Fundamentals of Cryogenic Engineering

Content:

References:

- Fundamentals of Cryogenic Engineering, Mamata Mukhopadhyay, PHI, 2010.
- The Art of Cryogenics, Ventura and Risegari, Elsevier, 2008.
- Fundamentals of Vacuum Techniques, W. Umrath, Leybold Vacuum, 2007.
- Cryogenic Technology and Applications, A. R. Jha, 2006.
- Cryogenic Engineering, Thomas M. Flynn, Marcel Dekker, New York, 2005.
- Cryogenic systems, R.A. Barron, Oxford University Press, New York, 1985.
- Cryocoolers: I- Fundamentals, Graham Walker, Plenum Press, New York, 1983.
- Cryocoolers: II- Applications, Graham Walker, Plenum Press, New York, 1983.
- Cryogenic Fundamentals, G. G. Haselden, Academic Press, 1971.

Course Description:

At cryogenic temperatures, i.e. temperatures below 120 K, materials show interesting behaviors, not seen at the temperature range we experience in the Earth's atmosphere. Also, there are processes that can only be materialized when we approach and go beyond the cryogenic temperature boarder line. For example, the life time and performance of stainless steel parts are both enhanced by keeping those parts at cryogenic temperatures for a limited time. Liquid forms of important elements such as Helium, Hydrogen, Oxygen and Nitrogen, which are known as cryogens and have numerous important applications, are obtained through liquefaction at cryogenic temperatures. Likewise, Cryogenic processes are required to separate widely used inert gases, e.g. Nitrogen and Argon, from air. It is now possible to store, transport and manipulate cells and genes at cryogenic temperatures. Some scientists even believe that more complex organisms have a chance of recovery after the death if kept at cryogenic temperatures. Cryogenic liquid rocket engines are essential in space exploration. A Magnetic Resonance Imaging (MRI) unit, which is a kind of scan that can produce detailed pictures of brain and other parts of the body, needs liquid Helium or a cryocooler. The same is true regarding Nuclear Magnetic Resonance (NMR) spectroscopy units, used in analytical chemistry and biochemistry studies. The list goes on and on and there are now many crucially important applications as well as research ideas in the field of cryogenics. Therefore, engineers are necessarily involved in the design, manufacturing, improvement and maintenance of cryogenic systems. Mechanical engineers, particularly those with the thermo-fluid background, have an important role to play in this vital and still rapidly growing industry.

This course is an introductory course on the fundamentals of cryogenic engineering and aims at last year undergraduate or first year graduate students in mechanical engineering. Students with majors in aerospace and chemical engineering are also qualified to take the course, if they have the required background in thermodynamics and heat transfer.

The course covers eight topics/chapters.

Chapter 1 provides the fundamental concepts and definitions and introduces a number of important applications of the cryogenic engineering.

Chapter 2 explores the thermodynamic behaviors of cryogens, i.e. materials that exist in liquid form at cryogenic temperatures.

Chapter 3 provides various thermal, mechanical and electrical properties of a selected number of solids at cryogenic temperatures.

Chapters 4 and 5 are devoted to two very important areas of applications of cryogenic systems, i.e. gas liquefaction and separation systems.

Chapter 6 reviews the methods used to achieve cryogenic temperatures. Cryocoolers are categorized in this Chapter and thermo-fluid aspects of these types of refrigerators are discussed.

Chapter 7 focuses on an important subject, vacuum technology, which is usually required and employed, in one form or another, in cryogenic systems.

Chapter 8 is the closing Chapter. Here, cryogenic insulation techniques and safety issues are briefly considered.

Evaluation:

Students are evaluated based on the qualities of their reports on term projects (40% of the final mark) and their final exam marks (the remaining 60%). Term projects are assigned by the instructor. However, students with interests in particular areas of applications are welcome to propose subjects for their term projects. The final exam has two closed (25%) and open-book (35%) sections.