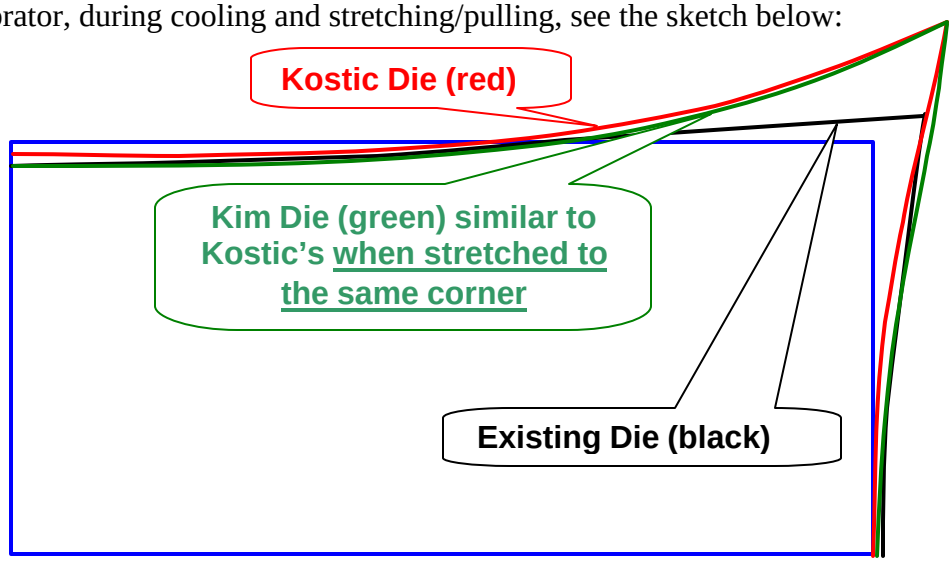
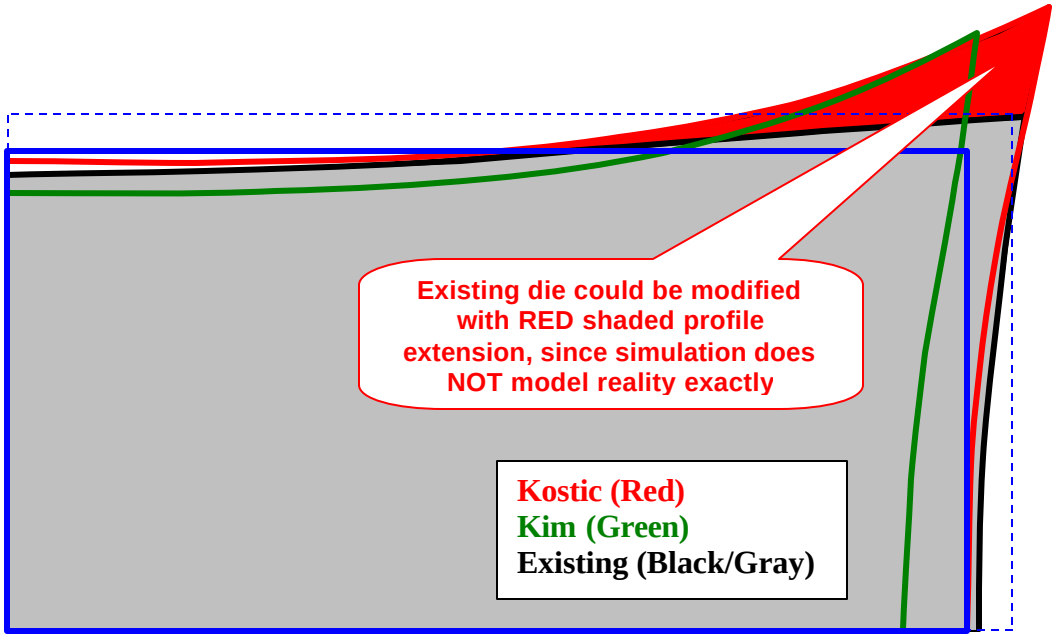
Extrusion Simulation Comparison:
After-12/9/03-Meeting Comments *(by M. Kostic)*

To further help you in simulation evaluation and your decision, I will summarize important points about the simulation as related to actual extrusion and final objective in getting good quality and dimensions of the extrudate final product.

1. The two new die-profiles, by Kim and Kostic's teams, are virtually the same if scaled to 5% increased final profile, as is the usual practice (including existing die) due to shrinkage in calibrator, during cooling and stretching/pulling, see the sketch below:

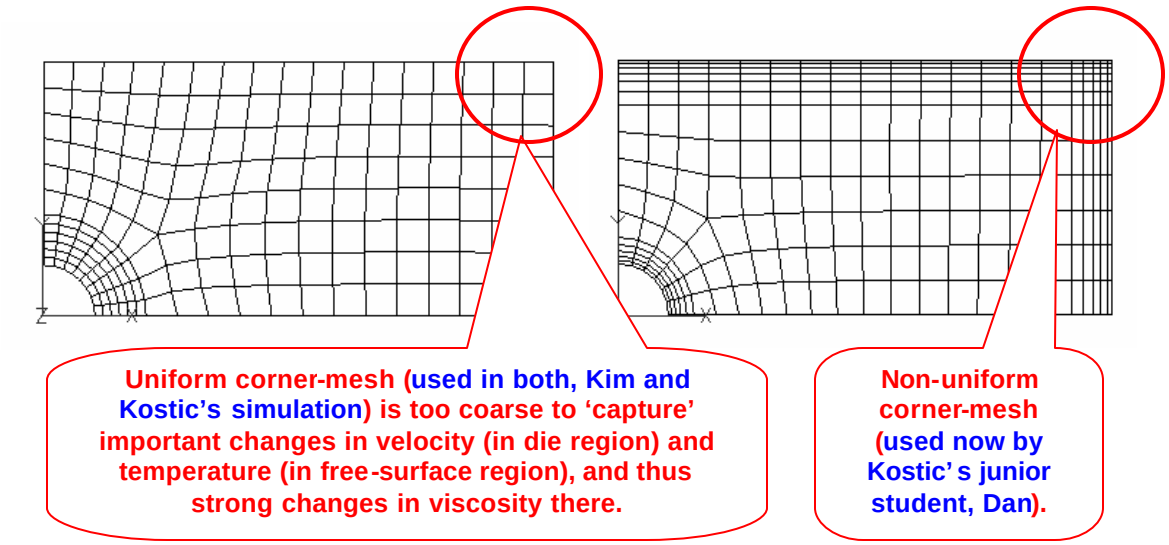


2. If the profile before the calibrator is exactly the same as final product, then calibrator will not have 'extra bulk' to finalize or size the final dimensions, let alone shrinkage after calibrator.
3. If customary 5% allowance is used, then existing die may be modified for additional corner extension, see the red-shaded corner-area on the sketch below:



4. It is not surprising that Kim and Kostic teems' simulations are very similar, since they represent almost duplication of the same simulation: similar mesh, material and boundary conditions, using the same commercial software (will be elaborated in another correspondence).

5. The minor differences in the two simulation results are irrelevant since both modeling are approximations: (1) do not include important viscoelastic properties, (2) simplify many boundary conditions (zero radiation heat transfer, zero pressure in inside-surface hole and outlet, etc.), and (3) do not have fine enough non-uniform mesh in the corner area and in the axial flow-direction in vicinity after die-exit, where changes in velocity and temperature field are the largest, see sketch below:



6. Dr. Kim's claim that his simulation is rigorous is without due justification, his team never validate their simulation against any well-established results. Furthermore, Dr. Kim's arguments that their simulation is superior to Kostic's because they used transitional region before die-land plate, longer free-surface region and did not use the 5% usual allowance, indicate that their comprehension of physical problem is questionable (I will elaborate with specific facts in another correspondence). In fact, <u>too large free-surface region is not necessary</u> since the relaxation of stresses and redistribution of velocity profiles is mostly taking place in close proximity after exiting the die. Also, <u>influence of pre-die-land flow on simulation results is minimal</u>, since purely viscous non-Newtonian viscosity model (we both use) does not account for fluid upstream history (has no memory), i.e., the flow results, for a given (fixed) inlet conditions, are not function of upstream flow conditions (except that inlet BC will somewhat change). <u>However</u>, this will become important when we include viscoelastic fluid properties in the future.

7. In any case, if influence of any input parameter (geometry, meshing, BC, properties, etc.) is expected (or to be ruled out), it should be varied and verified (quantified) by simulation, before one self-praise his results or criticize the others. Moreover, claiming that any current simulation is very rigorous is troublesome to say the least, when we know for fact that modeling has a number of critical simplifications (not accounting for a number of important physical parameters, as I already stated elsewhere) and the corner- and near-die free-surface uniform meshing is inadequate.