MOOSE Grading Part 3

Anthony

Good intro, outlining the problem(s). Quotes in latex are ``your text”. Otherwise they are backwards. Good explanation of mesh convergence setup. Good explanation of how burnup was included. Should have defined that burnup is in FIMA. You should have defined what the other eigenstrains are. What is SFP and GFP? Need to define all your terms. Could have elaborated on the gap conductance and the contact module, youre pretty brief. The discontinuity in the error for figure 1 is likely from having mesh elements which contain both gap and non-gap materials. So you get a mixture, and that leads to errors. Don’t think you talk about fig 2b. If you show it, you should discuss it. Fig 8/9 should be referred to as figures in the appendix. Ideally you would have relabeled these as A1/A2. Should have mentioned the burnup when your gap closes. Your gap closure profile looks really good. You didn’t label fracture stress in fig 7b, but I assume it is the dashed line. Showing the stress profile as a function of r early in life would have been beneficial, perhaps more so than showing stresses vs time. You don’t present your BCs for part 3 anywhere? Should have reported on stress free T. Overall this looks great. Minor quibbles with some things, but largely you nailed it.

Grade: 98

CeCe

Wouldve preferred a paragraph style discussion of each part of the problem, instead of a numbered list. Your listed mesh for part3 doesn’t match what you did in the input file. Also, you don’t state that you are not meshing the gap in part3, which leads to a confusing discussion of your mesh convergence study for part3. Appropriate choice of materials, good justification. Mislabeled figure 3 in text. You meant fig 4. This continued in your figure labeling. Would prefer equations to be written, instead of copy/pasted into the doc. You don’t properly refer to your equations in the text, they are just listed as (#), and sometimes occur after periods. Just sloppy formatting. Fig 6 is analytical, but based on the initial Q value at t=0? Its not clear. Don’t like the way you did the y BCs. I would have preferred y to be unconstrained, allowing axial expansion of the pellet. I don’t like fixing the gap conductance, but I understand the complications. Part1/2 results all look good. Appropriately handled burnup, but your discussion didn’t fully explain how you did it. Your input file looks good. Gap versus time looks good, except that it goes negative. I like the temperature versus time plots. Fuel stresses look good, good analysis. Numbers all look reasonable. Would’ve liked to have seen the burnup equivalent for time when the gap closes. Overall very good. Bit sloppy in parts of the report. I will assume that my version of moose cant run your file because of version differences, as everything else seems correct.

Grade: 96

Cole

Would have liked an overall introduction. I like the way you structure the discussion of each part, breaking it down to what goes into the moose blocks. Makes it very ordered and organized. Parts 1 and 2 look good. Appropriately converted burnup to time. Appropriate properties for part 3. I was able to use different meshes than you, and still get it to run fine. So i don’t know why you had trouble with it. I think your meshes are likely too coarse. Don’t like your justification for restricting expansion in the y direction (you state this as z). Pellets can and should expand axially. Why did you only simulate for a fixed period of time? This time is also way too short, you shouldn’t be coming close to gap closure here. I ran your code, and I can run it out to very large times, without any errors. You don’t show any plots of stresses. Your stresses should be compressive in the fuel, and at a minimum (most negative) value at the centerline. 2.1 GPa is a super high stress. Did you not visualize your system to see if contact was made? I doubt it. I think the code your wrote was very close, but needed more careful analysis. You could’ve gotten all the way, but I needed more.

Grade: 90

Gwen

Good intro. I would say that contact is not required for stresses in the fuel. Only a temperature gradient leads to stresses. Contact then modifies the stress state of the fuel. Still think part1 results could have been cleaned up to better match the analytical solution. Proper definition of burnup. Proper equations for kth with burnup. I don’t like the justification for the axial BCs, but I understand it. In theory, I wanted expansion to be unconstrained in your y direction, but it shouldn’t make a difference with the stress state. Your equations 14-16 seem out of place in the text. Why does fig 3 show a big difference in constant kth vs kth(T), but figure 4 does not? Arent you using the same material properties? You handwave the similarities away, which is bad practice. There should be a physical reason, just saying ‘the BCs did it’ isn’t good enough. Why would the BCs impact this in this way? Did you fix your part 2 results? It looks like you are still showing a constant fuel surface T, which is not correct. I think the axial vs radial displacements might be different because of your boundary conditions. Also, your labels in fig 6 show stresses, but you meant displacements? You are showing the correct general behavior of the gap closure, but then your gap width goes negative, which is unphysical. The simulation should stop here, or you should truncate your data, because everything isn’t going to make sense after that point. The average stresses are taken from where? Over the fuel? At what value of r? Over all values of r? This analysis doesn’t really make sense unless you tell me where it is occurring. The peak value of your hoop stress is what determines fracture on startup. Since you don’t have contact employed, you don’t get stresses induced from the cladding. You say “After the gap closes, hoop stress rapidly rises and becomes the dominant stress component.” Your data specifically does not show this. Your only stresses are from thermal effects, there is no mechanical contact. You did a lot of the coding work, and it looks good, but your understanding of what you did is lacking. Think through what it is you have prescribed and what your system is doing. Don’t put your assumptions of what should happen onto the code, it only does what you tell it to do.

Grade: 91

Hongsup

Would have liked to have seen an all-compassing intro for all parts. Error in an equation label. Parts 1 and 2 results all look good. I think your fig 6 is the ideal way to show the data. Figure reference error. Interesting modification to only impart strain in the x direction. Makes handling BCs easier, but is factually untrue. I might modify the problem definition in the future to prevent this assumption, but its fine here. Where do elastic properties come from? I think you are off by an order of magnitude on youngs modulus. Conversion of burnup to time looks good. Really should have done more than one mesh unit across your gap. I like the concept of doing post processors to look at each type of strain. However, some things seem off, such as, why your densification strain is non-zero in the gap. Same with the SFP strain. Not sure why you plotted displacements going into negative values, as I would expect them to all be positive. Your fig 7b seems to show this as well. Your simulation stops so early, that you don’t really have time-dependent behavior. Thus, discussing the results as a function of time doesn’t necessarily make sense. This is only thermal expansion, and the thermal expansion leads to gap closure. What did you use for your coefficients of thermal expansion? I don’t think you reported this. Does your cladding not expand outward? Or your temperature is basically already at the cladding temp, and thus thermal expansion is minimal? The convergence here is really quite poor. Did you try doing this with a stitched mesh? You have hoop stress computed in your input file, but you don’t really show it. This is a critical part to inform the stress state in the fuel, and the existence of thermal cracks. You should have talked about it and/or shown it. While I said it wasn’t needed, including contact would have made your life easier. I will push for that next year. Got all the strains right, got the burnup dependence right. Without conducting a SUPER deep dive, I would say things generally look good. Mesh is a problem for part 3. Needed appropriate contextualization of the results.

Grade: 93

Joy

Good review of parts 1 and 2. Still have the output discretization errors in figs 4 and 5 that makes it look like your gap is wrong. Maybe I missed this before, but you say for part 1 that some of the error in the centerline temp is from the BCs. This shouldn’t be the case, as the BCs are handled exactly the same for the analytical and the MOOSE setup. Would prefer to see equations typed, instead of images pasted into the report. Looks much better that way. Part 2 results all look good. All extra swelling terms accounted for. Did you include thermal expansion? Good conversion of burnup to time. Nu is the number density of U atoms (metal atoms), not nuclear density. Why stop at t=100? If I run your system for longer, weird things start happening. You should have defined in the report the thermal expansion coefficients and the elastic properties. Why is axial displacement high at the bottom? How were displacement BCs handled? You didn’t specify. You only show linear increases in displacement with time, but you discuss something about levelling off? I don’t get it. Gap closure happens very quickly here… Too quick. Don’t see how you came to this conclusion. Would have rather seen hoop stress as a function of r, to indicate where the cracking occurs. I don’t know why your stress keeps increasing, this doesn’t seem right. Your temperatures in fig 16 are crazy. This is not right. But you don’t show any indication of realizing that this cannot be the case… Think about what your data is showing. Looking at your files, your BCs are functions of time! That’s why your displacement is linear with time, you are defining it to be that way! This is wrong! You’ve got most of the pieces in place, but a lot of things are erroneous. You could have gotten there with some tweaking of your file, I don’t think it was far away. But you should have realized that you had some major errors.

Grade: 90

Lexi

Good intro, good outlining of the three different parts. Good workthrough of the mesh convergence. I like using hoop stress as convergence criteria, but probably shouldn’t have done it as a function of time. Easier to just reach a thermal steady-state with only thermal expansion and determine hoop stress convergence. You should have been more specific that you changed the mesh setup in part 3, in that you aren’t meshing the gap anymore. Good use of postprocessors. Good definition of material properties. Good conversion of burnup. Did you cite the kth(T) functions? Skipped writing the SFP strain equation. Results for part 1 and 2 look good. Gap width closure looks good. What is the context behind the gap width change vs time? And the displacement vs time? How are you averaging your stresses? Over all r? That’s not ideal, as they change signs with r. Showing stress state vs r would have been good. How does temperature look vs time? Your justification for greater radial displacement is wrong. You don’t model fission gas diffusion here! How can it be doing anything in your simulation? MOOSE cant do what you don’t tell it to do. Don’t extrapolate what you think should be happening to what is actually happening. The cracks will occur as soon as the hoop stress becomes greater than the fracture stress. Thus, you should only analyze cracks on the first instance of stress exceeding fracture stress. Beyond that, you have cracks, and the actual stresses will be different. Thus, only analyze cracks on initial heating/expansion. Everything is there and works great. You extrapolated a bit too much on your conclusions/discussion. But this is quite a good job overall.

Grade: 98

Tim

Good workthrough of part 1 and 2. Good outlining of analytical equations. While you justified your mesh, a convergence study would be better. You approach part 2 in a very engineering way. I haven’t thought about steam tables in a long time. The one part missing in part 2 is that you used a volumetric LHR, instead of the axially varying LHR. This makes your heat generation much higher and shifts your peak centerline temperatures up in the axial direction. Everything else looks good now. Properly outlined all of the strains. The fuel is still able to expand axially in a real reactor system, it is just held in place with springs. The cladding will expand outward, and should not have been pinned radially. Think back to the gap change examples that we talked through in class. In doing this, you introduced other code-related approximations which are a bit sketchy, but understandable. Regardless, you shouldn’t have made this assumption. The file you gave me was only steady state. I had to make some changes to see the same results you presented. Your mesh wasn’t appropriate either, was far too coarse for part 3. It almost looks like you sent me a test file. You had test ICs that I wasn’t sure what to make of. I couldn’t get it to converge to a single timestep. So… I’m not sure how you got the results you got. Analyzing the results you showed… while the gap size change is reasonable, it is missing some of the effects that I anticipated seeing. I don’t see the thermal expansion and densification behavior early in life. There is a slow gap increase instead. Would have liked to have seen time as well as burnup for gap closure and other quantities. Centerline stress should be negative, if youre looking at hoop stress. Von mises squares everything and makes it positive, but would’ve liked to have seen stress components. I also don’t quite understand why your stress state evolved in the way it did. I think you got most of the parts. There are issues with your code which prevent me from running it. Some context is lacking in the analysis, and the results don’t show exactly what I would expect. It seems you got close, and could’ve gotten all the way with a bit more tweaking of the code. Not bad.

Grade: 90

Vaughn

Good intro, but it seems you didn’t update it to reflect part 3. Excellent mesh convergence studies for part 1 and 2. Results for parts 1 and 2 look great. Proper elastic properties. Fixing the top/bottom of the fuel will results in higher compressive stresses. The pressure BC shouldn’t do anything here. Or I would be surprised if it did anything. You don’t include creep, so its not really relevant. I found convergence to be better with your file with a more coarse mesh in the x in the gap, and a slightly more fine mesh in the fuel/cladding. Clever to have a termination criterion for gap closure. Good conversion of burnup to time. Don’t need to establish densification as a min. Its an exponential decay function and will drive towards -0.01 and stay there. Fig 9 looks good, all strains implemented correctly. This is a very good check. Scaling factor in Fink-Lucuta? Do you mean a unit convergence? Your gap closure happens very quickly, much quicker than it should. Isnt sigma\_yy going to be the axial stress? And youre showing that your crack goes though 0.4 cm of the fuel? Yeah, that’s too much. I don’t quite know why your expansion is so rapid. Must be because of the BCs that you set, forcing it to expand farther in x. This is also going to increase your sigma\_yy. Did you look at the magnitude? Did you have negative and positive stresses as a function of r in your fuel? You also seem to have fixed your cladding, preventing it from expanding outward! I changed your fixed BCs restricting displacements to Neumann BCs. This makes convergence pretty slow, but your behavior is more appropriate. But you got all the parts there and implemented correctly. Overall this is quite good. But some errors in your BCs skewed the results you found in part 3. Good job.

Grade: 95