



post on the understanding stresses in steel components during galvanizing of structural steelwork

new perspectives on thermal dynamics during dipping
MSc Vlastimil Kuklík PhD & al



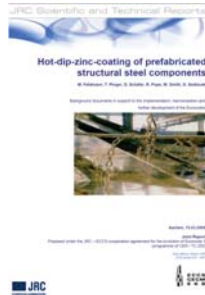
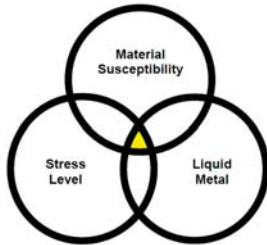
safety of galvanized steel structures



Stadium Fritz-Walter Kaiserslautern

liquid metal induced stress corrosion cracking?

state of the art 2009



experience from practice

large deformations

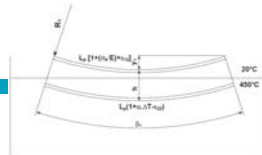


irrelevant deformation

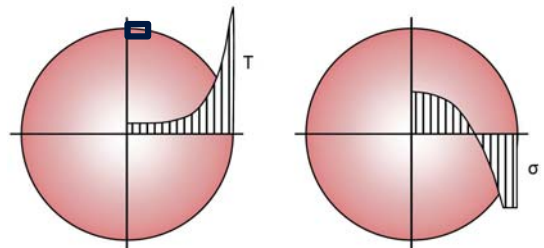


bimetallic variables thermal stress

$\sigma_{max} \approx 540 \text{ MPa}$
 $\epsilon_{max} \approx 0,515 \%$

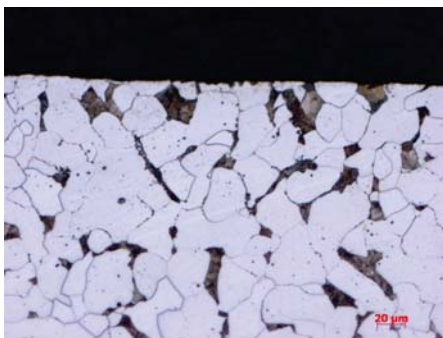


temperature gradient



temperature gradient

S355J2
ø 50 mm



before

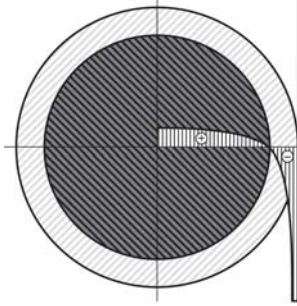


after



temperature gradient

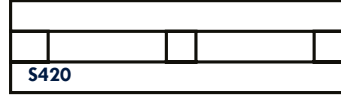
- on the tension rod acts additive tensile stress
- at the drawn bars will take effect the reduction of carrier-section



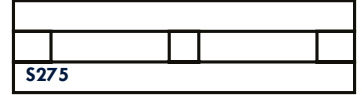
the susceptibility of high-strength steels to LMAC?

level of the reference
bimetallic thermal stress

$\sigma_{ref} = 0 \text{ MPa}$



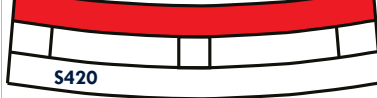
$\sigma_{ref} = 0 \text{ MPa}$



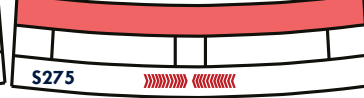
the susceptibility of high-strength steels to LMAC?

level of the reference
bimetallic thermal stress

$\sigma_{ref} = 420 \text{ MPa}$



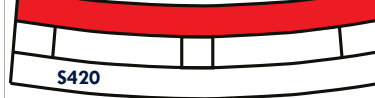
$\sigma_{ref} = 275 \text{ MPa}$



the susceptibility of high-strength steels to LMAC?

level of the reference
bimetallic thermal stress

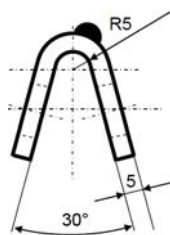
$\sigma_{ref} = 420 \text{ MPa}$



influence of stress and strain on the LMAC



experiments with samples of the "V"



S235JR
S355J2
 $\epsilon_{loc} \approx 50 \%$

influence of stress and strain on the LMAC

experiments with samples of the "V"



experiments with samples of the "V"

1. specimens squeezed of 10 mm

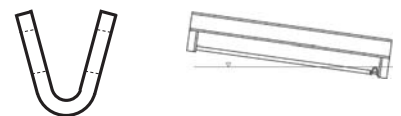


2. squeezed specimens immersed in the zinc bath



experiments with samples of the "V"

1. specimens immerse in the zinc bath



2. immersed specimens squeeze of 10 mm

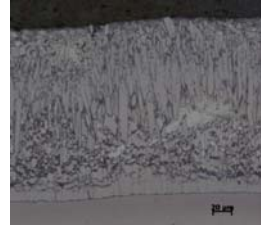




none crack

influence of tin

specimen "V" of S355J2 galvanized in a bath containing 2% Sn



influence of tin

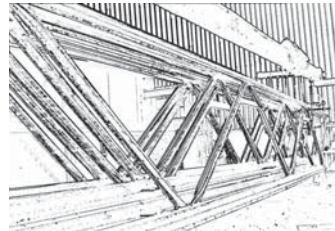
SEM analysis on the electron microscope JEOL JSM-7600F with resolution to 0.8 nm

none tin in steel surface



three-phase model of nucleation of LMAC

indicia for the hypothesis



three-phase model of LMAC nucleation

I. phase tensile stress



three-phase model of LMAC nucleation

II. phase compressive stress



three-phase model of LMAC nucleation

III. phase tensile stress

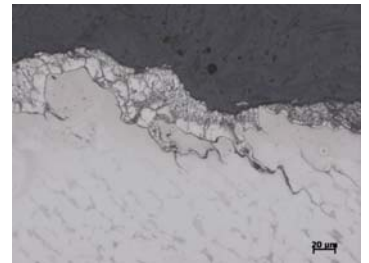


blasting stool for 3F simulation



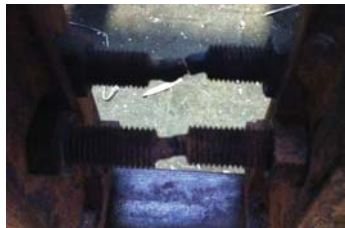


crack along grain boundaries



different nature of the quarry after 3F simulation

simulation of real conditions for the 3F model



different nature of the quarry after 3F simulation





S355J2 specimen notched



AISI 4130 specimen without a notch



classification

- crack originating in the weld..... 
- material cracks origin..... 
- LMAC type of „A“..... 
- LMAC type of „B“..... 

classification - crack originating in the weld

precipitation of phosphides, sulphides, silicates and carbides

dislocations and micro-cracks

hydrogen



classification - material cracks origin

precipitation hardening



tempering brittleness



classification - LMAC type of „A“ and „B“

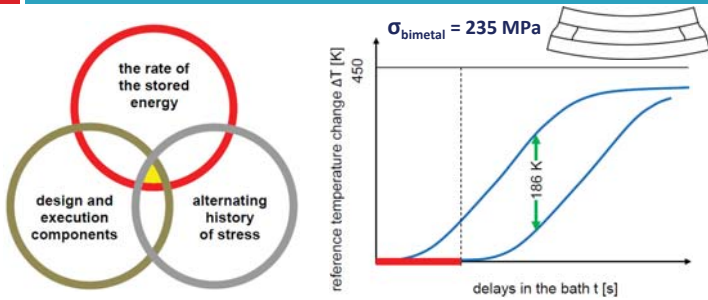
„A“ brittle braked rupture



„B“ crack formed upon cooling

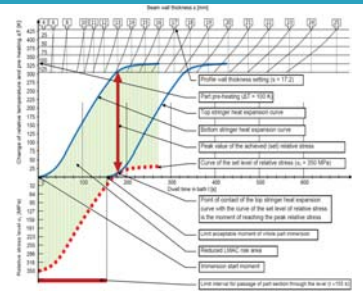


conditions for LMAC at galvanizing



control a susceptibility to LMAC

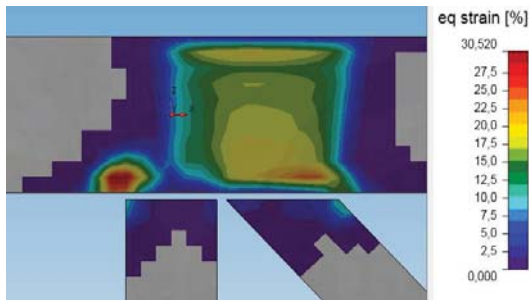
- application requires knowledge of curves warming profiles of different wall thickness
- the aim is to reduce the level of bimetallic thermal stress
- result of the assessment is the critical time for immersion parts into the zinc bath



CBFEM Component Based FEM

prediction of local stresses

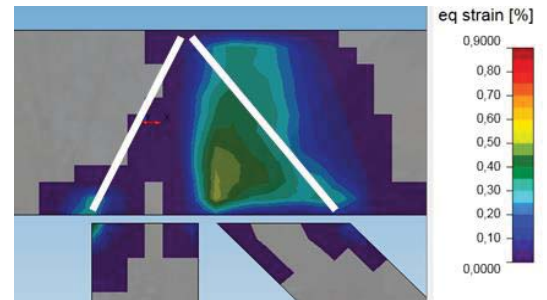
strain in joint without stiffener



CBFEM Component Based FEM

prediction of local stresses

strain in joint with two inclined stiffeners



responsibility designers

the primary obligation of the designer is to design the parts so they can safely withstand all the effects, which will be issued



responsibility designers

of course, these effects include thermal stress during galvanizing



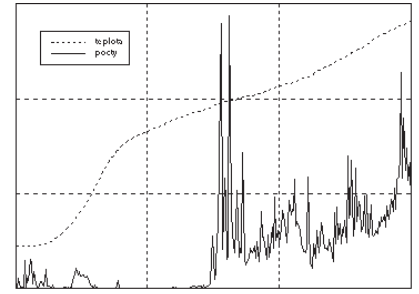
galvaizing with due diligence

but responsibility of the designer must be accompanied by competence galvanizers



nondestructive testing

alternative to NDT tests could be sensing of acoustic emissions during galvanizing



CZECH TECHNICAL UNIVERSITY
IN PRAGUE

EGGA
European General
Galvanizers Association

thank you for your attention