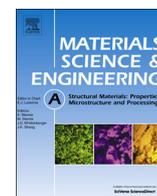




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Rapid communication

# Comment on “Experimental verification of segregation of carbon and precipitation of carbides due to deep cryogenic treatment for tool steel by internal friction method” by Li et al. [Mater. Sci. Eng. A 575 (2013) 51–60]

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## ABSTRACT

We want to make three comments to the article by Li et al. [1]. The first one is the interpretation of the internal friction peak at 382 K, which they attributed to the Snoek effect, but other authors suggest that this effect is not possible in martensite [2–4]. The second one is the interpretation of the changes in the height of internal friction peak at 580 K. They attributed it to the segregation of carbon, but we believe that it can also be associated to the increasing dislocation density. Finally, we want to indicate that the increasing of dislocation density can also be a mean reason of the enhancement of wear resistance by deep cryogenic treatment as well as segregation of carbon and the transformation of austenite into martensite.

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## 1. Internal friction peak at 382 K

This peak has activation energy similar to the carbon diffusion energy, and thus Li et al. [1] attributed it to the Snoek effect. However, the martensite tetragonality generates energetical differences between the octahedral interstitial sites [5], and thus it does not permit the free movement of the carbon atoms between these sites when the external load is applied, which is necessary for the Snoek effect [6]. Johnson [7] shows by numerical simulation that the deformation used in internal friction is not enough to produce the migration of carbon atoms in martensite associated to the Snoek effect.

Additionally, Ward and Capus [2] conclude that there is no evidence for internal friction peak attributed to the Snoek effect in a fully martensitic sample, and the opposite reports can be explained by relaxation mechanisms related to the dislocation movements or the presence of ferrite in the sample. And Stark [4] showed that it is necessary to make tempering treatment at high temperatures (485–650 °C) to observe the Snoek effect in tempered martensite. In other works, this peak has been related to the precipitation of epsilon carbide [3,8]. As it is known, epsilon carbide precipitation

takes place around 380 K (first stage of tempering), with activation energy similar to the carbon diffusion energy [5].

## 2. Internal friction peak at 580 K

This peak is attributed to Snoek–Kê–Köster relaxation (SKK). They conclude that the changes of peak height are related to carbon segregation, but they do not consider the changes on dislocation density by heat treatment. In both groups of samples, the quenched samples, and quenched and DCT treated samples, the peak height increases when the austenitizing temperature is higher. They attributed this to the increases of interstitial carbon content in martensite, but this increase can also be associated to the higher dislocation density [5,9].

In both samples, they attributed the reduction of height peak during tempering to carbide precipitation. But, it is important to consider that the dislocation density diminishes during tempering [5], and this is agreed with the lower height peak [3]. Additionally, they attributed the higher peak height of quenched samples with respect to the DCT samples to lower carbon content. But, this can be associated to increases of amount of martensite by DCT. The tempering has a more strong effect on microstructure when the amount of martensite is increased [5].

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Similarly, the increasing of the peak height of quenched samples during DCT can be associated to the increase of dislocation density. DCT produces high internal stress by the transformation of retained austenite into martensite, and by the thermal contractions of the phases, increasing the lattice distortion. They conclude that this promotes the carbon segregation, forming new groups of atoms near the dislocations, and then this group acts as nuclei of carbides during tempering. However, these phenomena also increase the dislocation density [5], which is agreed with the higher peak height [3]. And thus, the increasing of height peak during cyclic DCT can be associated to the increasing of dislocation density.

### 3. Increasing of wear resistance by DCT

Li et al. [1] attributed the enhancement of wear resistance during DCT to two main reasons: the transformation of austenite to martensite, and the carbon segregation to the dislocations. However, the height peak of internal friction peak at 580 K can also be associated to

the increasing of dislocation density, and thus this phenomenon may contribute to the enhancement of wear resistance.

We recommend using complementary characterization techniques as X-ray diffraction to verify the carbon segregation and the increasing of dislocation density during DCT. These two phenomena can be studied by the analysis of profile of diffraction peak width [8].

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