

Scratch damage mechanism transition maps of DLC coated cold work tool steels using instrumented scratch test and fractography



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Abstract

The most general feature to evaluate the scratch resistance of ceramic coating is the critical loading force leading to total detachment of the coating from the substrate. Our research aims at comparing the scratch resistance and mechanisms arising during an instrumented impact test of a widely used cold work tool steel with different – nitride and nitride + DLC – ceramic coating systems. Scratch tests were performed with increasing normal load, the scratch behaviour was characterised by the friction coefficient vs. scratch length diagrams and scratch morphology using OM and SEM.

Substrate

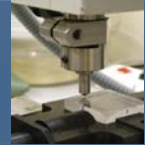
Base material: K100 (1.2080)
Treatment: precipitation hardening;
Surface: polished

Coatings and processing:

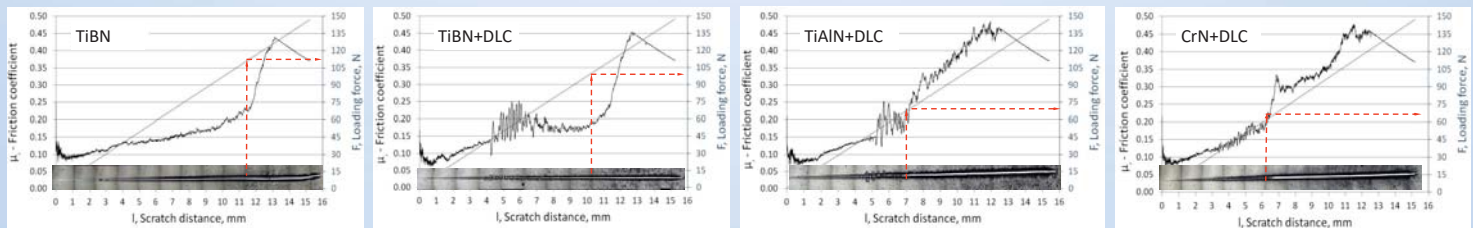
- Nitride (TiBN) monolayer – PVD
- Nitride (TiBN, TiAlN, CrN)
+ WC + DLC multilayer – PVD + PACVD

Test parameters

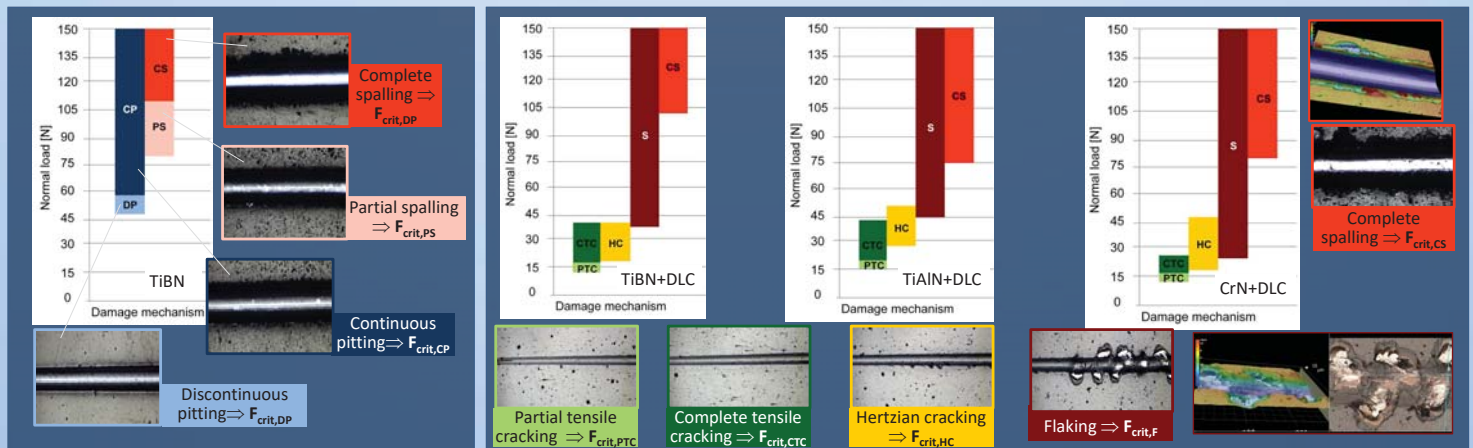
Loading force: $F=2-150$ N
Table speed: $v=5$ mm/s
Force gradient: $F_{grad}=10$ N/mm
Length of the scratch: $L=15$ mm



Traditional scratch test $\Rightarrow F_{crit}$ belonging to the complete spalling $\Rightarrow$ **Limited information**



Scratch test + Fractography $\Rightarrow$ Several F_{crit} belonging to different damage mechanisms $\Rightarrow$ **Extended information**
 $\Rightarrow$ **SCRATCH DAMAGE MECHANISM TRANSITION MAPS**



Nitride monolayer

different damage behaviour

Nitride + DLC multilayer

Layer	Coating	$F_{crit,DP}$	$F_{crit,CP}$	$F_{crit,PS}$	$F_{crit,PTC}$	$F_{crit,CTC}$	$F_{crit,HC}$	$F_{crit,F}$	$F_{crit,CS}$
MONO	TiBN	48 N	58 N	79 N	—	—	—	—	109 N
MULTI	TiBN+WC+DLC	—	—	—	13 N	17 N	19 N	38 N	101 N
	TiAlN+WC+DLC	—	—	—	12 N	20 N	29 N	43 N	75 N
	CrN+WC+DLC	—	—	—	13 N	16 N	19 N	26 N	80 N

Conclusions

- Damage mechanisms for the single layer and the multilayered coatings with DLC top-layer are different.
- The DLC coated systems with a different nitride underlayer showed similar damage mechanisms, i.e. partial tensile cracking, complete tensile cracking, Hertzian cracking, flaking and complete spalling. In contrast, the TiBN single-layer coating showed different damage mechanisms, i.e. local peeling at the groove edge, discontinuous and continuous pitting, partial spalling and complete spalling.
- The highest F_{crit} belonging to the complete spalling was obtained for the TiBN coating ($F_{crit,CS,TiBN}=110$ N).
- Imposing an additional WC+DLC top layer onto the TiBN coating slightly decreased the average $F_{crit,cs}$ ($F_{crit,CS,TiBN+DLC}=100$ N) and the combined TiBN+DLC coating system showed much higher damage sensitivity.
- The F_{crit} belonging to partial and complete tensile cracking were similar for the DLC coated systems. It suggests that these damage mechanisms are inherent features of the DLC top layer, and not directly dependent on the underlayer.
- Scratch test completed with fractography provides extended information on the damage behaviour of the different coating systems, based on which characteristic scratch damage mechanism maps can be created for the different coatings.