GTT User meeting – 2022

Application of private database development feature in FactSage for modeling the liquid steel solution

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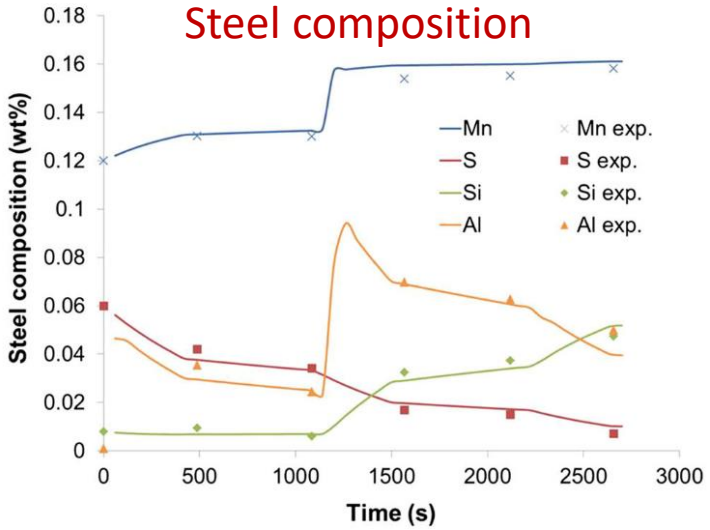
Contents

- Introduction
- Issue of calcium solubility
- Development of a private database in FactSage
- Comparison with FTmisc (Fe-Ca-Al-Mg-O system)
- Predicted calcium pick-up: steel-slag reaction
- Conclusions

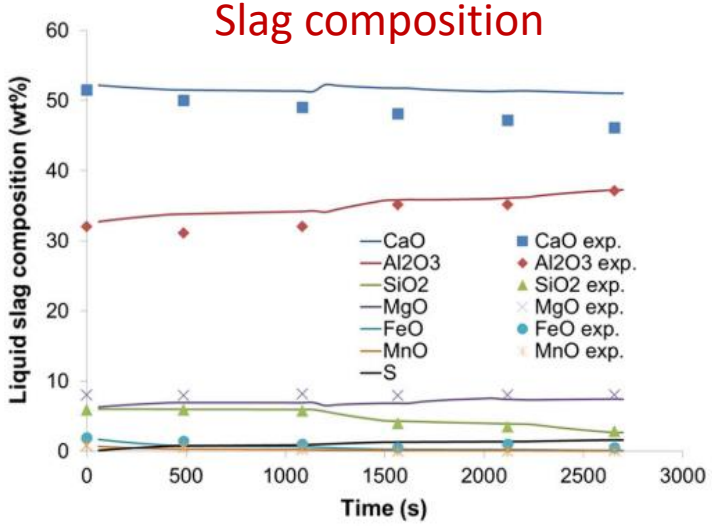
Introduction

- Steelmaking process: BF-BOF/EAF → Ladle/RH/VD →continuous casting
- Secondary steelmaking: composition adjustment, clean steel
- Modeling work:
  - Earlier focus: mixing in ladle, composition change of steel and slag
  - Recent focus: comprehensive model to determine changes in steel, slag and inclusion during secondary steelmaking; FactSage is popular here

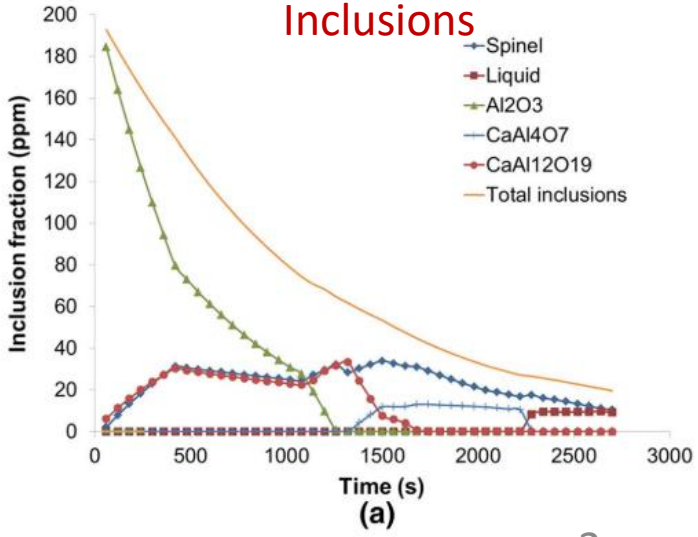
Steel composition



Slag composition



Inclusions

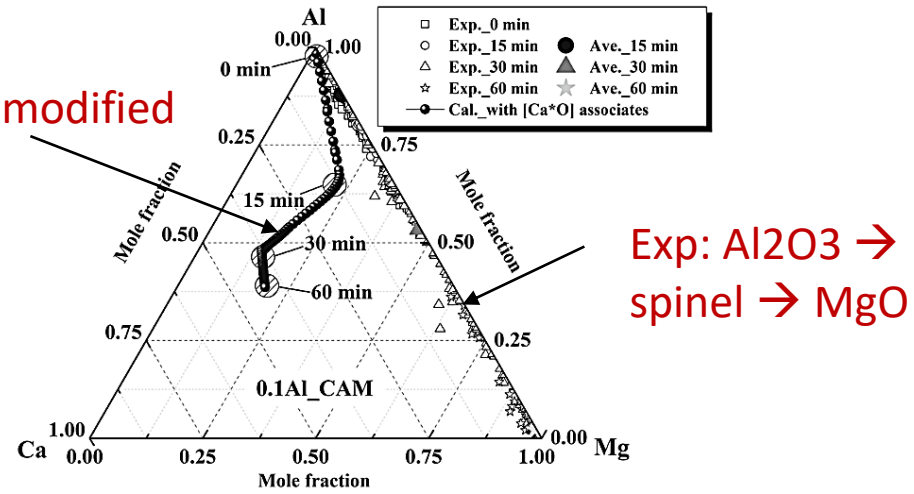


Ref.: Van Ende & Jung, MMTB, 48 (2017), page. 28-36

Inclusion prediction models

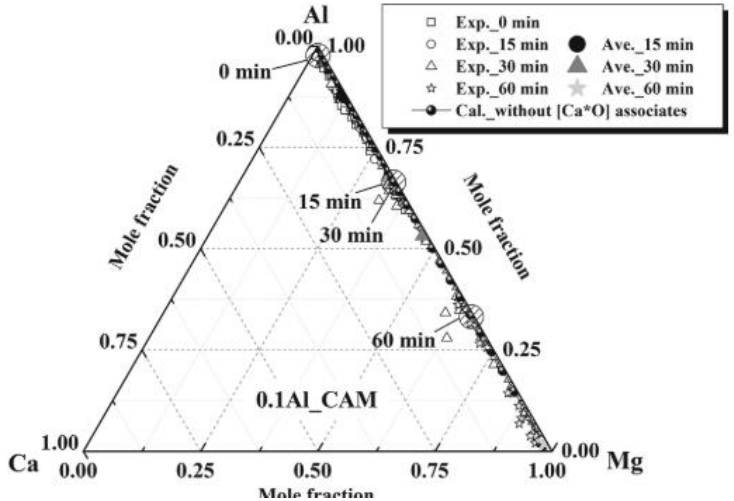
- Reaction between Al-killed steel and CaO, MgO saturated slag
- FactSage based kinetic model tends to predict higher CaO content in inclusions
- FT-misc without Ca*O associate shows better agreement with exp. for 0.1% Al
  - But it does not explain Ca pick-up in inclusions for other cases

Model: fully modified inclusion



Exp: Al2O3 → spinel → MgO

Steel (0.1% Al) with CAM slag in MgO crucible
Model: FTmisc with associate



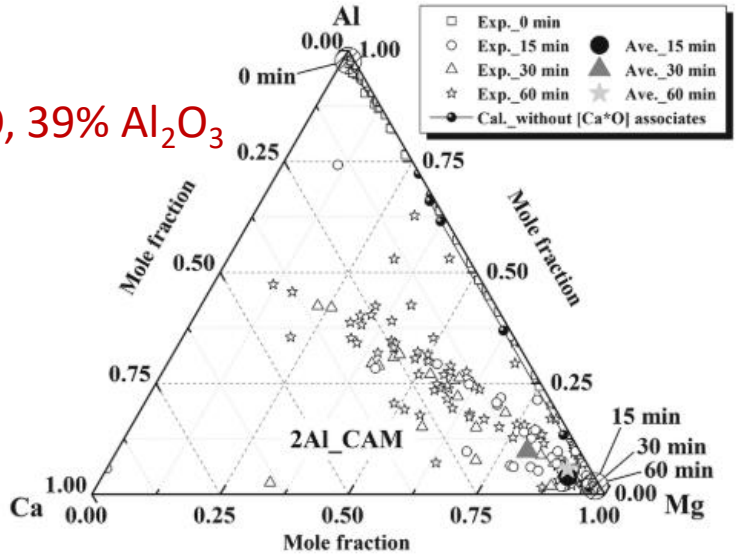
Steel (0.1% Al) with CAM slag in MgO crucible
Model: FTmisc without associate

Ref: Liu et al., MMTB, 51B (2020), 529-542

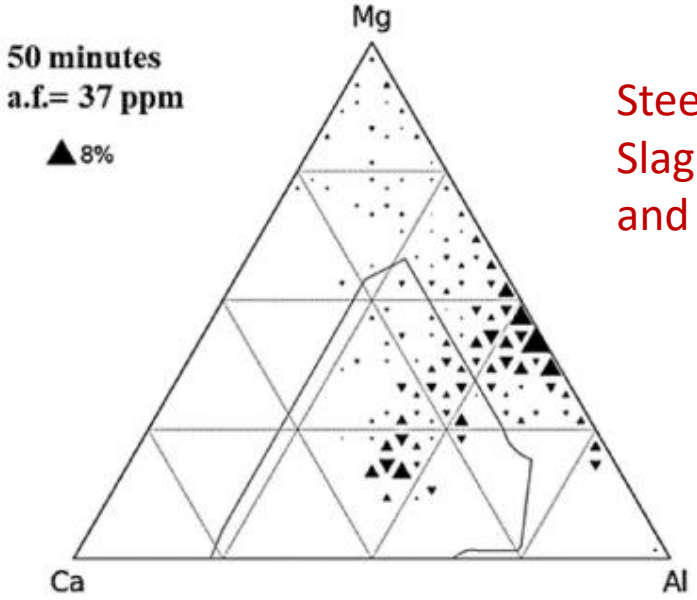
Conditions for calcium pick-up

- Combinations of slag composition, crucible material were tested
- Conditions for significant calcium pick-up in inclusions (without calcium treatment):
  - 2% Al containing steel in contact with double saturated slag
  - Addition of 1% electronic grade silicon in Al-killed steel in contact with double saturated slag
- Ignoring Ca*O associate does not help here!

Steel: 2% Al
Slag: 51% CaO, 39% Al_2O_3 and 10% MgO



Ref: Liu et al., MMTB, 51B (2020), 529-542

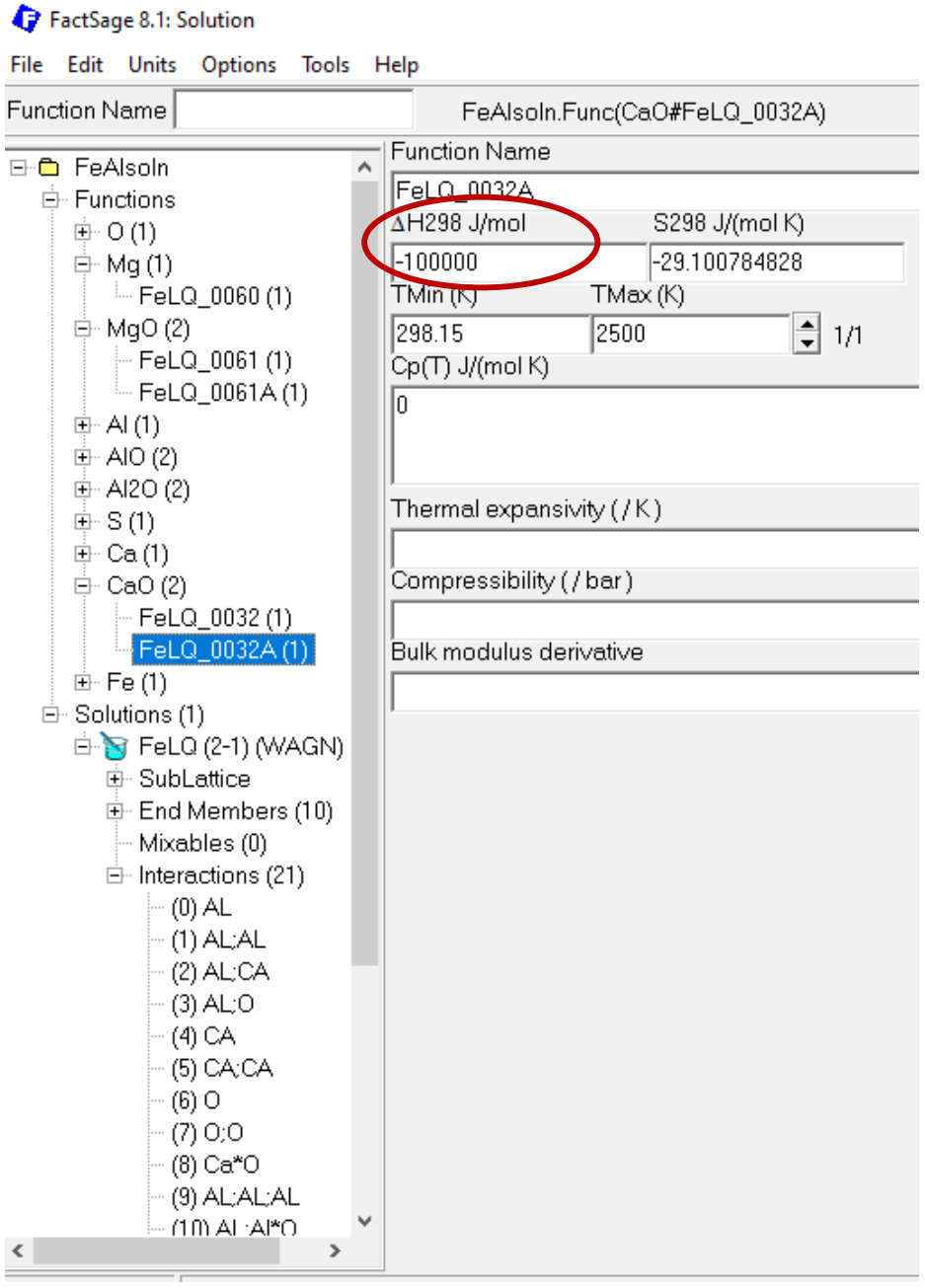


Steel: 0.3% Al
Slag: 51% CaO, 42% Al_2O_3 and 7% MgO

Ref.: Kumar & Pistorius, MMTB 52B(2021), 163-177

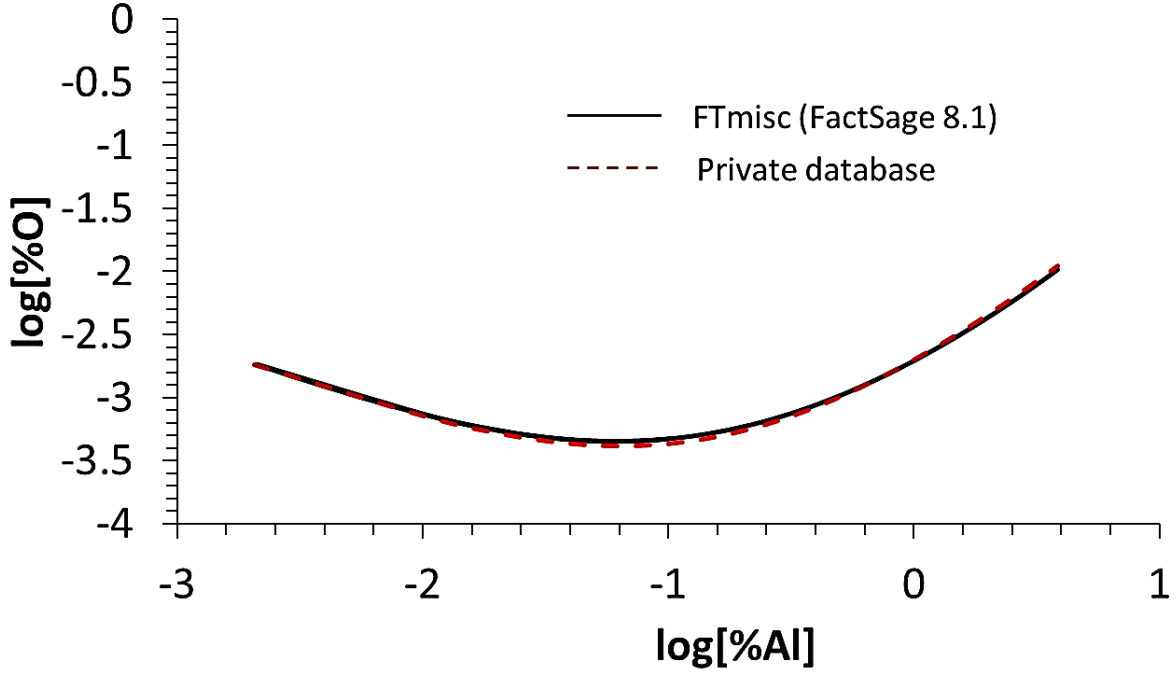
Current approach

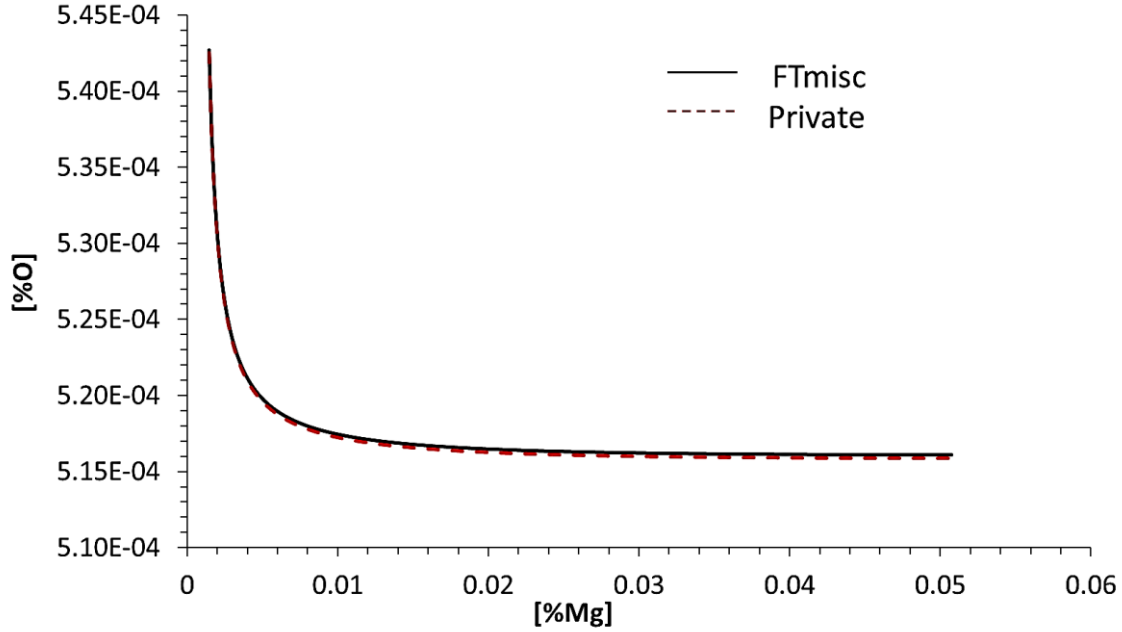
- Create an associate solution for liquid Fe using solution module in FactSage (private database)
- The free energy of associate formation for Al*O, Al*O*Al and Mg*O are found to match FTmisc
- Adjust free energy of formation for Ca*O that can explain experimental observations



Fe-Al-O and Fe-Mg-O: FTmisc vs Private

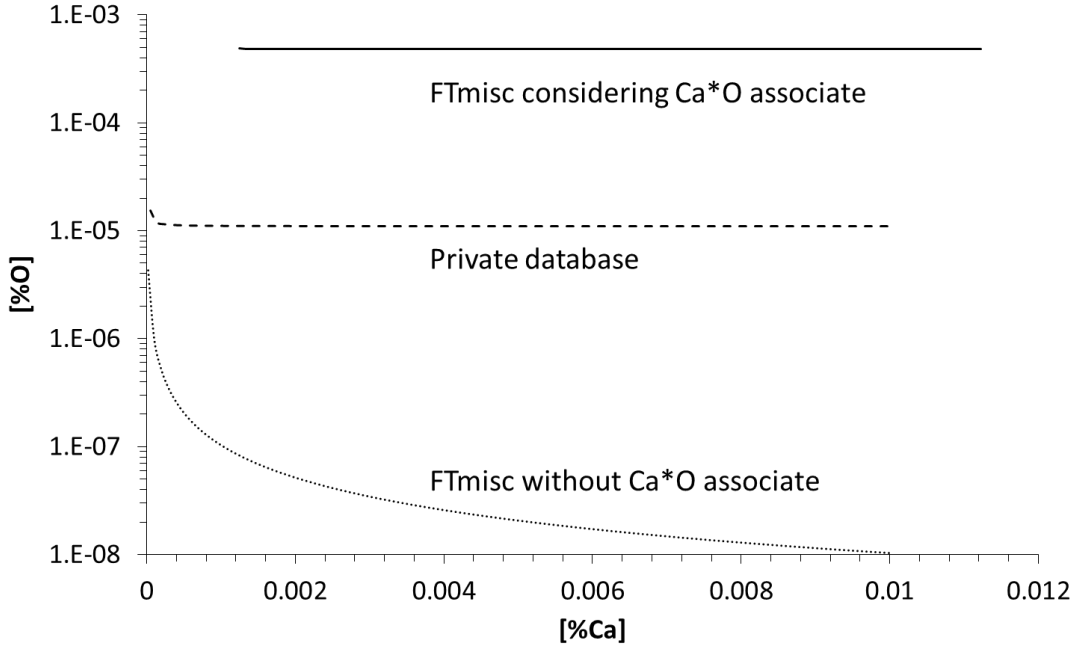
- The agreement between FTmisc and the private database is good for Fe-Al-O and Fe-Mg-O system



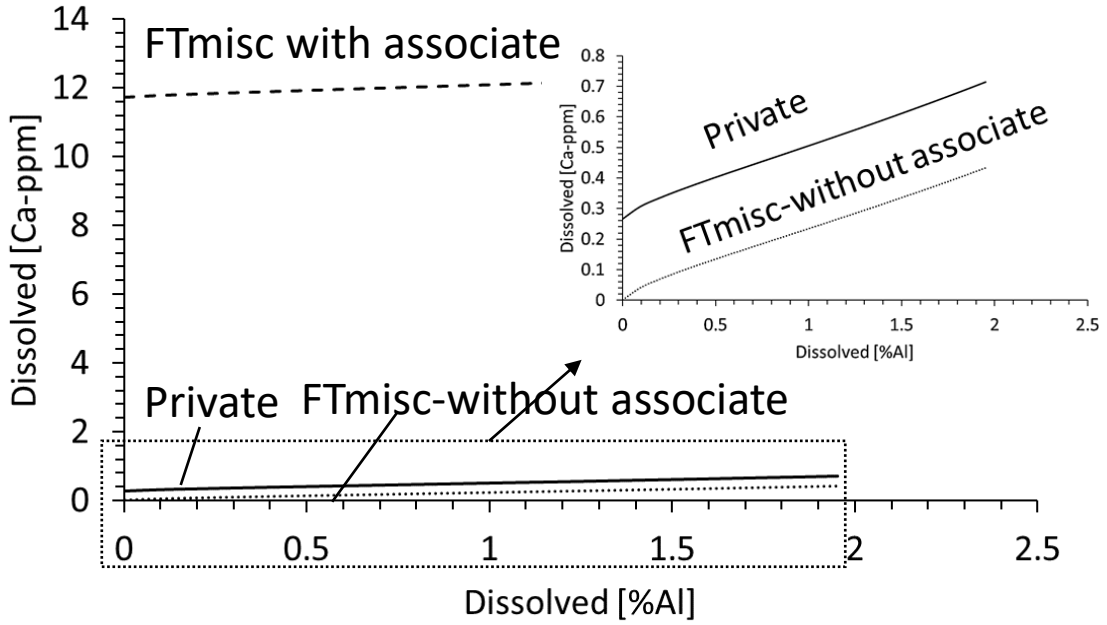


Calcium solubility: FTmisc vs private database

- Private database considers limited Ca*O associate formation
- $a_{CaO} = 1$



- 500 g of steel containing variable amount of Al is equilibrated with 75 g of slag (51% CaO, 39% Al_2O_3 and 10% MgO)



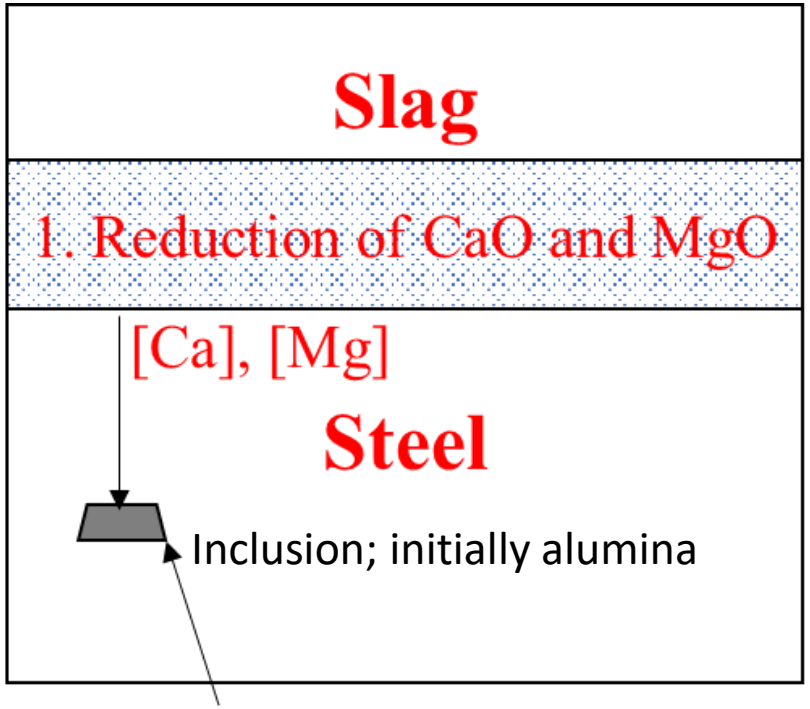
Kinetic model

- Calcium solubility is too low; difficult to measure
- Measuring inclusion composition is relatively easier
- Effective equilibrium reaction zone model
- Reactions/phenomena:
  - Steel-slag reaction
  - Steel-inclusion reaction
  - Inclusion flotation
- Inclusion transformation is a two-step process:
  - Reduction of CaO and MgO at the steel-slag interface

$$3(CaO)_{slag} + 2[Al] = 3[Ca] + (Al_2O_3)_{slag}$$

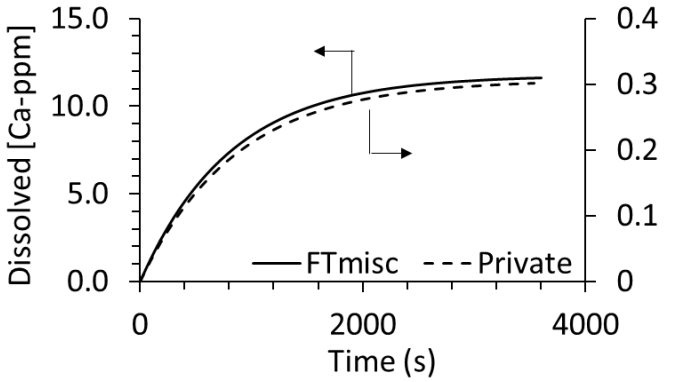
$$3(MgO)_{slag} + 2[Al] = 3[Mg] + (Al_2O_3)_{slag}$$

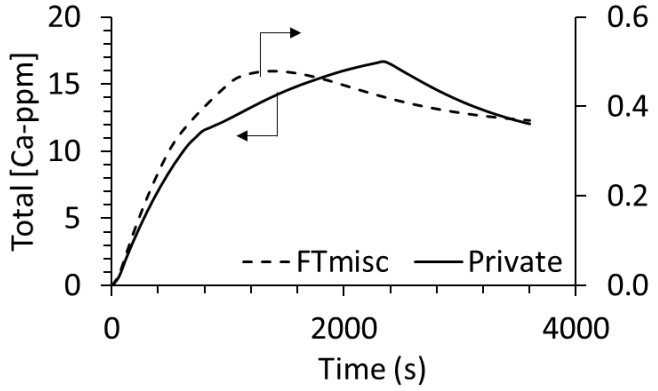
- Reduction of Al_2O_3 at the steel-inclusion interface



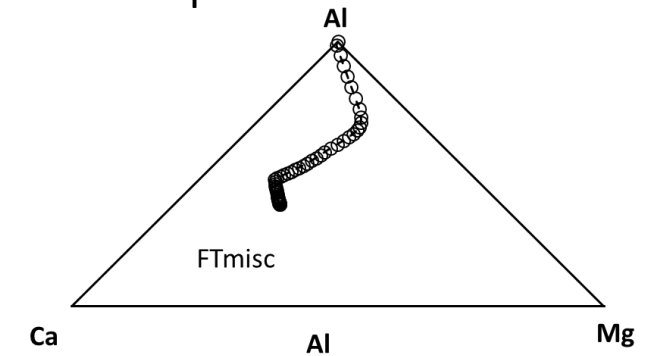
Calcium pick-up: 0.1 wt% Al

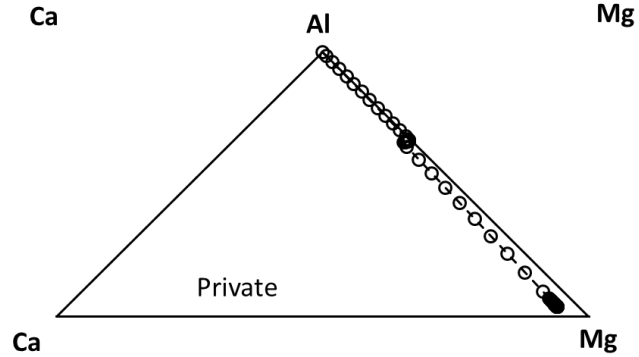
- Dissolved calcium is about 50-times less for private database
- Decrease in total calcium is due to inclusion flotation
- Predicted inclusion composition from private database is closer to experimental observation





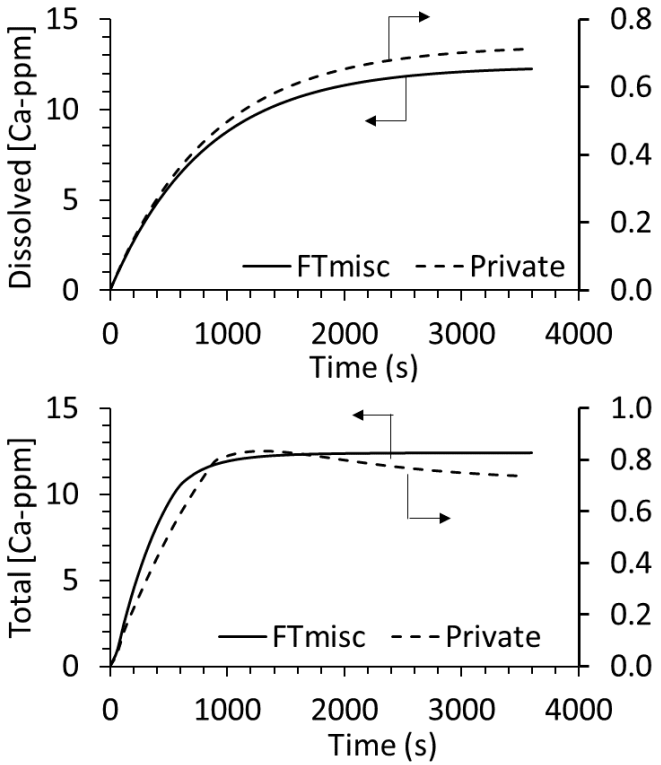
Inclusion composition: cation mole fraction

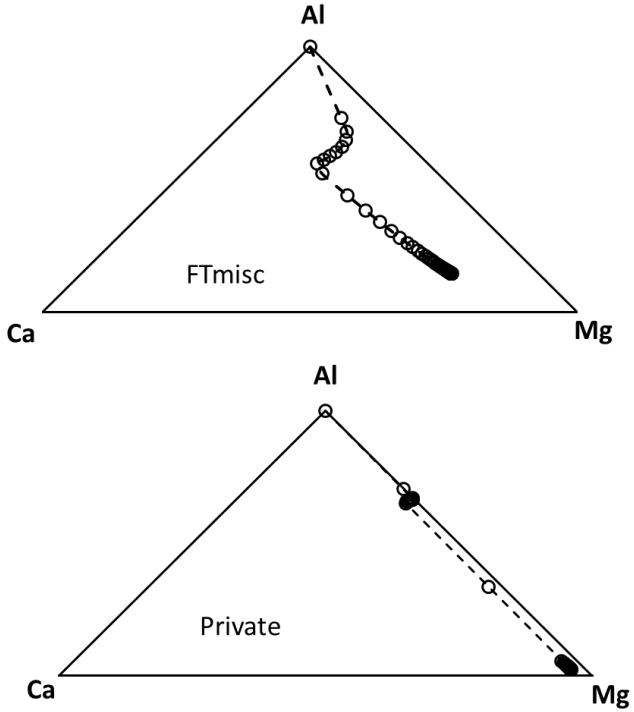




Calcium pick-up: 2 wt% Al with slag

- Private database significantly reduces calcium pick-up by the melt
- Kinetics of Ca and Mg pick-up is much faster





Conclusion

- An associate solution model developed in FactSage is an excellent tool to test experimental data
- Kinetic changes in inclusions during steelmaking may be used to test and understand the behavior of liquid steel solution
- More experimental data are required to resolve Fe-Ca-Al-Mg-Si-O system; silicon is to be incorporated

Acknowledgment

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Thank you ☺

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