New scientific achievements

1. Wear tests were carried out to study the typical wear and failure mechanisms of the unidirectional fibre-reinforced polymer composites subjected to sliding steel counterpart Based on these tests, it was found that

1.a) In the case of normal fibre orientation the typical wear mechanisms are as follows: compacted wear debris layer formation and its wear, matrix shear, matrix sliding wear, fibre edge cracking at the rear edges relative to the sliding direction, fibre sliding wear, abrasive wear mechanisms and fibre/matrix debonding.

1.b) In the case of parallel and anti-parallel fibre orientations the typical wear mechanisms are the followings one: compacted wear debris layer formation and its wear, matrix shear, matrix sliding wear, fibre cracking, fibre sliding wear, move out of the broken fibre segments, abrasive wear mechanisms and fibre/matrix debonding.

2. To study the typical failure mechanisms of steel asperity/unidirectional normally, parallel and transversally oriented fibre-reinforced polymer composite sliding pairs, FE calculations were performed. Based on these, it was found that

2.a) To consider the real fibre/matrix micro-structure of the unidirectional fibre-reinforced polymer composite, FE contact macro/micro-models are needed to be developed. The contact, strain and stress results determined by the macro/micro-models, coupled by the displacement coupling technique, are significantly closer to the real conditions, than the results, which are evaluated base on the widely used macro-approach.

2.b) On the basis of calculations of non-frictional normal and frictional sliding contact problems performed by micro-models, it was found that in the case of normal and anti-parallel fibre orientations as a result of the friction force the contact pressure becomes higher, and the contact area becomes also wider. Contrary to this, in the case of parallel fibre orientation there is no significant change in the values of the contact parameters. In the case of normal fibre orientation, the maximum values of the asymmetric contact pressure distribution induced by the frictional force are appeared at the rear edges of the loaded fibers.

2.c) The calculation based on the micro-model with normal fibre orientation provides explanations for the following failure mechanisms observed experimentally: fibre edge cracking appearing at the rear edges referred to the sliding direction, compacted wear debris layer formation as a consequence of matrix push-up, shear and tension type debonding, matrix shear.

2.d) The calculations based on micro-models with parallel and anti-parallel fibre orientations provide explanation for the followings of the failure mechanisms observed experimentally: fibre cracking, shear and tension type debonding, matrix shear, fibre torsion.

3. In order to study the fibre/matrix debonding phenomena under sliding contact, FE debonding simulation micro-models with normal, parallel and anti-parallel fibre orientations were developed. Based on the numerical results, it was found that

3.a) The non-linear finite element micro-models, including interface elements and using the displacement coupling technique, are suitable for studying of the tension as well as the shear type debonding phenomena. The interface elements are located around each fibre.

3.b) On the basis of interface elements the following debonding types can be considered: tension type debonding, shear type debonding combined with radial tensile stress, shear type debonding combined with radial compression stress. In the latter case, depending on the magnitude of radial compression stress, prevented and limited debonding types can be also distinguished. The local debonding conditions are based on the tension and shear limit strain values specified in local cylindrical coordinate system.

3.c) In the case of sliding friction, the debonding is induced dominantly by shear loads for normal, parallel and also anti-parallel fibre orientations. In most cases the shear type debonding is combined with radial compression stress, which, as a braking force, slows down the propagation of debonding phenomena.