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Microstructure analysis of a banded work roll

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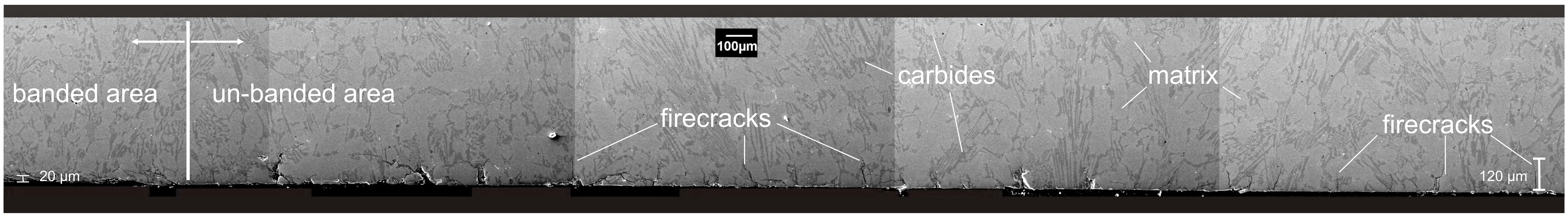
Abstract

In order to investigate the mechanisms leading to banding, material taken from a banded work roll has been analysed by LOM and SEM with focus on the transition between banded and un-banded regions. The mechanisms of the formation of cracks in carbides as well as firecracks in the matrix material are investigated with respect to the direction of loading. A comparison is undertaken of the observed banding depth and the extent of analytically calculated plastic zones.



Damage of a work roll on an overview of transition between banded and un-banded area in lateral view, SEM

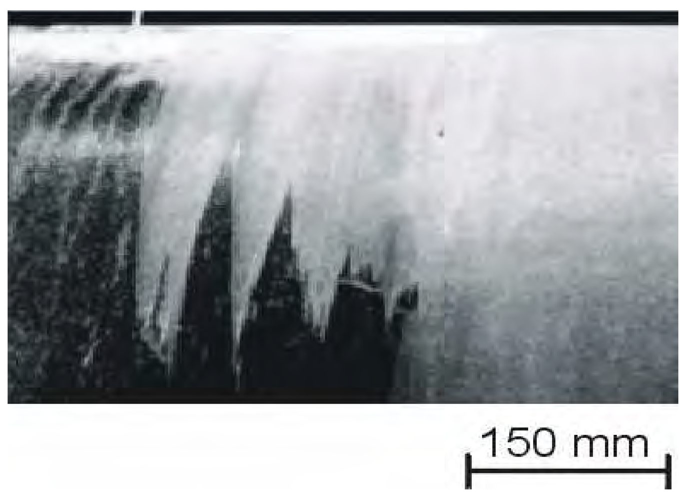
Damage of rolls in a hot rolling strip mill

Surface damage of work rolls determines their life-time and strongly influences the surface quality of the manufactured strip. The performance of the work rolls depends on several degradation phenomena, like mechanical fatigue, wear, thermal fatigue, and oxidation. It is well known that thermal fatigue is the most critical factor affecting roll surface damage at the first stands in the finishing train.

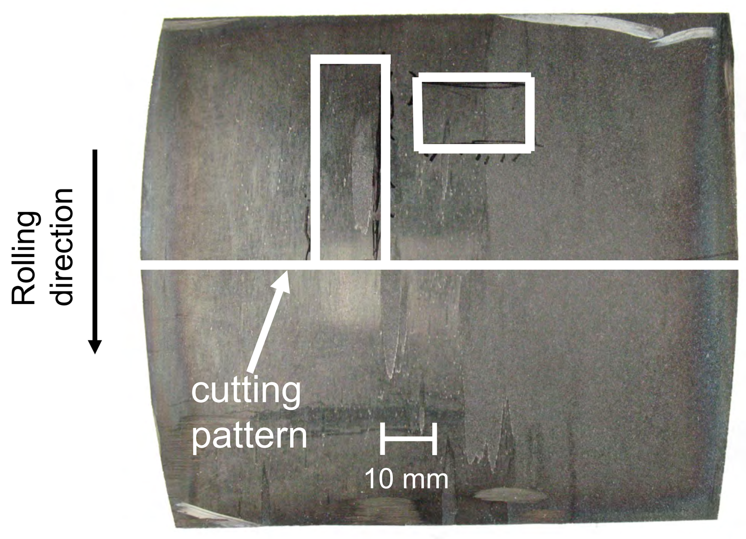
Chemical composition and phase content of the investigated material:

Chemical composition	C	Si	Mn	Cr	Ni	Mo	V	W
	2.82 %	0.63 %	0.95 %	14.84 %	1.32 %	1.13 %	1.15 %	0.04 %

Phase content (volume fraction)	Martensitic matrix	Primary carbides	Fine carbides
	64 %	22 %	12 %



Surface damage of an industrially used work roll

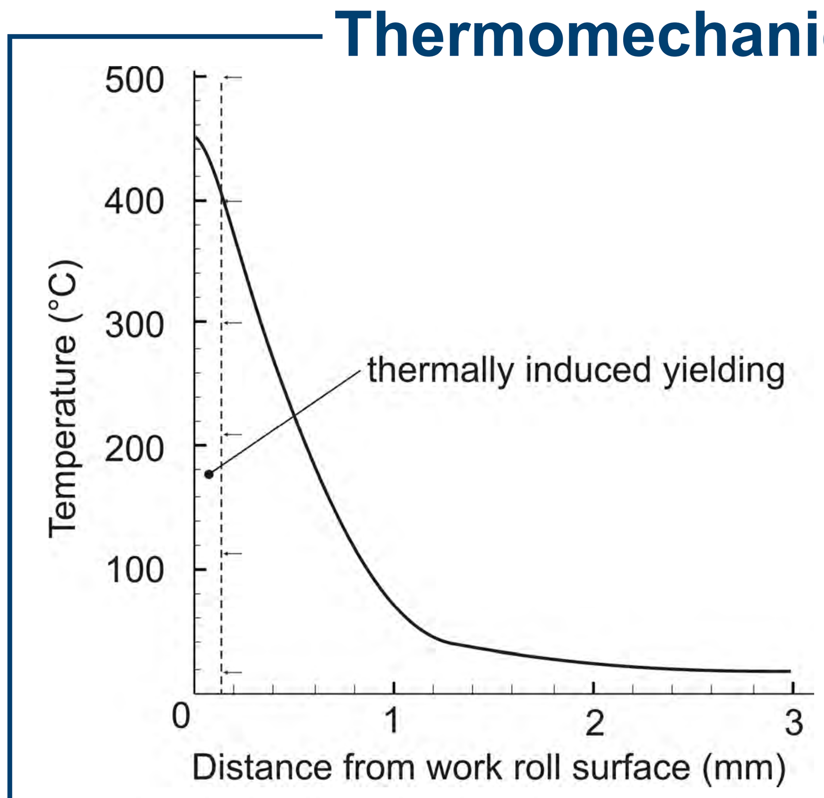


Investigated HiCr roll segment with banded surface

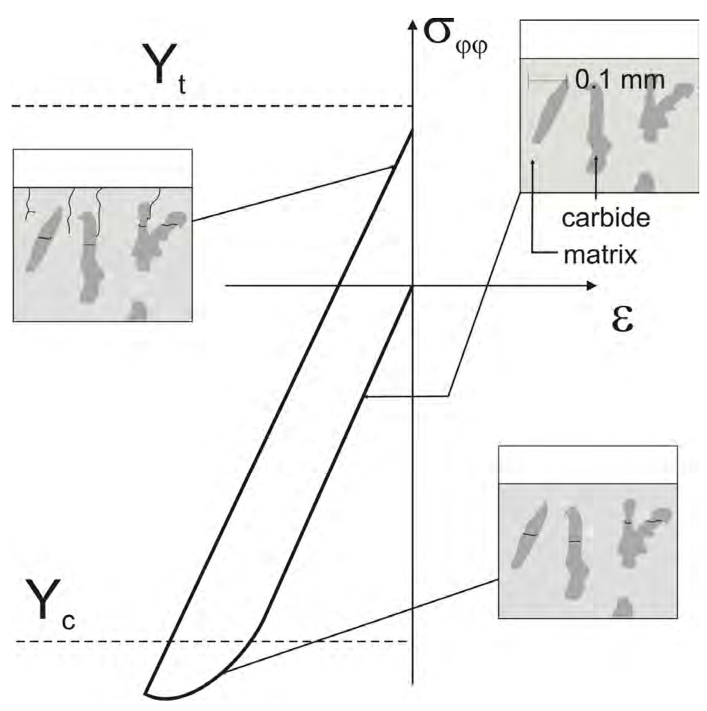
Observations

Banding is triggered by cyclic thermal loading and is assumed to occur in areas with a high density of broken carbides. Sufficiently high compressive loads in circumferential direction induce short cracks parallel to the roll surface within carbides. Tensile loads in circumferential direction lead to cracks perpendicular to the surface within the matrix. The damaged layer is separated by adhesion between the strip and the work roll or the back-up roll and the work roll.

Thermomechanical considerations

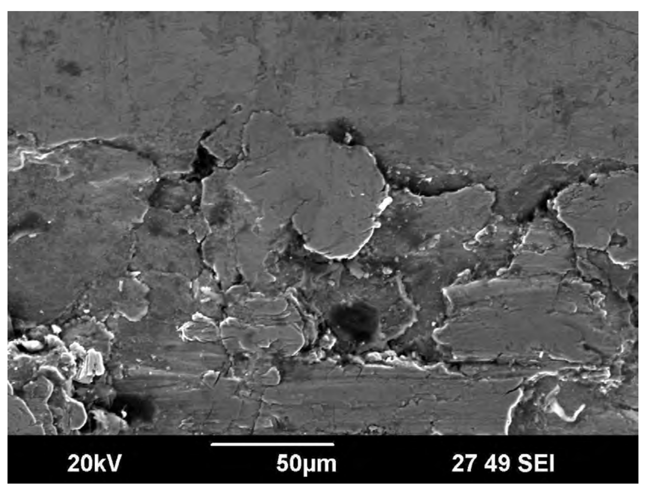


Analytically obtained temperature profile at the end of the rolling gap. Depth range of thermally induced yielding of the work roll material.

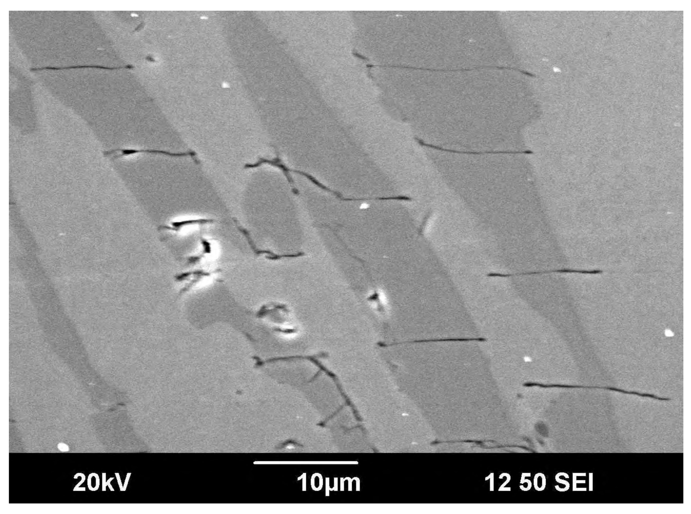


Stress-strain curve of one heating / cooling cycle. Depiction of crucial loading states inducing cracks.

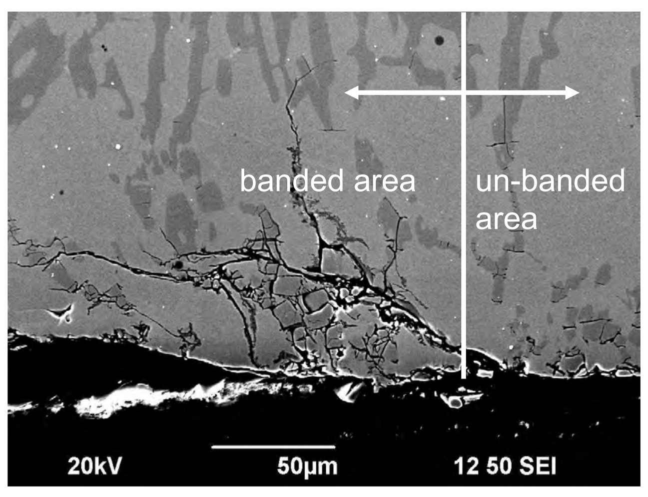
Damage appearance



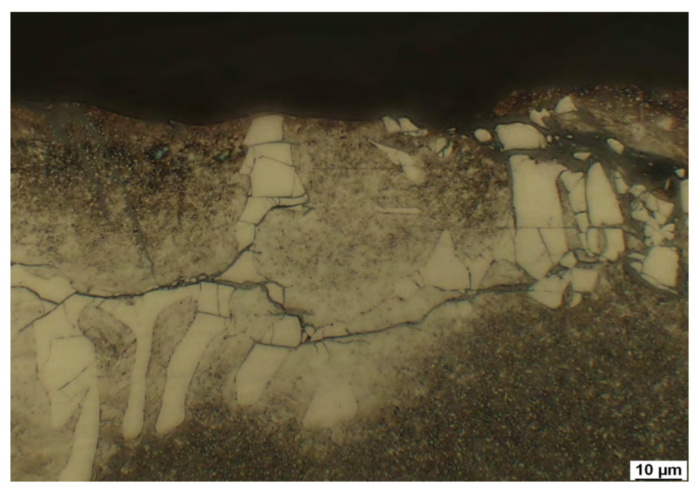
Transition of un-banded and banded area in topview on the roll surface, SEM.



Carbides fractured parallel to the roll surface (dark) and martensitic matrix (light), imaging perpendicular to the roll surface, SEM.



Transition of un-banded and banded area in lateral view, SEM.



Carbides fractured parallel to the roll surface (light) and martensitic matrix (dark). LOM, Nital etching.

Conclusions

Carbides show only cracks parallel to the roll surface, caused by a compressive load due to the high temperature gradient in the rolling gap. Crack propagation normal to the loading direction is assumed to be driven by tensile loads induced by high temperature gradients during cooling of the roll. Distributed short cracks of carbides and their coalescence with perpendicular cracks in the matrix (firecracks) combined with decohesion are the main failure mechanisms. Firecracks in areas without broken carbides are not critical regarding banding damage. Additionally it can be observed that the maximum thickness of the worn layers does not exceed 100 µm, which corresponds with the extent of the analytically calculated plastic zone.

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