

«Aircraft Fatigue Life Prediction by the Surface Deformation Relief of the Aluminium Skin and Fatigue Sensors»

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Fatigue damage diagnostic by the surface relief parameters

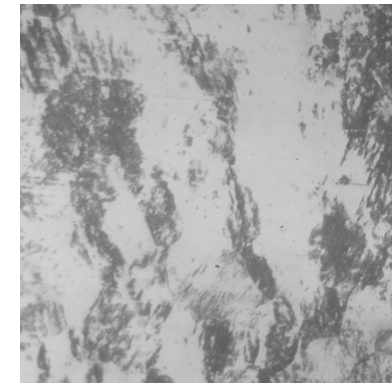
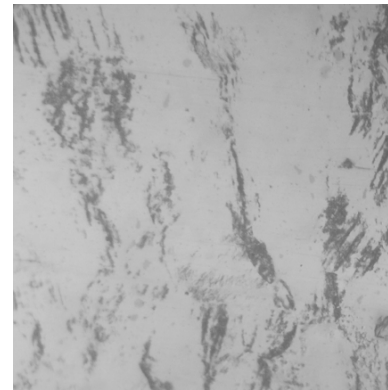
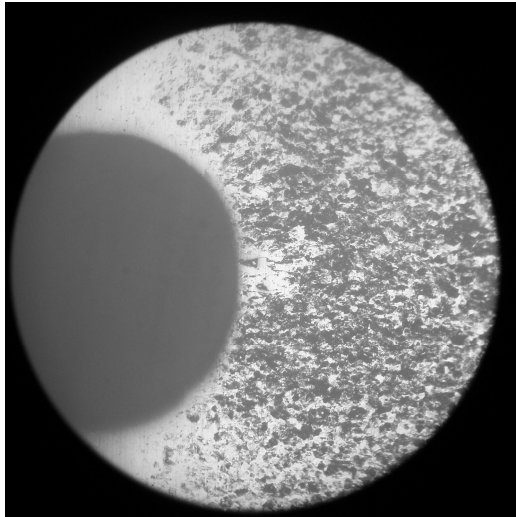
By the state of aluminium clad layer

By the state of rigid sensors with stress multiplication

By the state of foil polycrystalline sensors

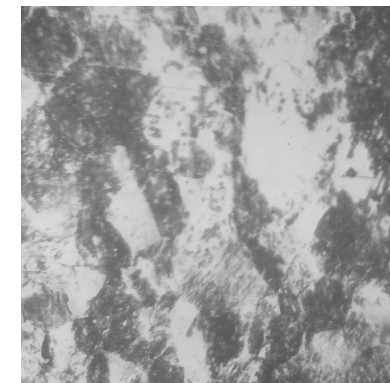
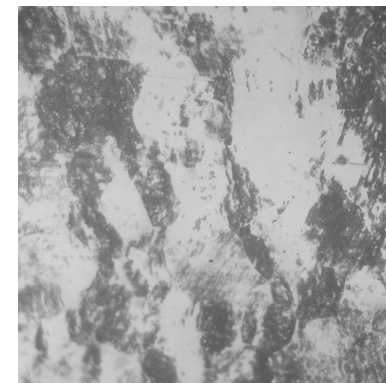
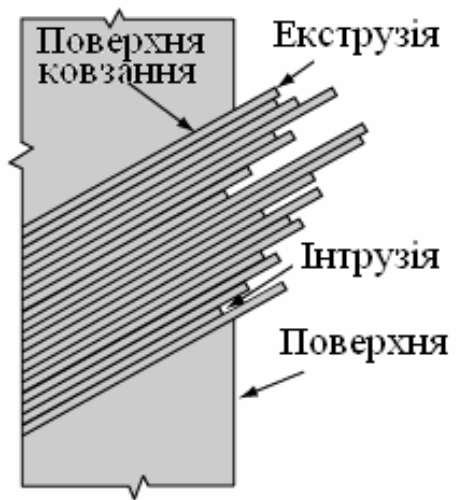
Deformation relief as an indicator of the accumulated fatigue damage

Optical images of the deformation relief. $R=0$, $\sigma_{\max}=147,0$ МПа



30000 cycles (1,9%)

100000 cycles (6,3%)



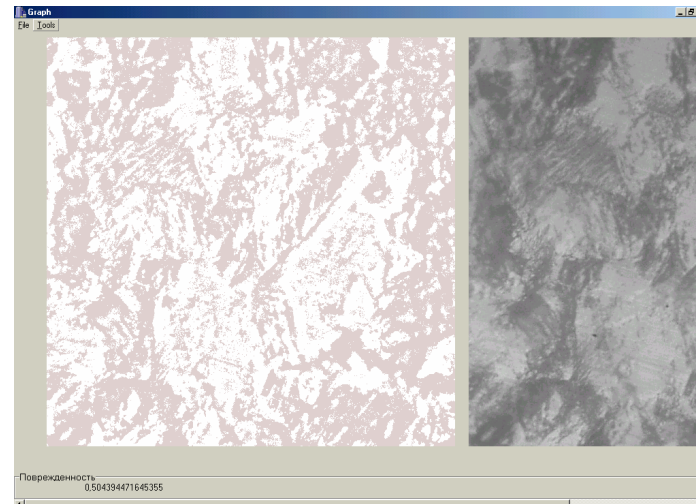
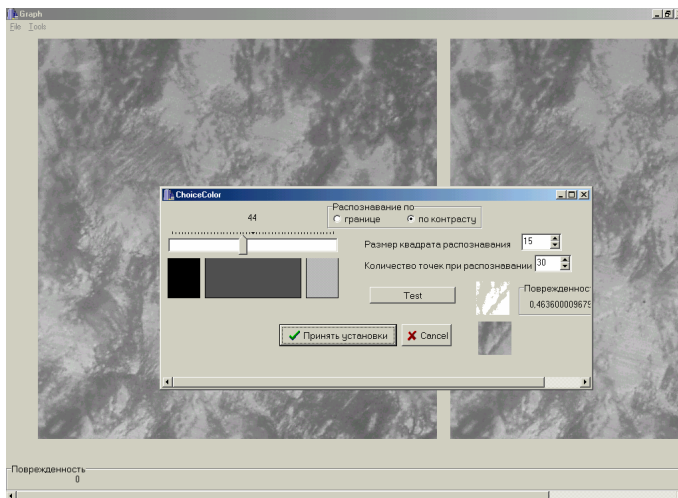
200000 cycles (12,6%); 400000 cycles (25,2%)

Damage parameter D

$$D = S_r / S_t$$

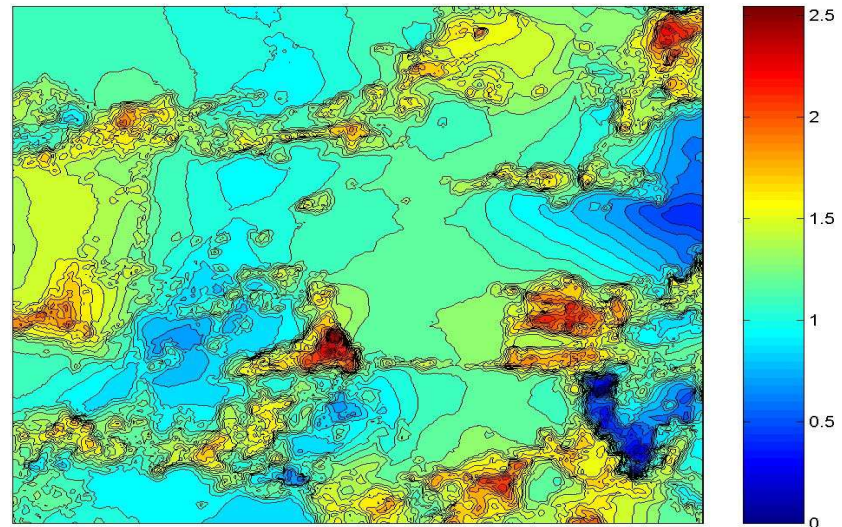
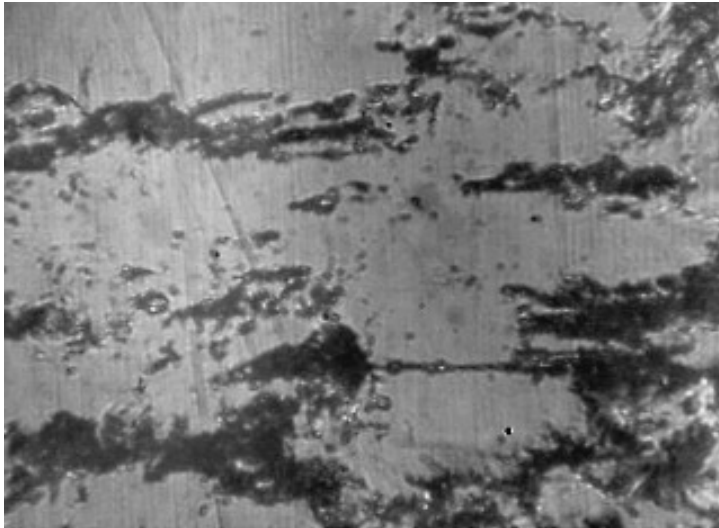
where: S_r – area of the surface with relief features;

S_t - total checked area

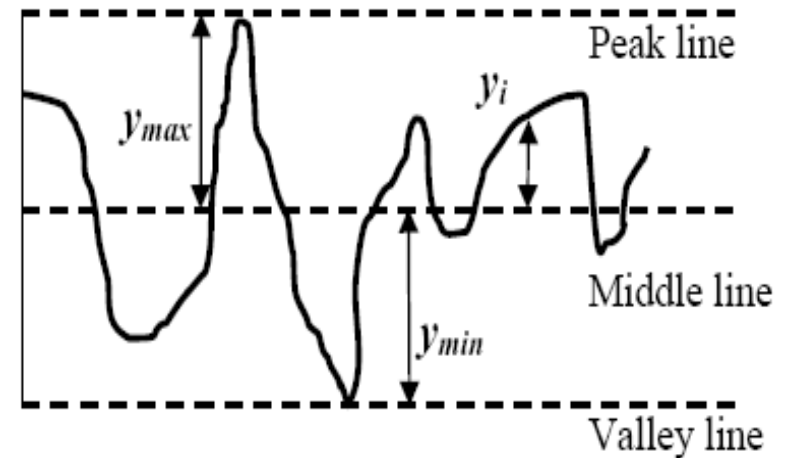
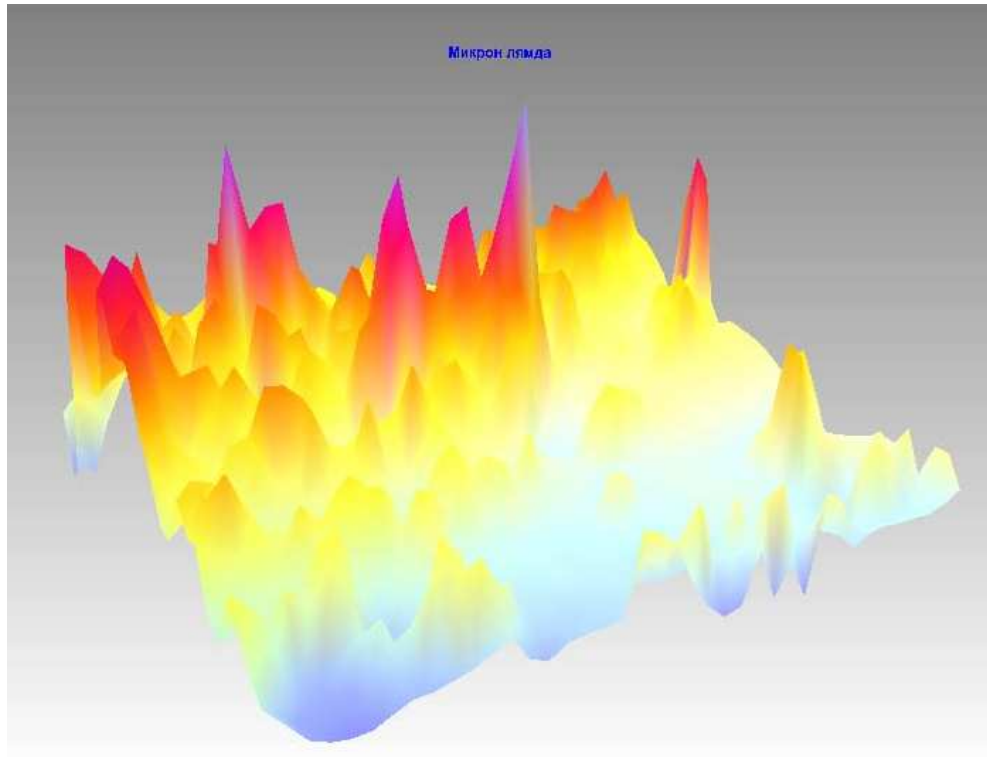


Procedure of the damage parameter D calculation

2-D & 3-D images of the deformation relief



Roughness parameter determination

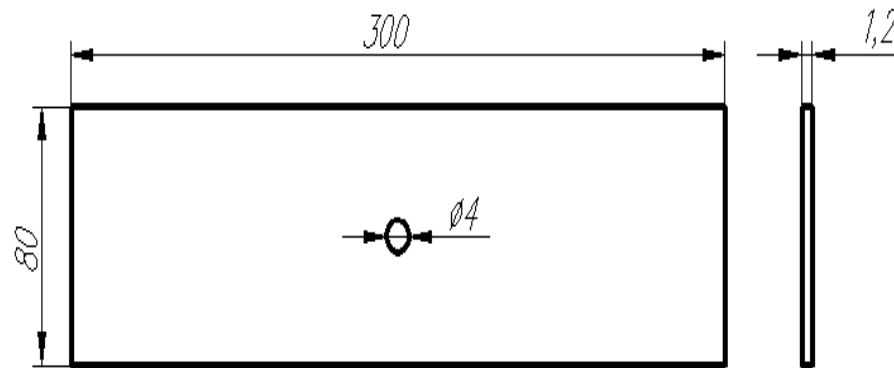


$$Ra = \frac{1}{l} \int_0^l |y(x)| dx$$

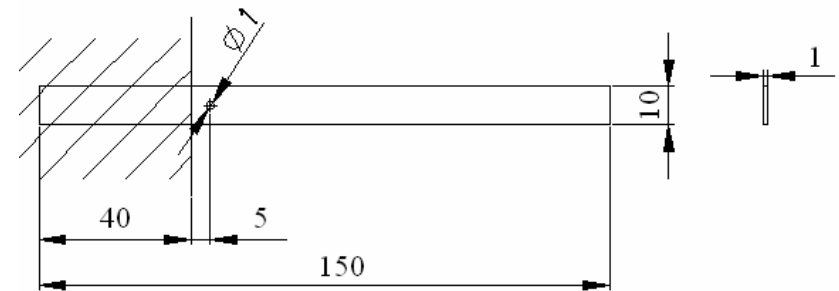
3D data array is used for:

- the surface relief monitoring
- roughness parameter determination

Specimens for fatigue tests

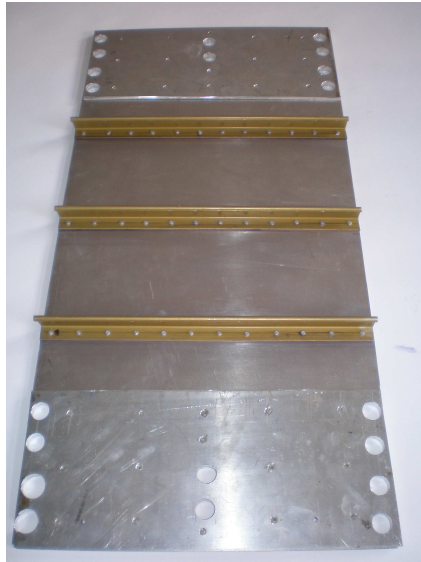


Specimen of the alclad alloy D16AT for the test under tension

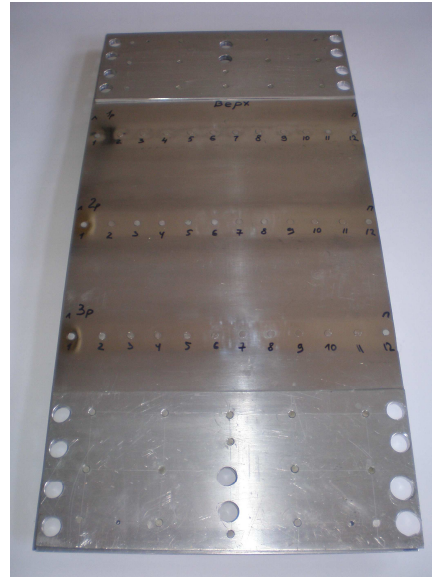


Specimen of the alclad alloy D16AT for the test under the bending

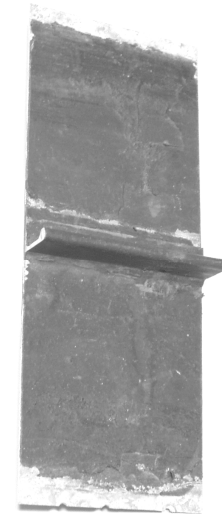
Structural components



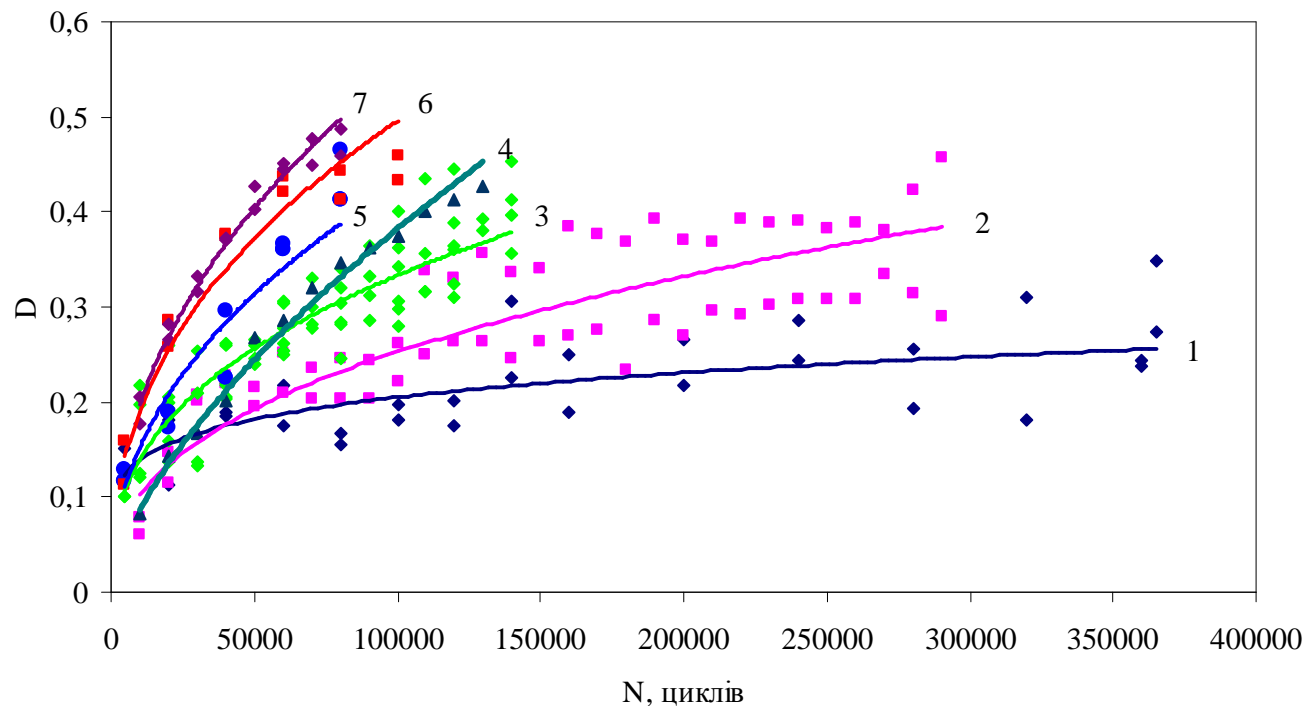
Multi riveted component



An-24 welded skin component

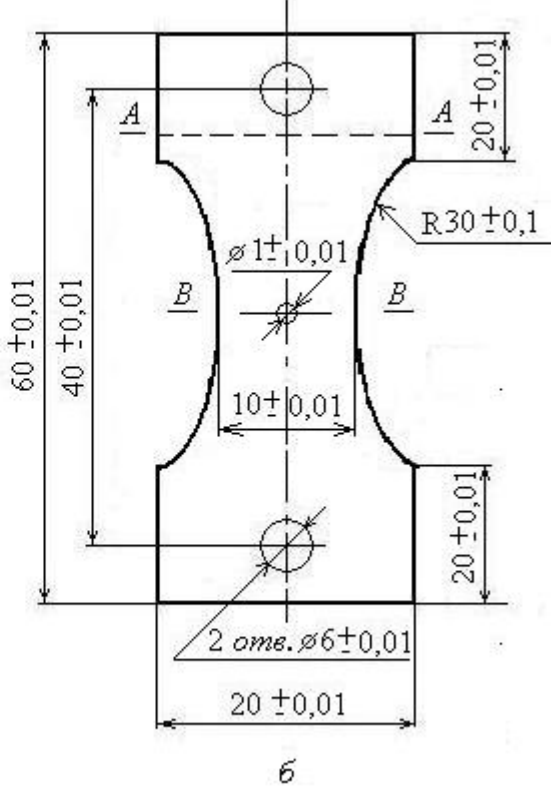
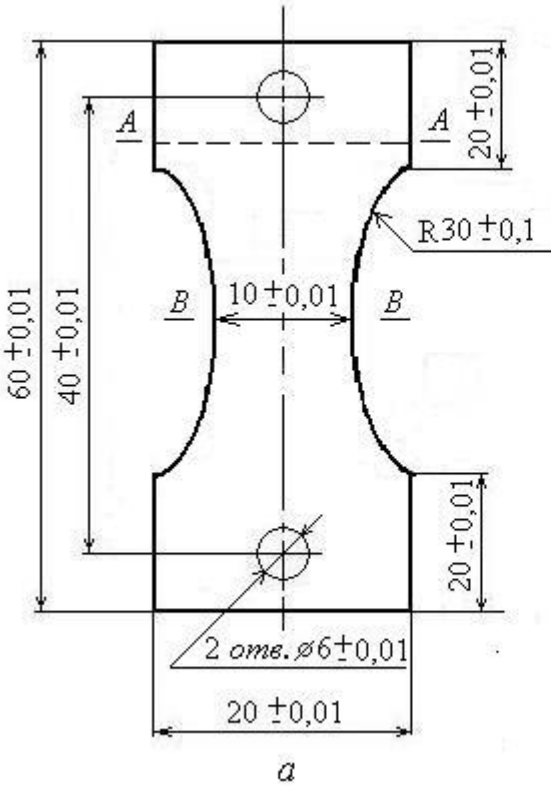


Sensitivity of the proposed damage parameter D to the maximum stress of loading cycle

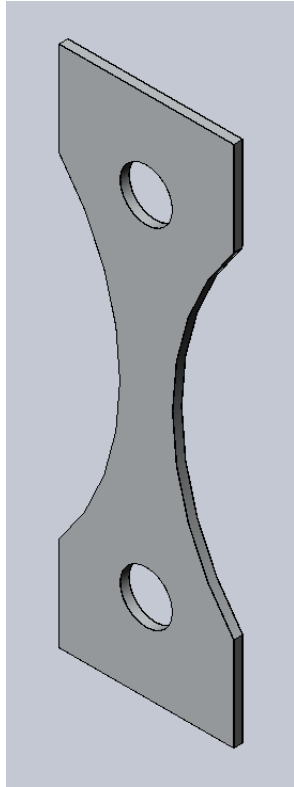


Dependence of the damage parameter D on the stress level:
1 - $\sigma_{max}=76,9$ MPa; 2 - $\sigma_{max}=81,7$ MPa; 3 - $\sigma_{max}=96,2$ MPa;
4 - $\sigma_{max}=105,8$ MPa; 5 - $\sigma_{max}=115,4$ MPa;
6 - $\sigma_{max}=129,8$ MPa, 7 - $\sigma_{max}=134,6$ MPa.

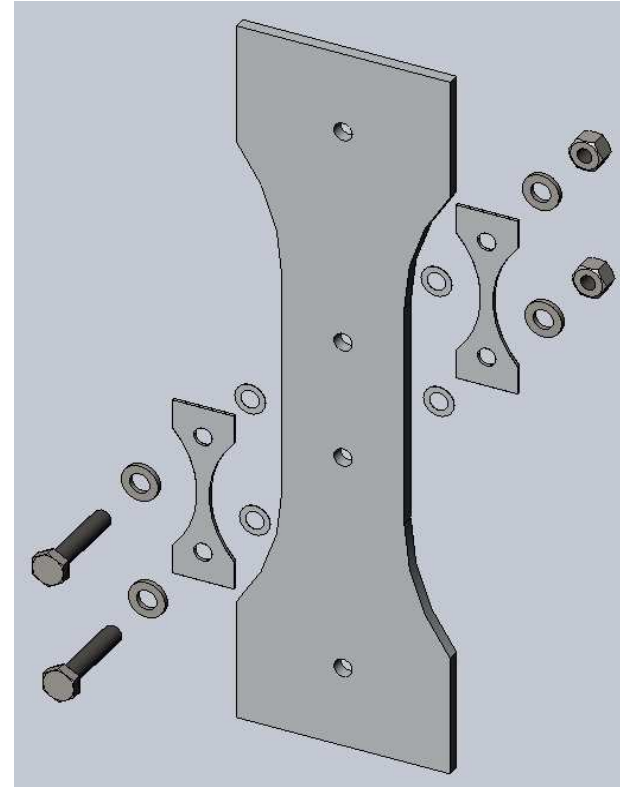
Conceptual version of the fatigue sensor with stress multiplication



Fatigue sensor with stress multiplication effect

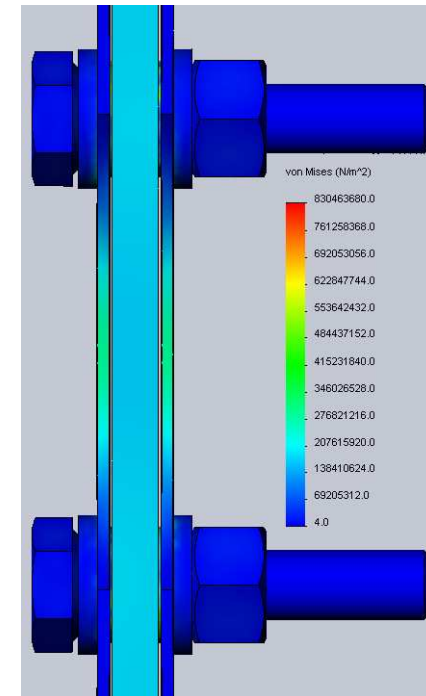
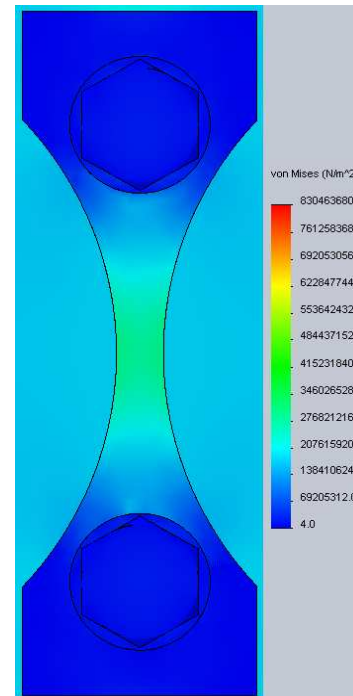
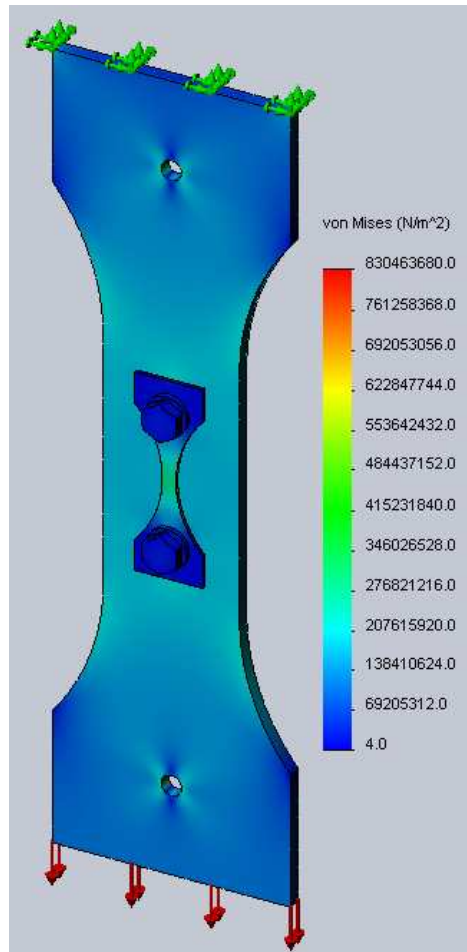


Sensor



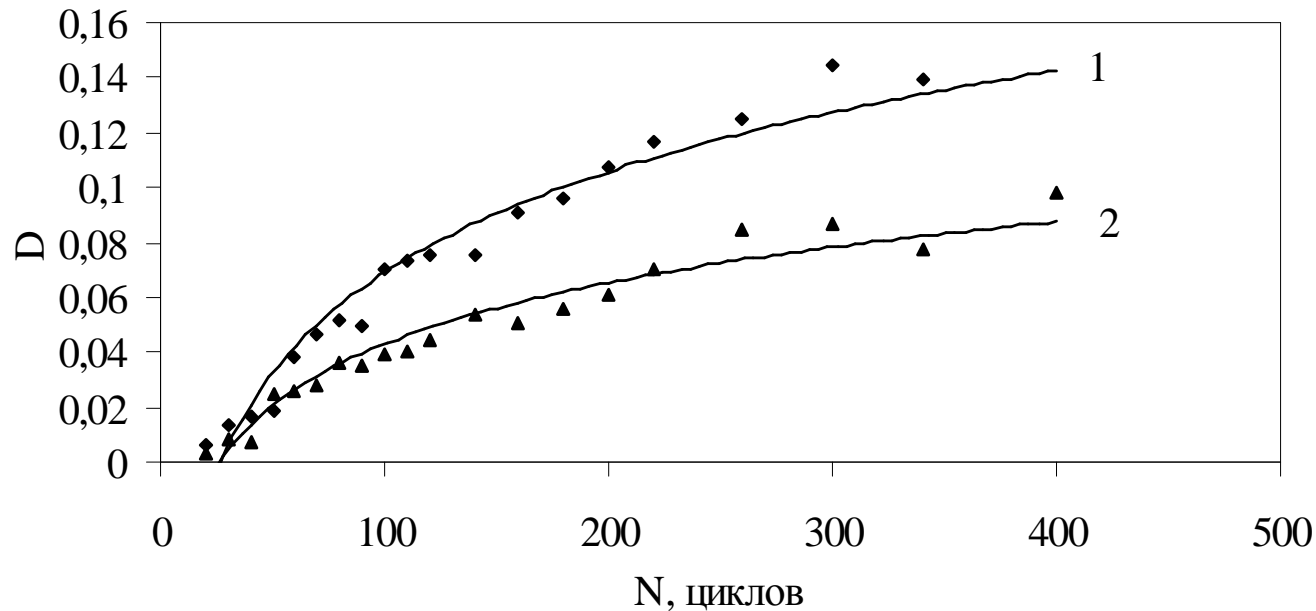
Attachment of the sensor

Sensor's sensitivity optimization by the Finite Element Method



Distribution of the stresses in the sensor and structure's component

Evolution of the sensor's damage parameter under fatigue



Evolution of the damage parameter D of the sensors with different sensitivity.

Stress level in the structure's component $\sigma = 157,0$ MPa.

1-stress in the sensor - 280,0 MPa;

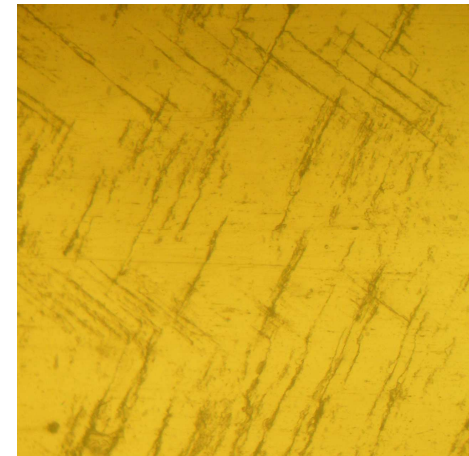
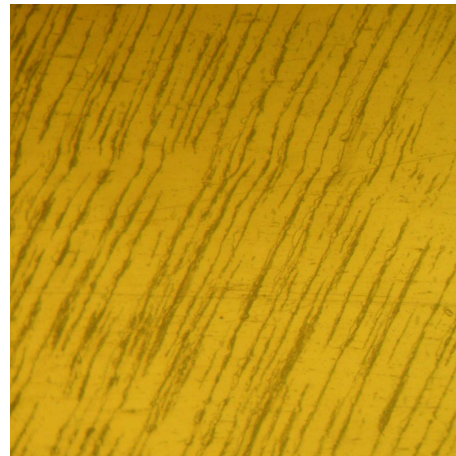
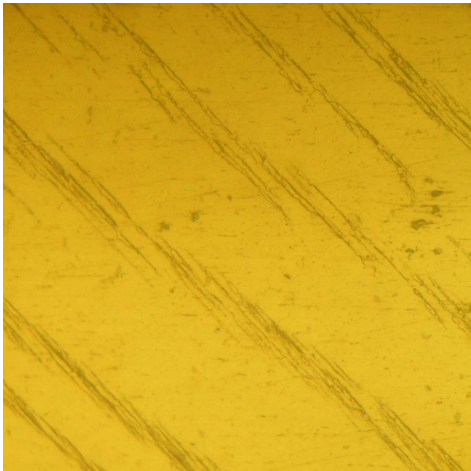
2- stress in the sensor - 240,0 MPa.

Increase of the sensor's sensitivity by the additional stress concentrator



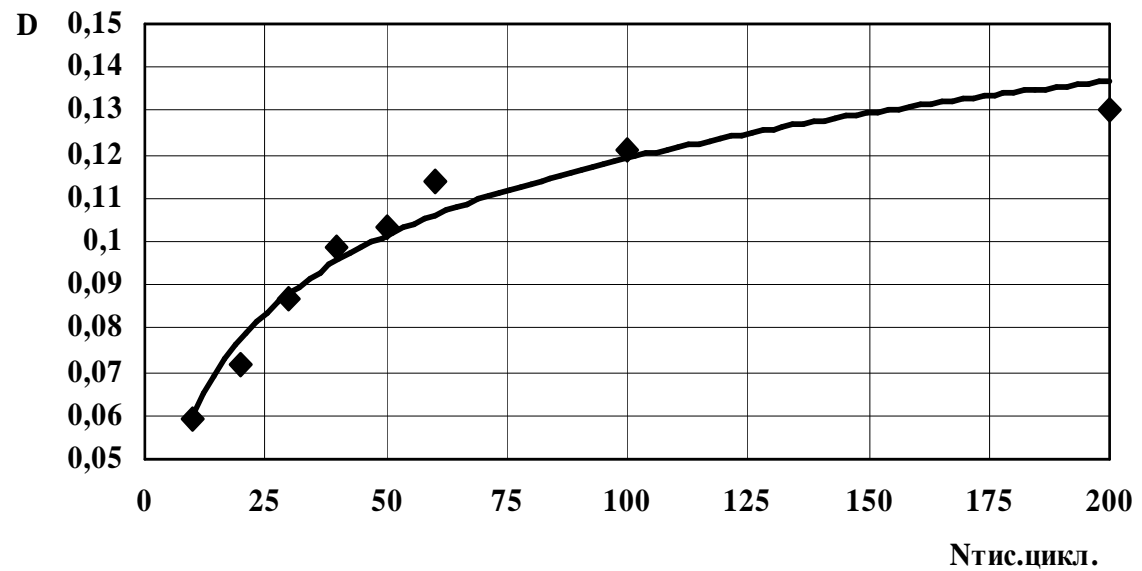
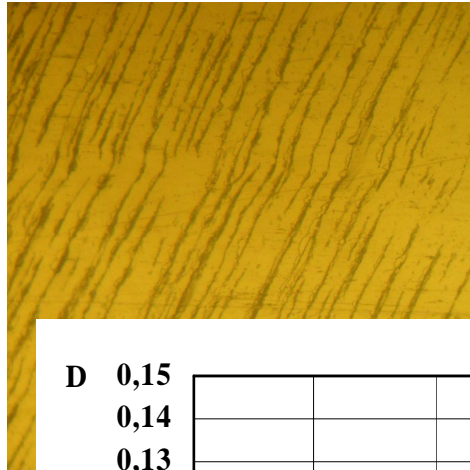
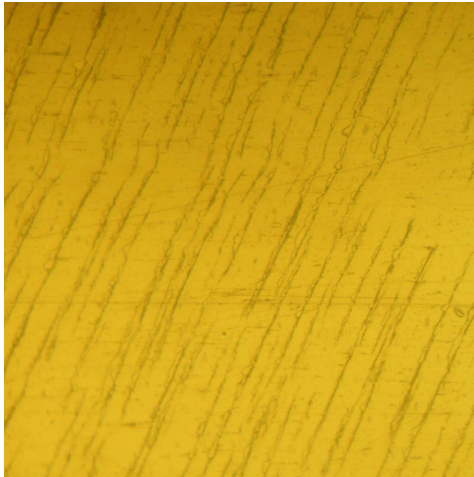
Sensor with fatigue crack

Foil sensors of the fatigue damage



Deformation relief on the foil sensor grains

Evolution of the foil sensor's state under fatigue



Proposal for the FP7:

Presented approaches for the fatigue monitoring can be considered as a part of the Aircraft Structural Health monitoring Systems