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Is ice a good substance for educating engineers about materials?

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Engineers are interested in applications: fast cars, aeroplanes, bridges, chemical factories, and silicon devices for electronics wizardry. Material properties are central to their applications. Knowledge of properties is essential for engineers when they select materials for design. While everything works fine engineers need only be concerned with materials properties. However, sometimes things go wrong – materials can deform and fracture; or engineers want to make something better. For this they need to know more about materials. The key to understanding why materials behave the way they do is microstructure. An important message to get across is that materials are often not isotropic and homogeneous.

Microstructure is a concept that many engineers do not grasp naturally. Typically in materials science microscopy and other techniques are used to probe the fine scale structure of the material. Information and images are obtained at length scales below what is visible to the naked eye. This is probably where some of the difficulties stem from regarding educating engineers about microstructure – it is just not something they are familiar with from their everyday experience. Here examples from ice and snow can help – and the students will be familiar with these. For example growth of dendrites: ice in puddles and snowflakes; although very few engineers will have seen ice from polar ice sheets the scale (mm to cm) of the grains deep in the ice is very accessible to the naked eye. The structure of snowflakes provides beautiful clues as to their underlying hexagonal crystallography.

Deep understanding of materials processing is strongly linked with microstructure and properties. There are some good examples of analogies that can be made with conventional materials processing and processes that occur in snow and ice:
• Powder processing of materials has many similarities with sintering of snow and ice.
• Casting of metals: dendritic growth, segregation, formation of pores from gases dissolved in the liquid metal (this is an easy experiment to do with water, and as a bonus the pores in ice can be seen), here there are analogies with freezing phenomena in ice.
• Thermomechanical processing of alloys, rolling and forging, involving recovery, recrystallisation and grain growth, here there are many parallels with the flow of glaciers ice sheets (and interestingly the metallurgical community use ice as a "difficult" model material because of its high plastic anisotropy).
There are, however, some parallels between ice and conventional materials that do not work, e.g. shrinkage porosity in castings is a serious problem – ice is obviously not a good material to try to replicate such behaviour...

I believe engineers can gain deeper understanding and fascination of "their" materials by knowledge of the material properties and microstructure of ice and snow. This helps engineers think beyond what is normal for them and gives them opportunities to interrelate this knowledge to their everyday experience, deepening their learning. So, a final question: can geoscientists use concepts developed in materials science and engineering for deeper understanding of snow and ice? Yes, and clearly they do. However, words of caution: make sure the physics is correct for the situation it is applied to – as although there are many similarities in materials there are differences too.