laying above the theoretical limit derived by Undrwood.

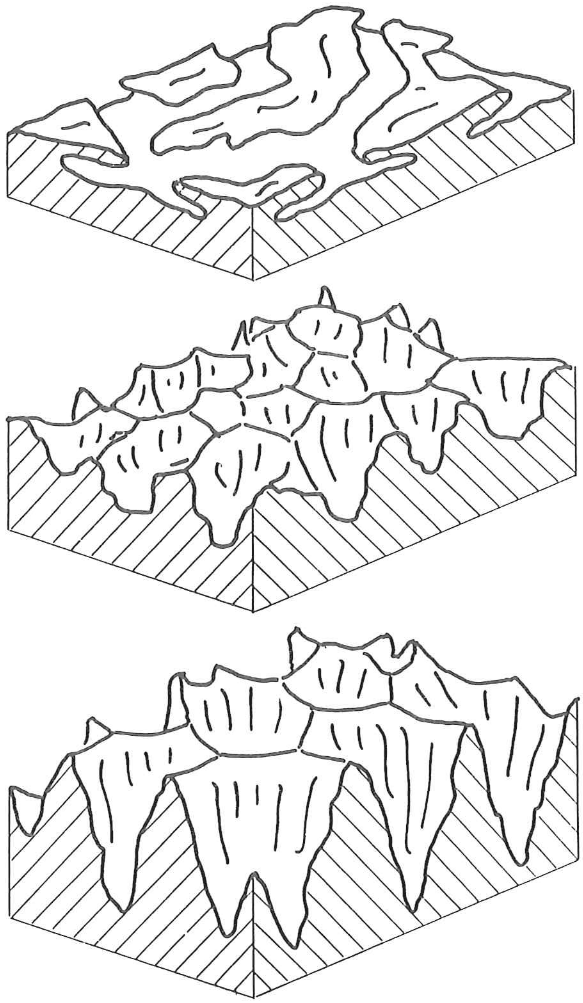

Fig.3. Model fracture surfaces. From top to bottom: relatively flat, randomly curved, deep.

So, the nature of misunderstanding lies in the fact that Underwood (1987,1990) assumes the upper limit is given by random fracture surfaces. This restriction is obviously incorrect.

The whole derivation of the corrected upper bound (equation (5) is published (Wojnar 1988, 1990, Wojnar and Kumosa 1990) and will be not repeated here.

EXPERIMENTAL PROOF

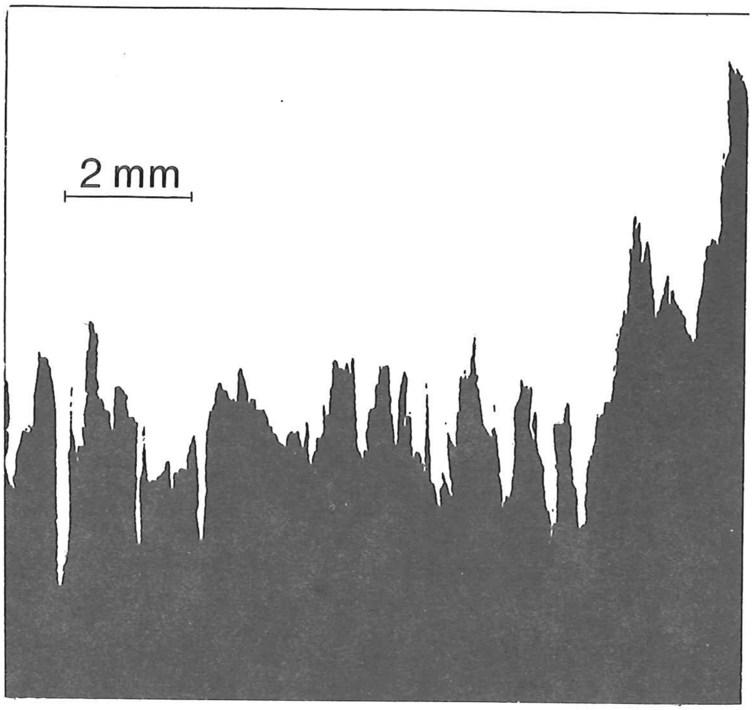

Fig.4. Fracture profile of the broken pine board.

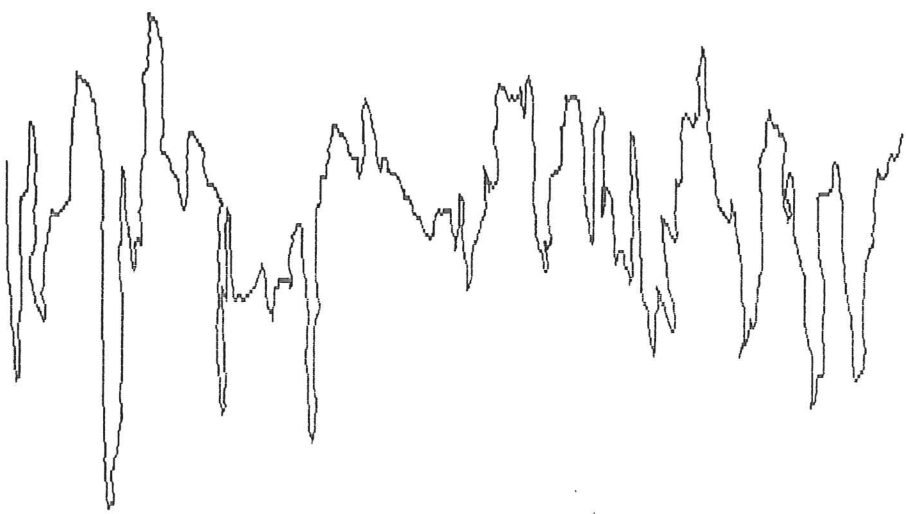

Fig.5. Computer representation of the profile shown in Fig.4.

To prove the correctness of the newly derived upper boundary equation the RL and RS values were evaluated for an example deep fracture surface of a pine board after tensile test (Fig.4). The fracture profiles were digitized (see Fig.5) and the subsequent analysis was performed on the digitized profiles. Evalution of the RL value from digitized profiles is an elementary numerical analysis. The RS value, in general, is difficult for exact evaluation. In this case the unbiased method of vertical sections (Baddeley et al. 1986) was adopted and applied (Wojnar 1990).

The following results were obtained from measurements: RL=7.63 and RS=11.35. Note, that for the given RL the upper boundary values are: 9.71 according to equation (4) and 11.52 according to equation (5). Thus, the experimental value was found within the corrected bounds and outside the bounds given by Underwood.

CONCLUDING REMARKS

It has been shown both experimentally and theoretically (Wojnar 1988) that the upper bound established by Underwood (1987) gives underestimated results. The corrected equation for upper bound has been derived (Wojnar 1988) and the differences between these two equations are explained as a result of different assumptions used for derivations. In the corrected upper bound equation the existence of deep fracture surfaces is assumed. In contrast, the previously derived upper bound equation is limited to random surfaces only, which is erroneous. The correct upper boundary is given by equation:

$$R_S = \frac{\pi}{2} R_L - \frac{\pi^2 - 8}{4} .$$

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