Quantification of microstructure evolution under hot forming for the control of mechanical properties of high chromium steel

東京大学生産技術研究所　柳本研究室

Chair for Hyper-functional Forming
Institute of Industrial Science, The University of Tokyo
Eduardo Dupin and Prof. Dr.-Eng. Jun Yanagimoto

Chair for Hyper-functional Forming (CHF)

Research Topic

Low carbon steels which contains chromium at 10.5% or more by weight are generally known as stainless steels. It is this addition of chromium that gives the steel its unique stainless, corrosion resisting properties. They are usually hot formed with some difficulties when compared to formability of ordinary steels. This difficulty generally increases with the alloy content on the material and make these class of materials to deserve especial attention during the manufacturing process.

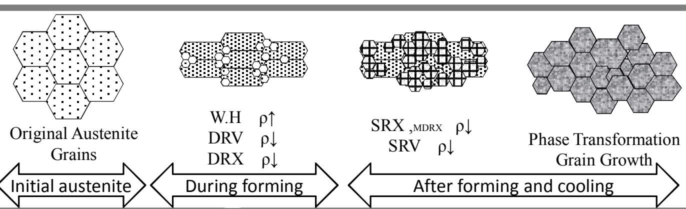
In this research, the microstructure evolution kinetics during hot forming of high chromium steels will be first derived based on single and double compression tests, micrographic investigations and inverse analysis[2,3]. This microstructure kinetics, known as the material genome, will be then coupled with a thermo-mechanical FE model in ABAQUS in order to predict the microstructure evolution during hot forming. The material genome provides the necessary material data to predict the flow stress for each step during the simulation.[6] The numerical results with transient changes in strain rate and temperature give us the results on microstructure and dislocation density of the metal under hot forming[1].

As post-processing operations, such as cold drawing, forging and heat treatments, are often performed on as –rolled materials, the second part of this research is dedicated to find a quantitative evaluation of the post-processing operations on the final microstructure of rolled materials. And at last, the relationship between mechanical properties and microstructure are estimated by a micromechanical FE model in ABAQUS.

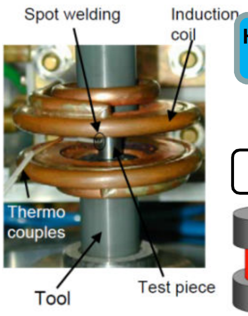
Materials

Steel	Chemical Composition (mass, %)									Class
	C	Si	Mn	P	S	Ni	Cr	Mo	N	
SUS420J2	0.36	0.37	0.52	0.031	0.021	0.23	12.28	-	-	Martensitic
SUS316	0.04	0.31	1.26	0.034	0.025	10.00	16.05	2.01	-	Austenitic
SUS329J3L	0.02	0.29	1.59	0.022	0.001	5.90	22.35	3.2	0.167	Duplex (Austenitic + Ferritic)

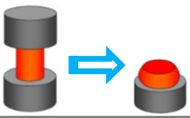
Microstructure Evolution[3]



Experiments[2]



Hot Compression Test → Load-Stroke Data



Material Genome Acquisition[2,3]

Thermo-mechanical FEM Analysis
- Inverse Analysis

→ Flow Curve

Material Genome
- Work hardening coef., c
- Dynamic recovery coef., b
- Critical strain, ε_c
- Rate of DRX, G
- DRX grain size, d_{DRX}
- Static recovery coef., b_s
- Time for 50% SRX, $T_{0.5}$
- SRX grain size, d_{SRX}

Coupled Microstructure and FEM[1,3]

Microstructural Model → Flow stress $\sigma \propto \sqrt{\rho}$ → Thermo-mechanical Model (FEM) → $T^{(n)}, \dot{\varepsilon}^{(n)}$ distribution → Microstructural Model

Influence of post-processing operations on the as-rolled microstructure and mechanical properties

As-Received Microstructure → Thermo-mechanical Processing[1-5] (Microstructure-control during forming process) → As-Rolled Microstructure

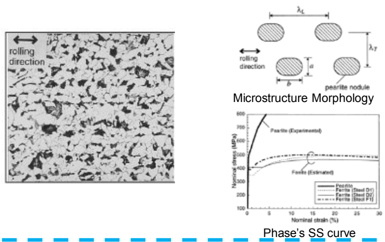
Post-Processing Operations
- Heat Treatment
- Cold Drawing
- Forging

→ Final Microstructure

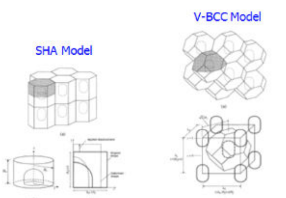
Micro-mechanical Model[7] (FEM (ABAQUS)) → Mechanical Property

Mechanical Properties Prediction[7]

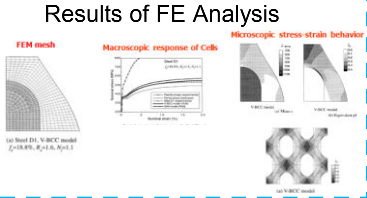
Microstructure Characterization



Micromechanical FEM



Results of FE Analysis



Basic References

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2) A. YANAGIDA. Doctoral Thesis, Japan: The University of Tokyo; 2007.
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6) R.L. PLAUT et al.. Materials Research. 2007; 10(4):453-460.
7) N. ISHIKAWA et al.. *ISIJ International*, 2000, 40 (11):1170-1179.