Example of Mathematical Models Available

Metal flow

- spread during rolling (evaluated and improved of approx. 10 methods)
- forward slip during rolling (evaluated and improved of 5-10 procedures)
- average roll diameter, work diameter and rolling speed
- tension correction for spread and forward slip
- steel grade or material correction for spread and forward slip
- free side contour of the stock after rolling
- homogeneity of local metal flow (especially for rolling of complicated sections)

Flow stress, force, torque and power

- over 10 ways of flow stress formulation, including those with activation energy
- reference flow stress calculated based on chemical composition
- flow stress determined from microstructure formation process
- mean flow stress
- roll separating force (evaluated and improved of approx. 10 different methods)
- contact area (evaluated and improved of approx. 5 prediction procedures)
- shape factor in function of roll gap geometry (for some procedures of force prediction)
- lever arm ratio in function of roll gap geometry and rolling process parameters
- rolling torque, power requirement
- effective strain, especially during low temperature, multi-pass rolling
- force, torque and power during high speed rolling (strain rate up to over 3000/s)
- tension correction for force and power requirements

Roll deformation and strength, mill vibration

- elastic deformation of rolls and stand
- stress concentration in the roll neck
- roll strength and stand capacity formulation
- model to determine material (e.g. Tungsten Carbide) and grade used to produce rolls
- vibration of stock, roll and stand, especially in high speed rolling

Heat transfer and temperature

- heat transfer and heat balance during casting
- heat loss and temperature process during transportation on roller table
- temperature and heat balance during reheating
- energy balance and temperature process during rolling
- interactive relationship between temperature and power requirement during rolling
- heat transfer coefficient during rolling, depending on scale formation, roll cooling, pressure
- heat transfer coefficient during controlled water cooling, in function of water flow (GPM), flow speed (FPM), water temperature and water pressure, etc.

- heat transfer coefficient during controlled air cooling, in function of air flow (GPM), flow speed (FPM), air temperature and air pressure, etc.
- heat transfer during controlled emission cooling

Microstructure formation

- phase transformation during casting (to be completed)
- austenite grain size change during casting (to be completed)
- grain growth during billet transportation
- grain growth during reheating
- strain or time at the start of recrystallization, dynamic recrystallization during rolling
- static and metadynamic recrystallization in the interpass time
- grain growth in the interpass time
- phase transformation during controlled water cooling
- phase transformation during controlled air cooling

Rolled Product Properties

- mechanical properties after rolling and controlled cooling, based on microstructure simulation
- mechanical properties after rolling and controlled cooling, from empirical estimation based on steel composition, grain sizes and primary rolling and cooling parameters. This is a collection of formula currently used in various steel plants and published by various authors. Examples are equations describing recrystallized grain size and ferrite grain sizes for major steel grades, and equations describing lower yield stress and tensile strength for 10 major grades

Material Data and Boundary Conditions

- flow stress in function of strain, strain rate, temperature and initial grain size
- friction during various rolling processes, in dependence on scale formation, stock and roll materials, relative speed stock/roll, rolling temperature, roll pressure and gap geometry, etc.
- specific heat in function of temperature
- E-modulus and Poisson's ratio in function of temperature
- other thermal and mechanical data such as thermal conductivity or temperature conductivity, density, etc., in function of temperature

Others

- A simplified FEM model, particularly suitable for coupling with roll pass design software, to determine local metal flow, temperature and microstructure, etc. at only approx. 0.5% of computational cost of a regular FEM model. Slab method is used to determine parameters in the length direction, and FEM method to predict parameters over the cross-section. Cross-sectional reduction, forward and backward slip, etc. are provided by a roll pass design program.
- Finite differential model, to be employed to determine temperature distribution and average temperature during casting, reheating, interpass cooling, rolling and controlled cooling, while the empirical models are used to predict other process parameters.