ROLE OF PARTICLES IN FRACTURE MECHANICS: EVOLUTION OF ONE APPROACH

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Since the early days of fracture mechanics, the importance of the particles present in microstructure was greatly emphasized. The particles in steels are either impurities (sulfides, silicates. aluminates, oxides etc), or second phase particles (predominantly carbides). To describe the role of the particles, it was necessary to take into account the chemical composition, shape and size distribution. Primarily, all particles were treated as stress concentrators, due to its sharp edges which were formed during solidification and/or following plastic deformation. Therefore, the main challenge for metallurgical engineers was how to avoid the presence of the sharp elongated particles in steels. The problem was mainly solved by increasing the steels purity (decrease in sulfur and phosphorous content is a permanent activity in steel production). Later, concurrently with the development of physical metallurgy, this approach was modified. The new approach was provided by achievements in industrial practice related to the possibilities of particles control. Therefore, the control of the particles had enabled two new different strategies: (i) control of the particle shape and (ii) control of the particle chemical composition. The shape control was applied primarily on sulfur based particles, mainly MnS. The addition of Ca led to the change in shape and increase in the Young's modulus. Therefore, MnS particles became spheroid and non deformable, i.e. MnS did not act as stress concentrator, in spite of the presence of sulfur. This approach was applied for the large particles (non-metallic inclusions). The other route was based on the knowledge of nucleation of the phases with high toughness. The nucleation of these phases preferentially starts on matrix/particles surface. Also, the relationship between particles and phases is well established. These particles are carbides, nitrides, oxides or carbonitrides of alloying elements, submicrometer in size. Therefore, the control of particle precipitation will lead to the final microstructure with high toughness and/or very small grain size. This approach has successfully enabled the development of microalloyed steels, significant improvement of the toughness of the weld metal etc.

Inclusions have undergone a long way from undesirable features in early days (stress concentrators) to necessary factor for excellent toughness in steel.