BECK ENGINEERING

eCFD

THE FUTURE OF MINE VENTILATION MODELLING

WHERE MULTI-SCALE MEETS MULTI-PHYSICS

Powered by enhanced CFD (eCFD).
Multi-GPU LBM solvers, sub-metre resolution at mine scale for ventilation design in the deep-mining era.

WHY IT MATTERS

Ventilation is a critical control in all underground spaces, becoming increasingly complex when considering temperature, gasses, dust, moisture and multi-scale geometries. Conventional ventilation simulation methods simplify the airflow physics, providing reasonable estimates for simple circuits. Uncertainties increase as complexities are considered in ventilation simulations.

WHY eCFD

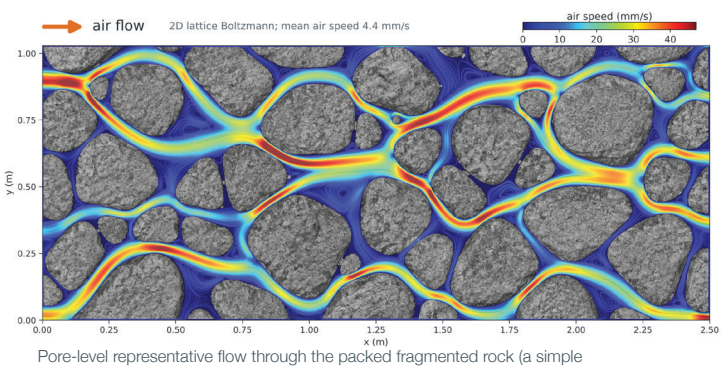
CFD approaches have been applied to mining, but are typically limited in computational capacity, rendering them inefficient at mine scale. Building on a decade of multi-scale, multiphysics simulation expertise, Beck Engineering has developed the eCFD framework on lattice-Boltzmann method (LBM). eCFD is a thermodynamically consistent ventilation simulator, coupling turbulent airflow, reacting multispecies gas transport and heat transfer.

WHY NOW

Underground mines are getting deeper and hotter, with more complex layouts. In such environments, the multiphysical (thermal, hydrogeological, geomechanical) phenomena and their interactions are of greater concern, whether the operation is block cave, sublevel caving, open stopes, room-and-pillar or longwall. Simplified low-resolution ventilation models cannot fully represent the airflow physics that such complex environments.

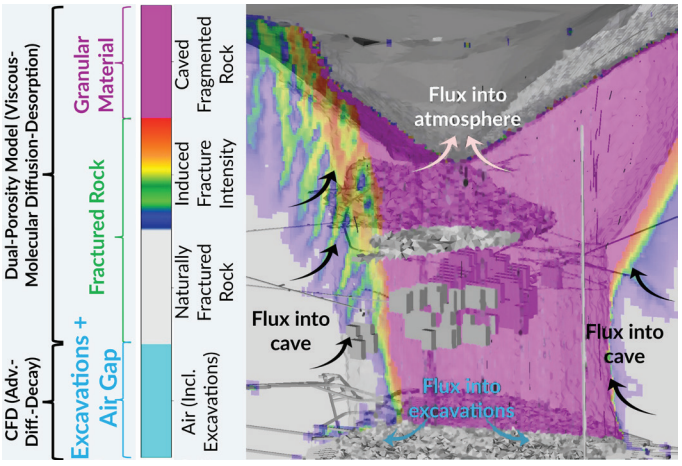
MULTI-SCALE IN THE DEEP MINING ERA

In challenging environments, mine ventilation design should account for phenomena at multiple scales, from pore flow in the broken rock fragments, through the muckpile and air gap, to the drawpoints on the extraction level. To this, add particle-scale phenomena like methane generation from coal, or radon emanation from ore. eCFD resolves these together and, linked with Beck Engineering's caving simulations, follows them through each stage of the mining.



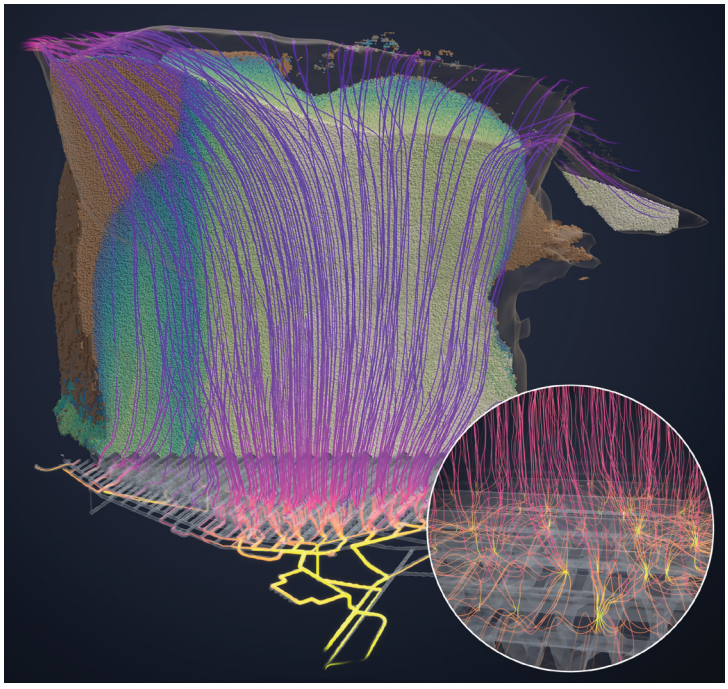
Pore-level representative flow through the packed fragmented rock (a simple schematic LBM model of fluid flow through porous media).

WHAT MINE-SCALE eCFD REVEALS



A conceptual mine: air and gas flux into the cave, out to the atmosphere and into the excavations, resolved across caved rock, fractured rock and open voids.

<1m	MULTI-SCALE	COUPLED
Resolution across a 2+km mine	From fragment to mine scale	Air, gas and heat in one solve



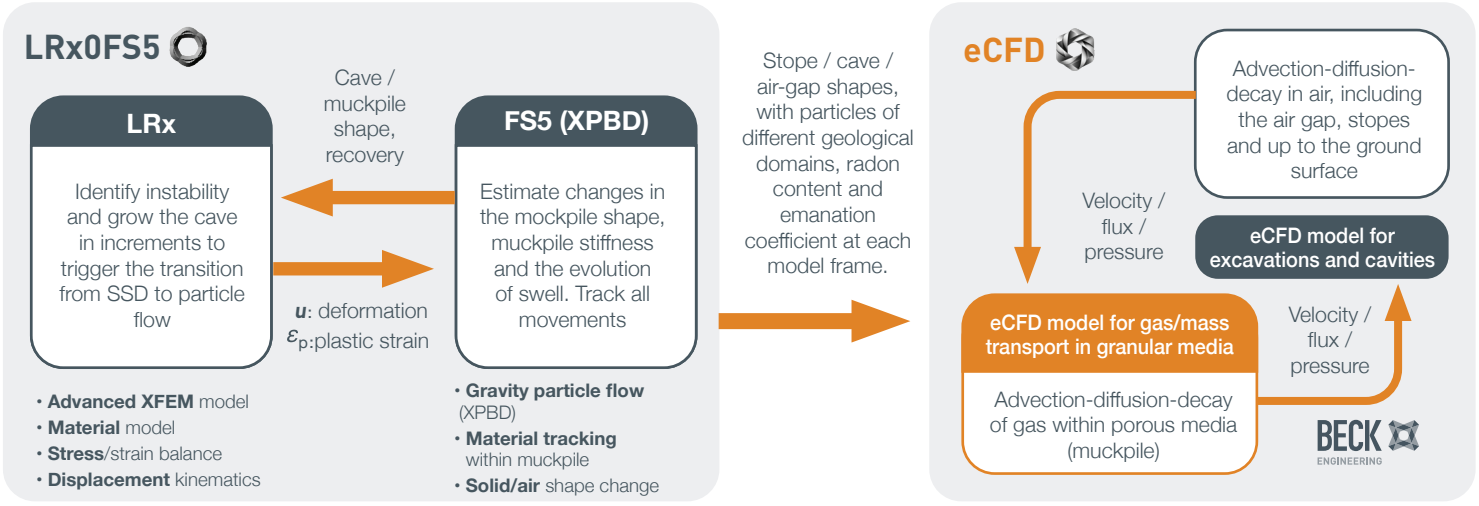
The cave breathing: modelled airflow rising through the cave; inset, air converging on the drawpoints.

HOW THE THREE APPROACHES COMPARE

	Network models	Conventional CFD	Enhanced CFD (eCFD)
How it computes	1D pipe network — no flow physics	One huge linked solve	Local steps, neighbour to neighbour
What you model	One number per airway	3D field — mesh-limited	Full 3D field for all geometries
Resolution	None — blind inside openings	Coarse — fine detail lost	<1 m over 2+ km
Real-world physics	Little: Kirchhoff laws	Bolted-on approximations	Built in
Hardware & scale	Laptop — barely computes	CPUs — scalability issues	GPUs — massively parallel
Mine 'live' digital twin	Never live, never local	Out of reach	Achievable

Real-world physics = turbulence, flow through broken and caved rock, mixing gases and heat. eCFD handles them natively.

FROM A MODEL TO A FULLY COUPLED SYSTEM



LRx–FS5 supplies the evolving cave, air-gap and muckpile geometry; eCFD returns velocity, flux, pressure, gas and temperature, today and after the next draw.

WHAT IT TELLS YOU ABOUT YOUR CAVE

Applied to a cave mining, the coupled rock-to-air workflow tracks naturally occurring radon from the rock into the air that carries it away.

What that gives a ventilation team:

Ventilation system design. All ventilation circuit components such as fans, boosters, regulators can be considered in the simulation, allowing for rapid testing of ventilation design options.

Coupled multi-physics. Nonlinear rock mass behaviour (LRx), cave flow, muckpile, airgap, and fragmentation (FS5) and gas transport (eCFD) are solved on the same evolving geometry, closely coupled frame by frame.

Complex 3D geometries. Entire mine is simulated, including vent rises, escape ways, crosscuts, declines, stopes, and caves, revealing short-circuiting and fresh-air mixing in evaluating whether a working area is ventilated.

The cave-excavation interactions. Transient fields can show how airflow, gas and dust concentration, can flow between the extraction level drawpoints and the evolving airgap/muckpile volume, at every stage of the draw. The spatial variability of gas-generating muckpile can also impact the gad concentration within the mine, and consequently the adequacy of a ventilation design.

DETAILS
Forecast gas, dust and heat hazards forming in the pockets and dead zones coarse models average away.

POTENTIAL
Opens the way to ventilation-ondemand and optimised fan & shaft placement.

DESIGN
Size and place fans, shafts and regulators against a true 3D field before construction, not after.

PHYSICS-BASED
Mine-scale 3D airflow that moves with the cave. More physics are being added.

BECK ENGINEERING

Simulation Aided Engineering in Extractive Industries

Let's Talk

Bring us your ventilation question. We start with a pilot study on one area of your mine, shape the tool around what you need, and scale up to the whole mine.

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