Essay 6

Introduction to a Complex Industry-Based Problem Utilizing ANSYS Software for its Solution

6.1 Introduction

Homework problems are useful in that they provide practice for mastering the technical steps in the application of a software package. However, when a complex industrial problem is to be solved, a significant amount of *modeling* must first be performed before the software can be utilized to good effect. Modeling is believed by many to be the essence of engineering. It requires the attainment of sufficiently deep understanding to enable identification of controlling processes and of marginally important processes.

Not only is modeling an essential feature for arriving at a rational form of a problem, but it is also important in situations where the assets of the software or of the computing equipment are limited. In particular, most software is licensed according to the assets that are provided. One quantitative measure of the assets is the upper bound on the number of nodes or elements that are available for a particular license fee. Licenses used for teaching are often without sufficient assets to solve real-world problems. In such cases, modeling becomes a means for reducing the complexity of the problem to a level that is compatible with the computational resources. In the problem to be discussed here, this need for modeling will play a major role.

6.2 Problem Definition

There are many processes that must be controlled in order to achieve high performance of any device that utilizes electronic equipment. Key among these processes is *thermal management*. It is well established that temperatures of certain types of electronic components must be maintained below a certain maximum. To achieve this objective, it is common to use a fluid as a coolant to extract heat from the electronic equipment. Over the decades, there has been an emphasis on using chilled air as a coolant. More recently, with the marked increases in the heat dissipated by the electronics, liquids have been employed. Still, air remains the fluid coolant of choice because of its ease of handling and its noninterference with the primary electronic functions. The chilled air stream is blown directly on the electronic components, either perpendicular or parallel to the circuit board on which the components are mounted.

There are numerous ways in which a thermal management system for electronic-equipment cooling can be configured. In the situation to be described here, the means for chilling the air is based on the use of the Peltier effect or more commonly identified as thermoelectric cooling. Before beginning a detailed description of the thermal management system, it is appropriate to provide a brief background for thermoelectric devices.

6.3 Thermoelectric Cooling

To begin, attention is directed to Fig. 6.1 which displays a setup for the measurement of temperature by means of a thermocouple. A thermocouple consists of two different wires. Each wire is coated to insulate it from making electric contact with the other wire. The color of the insulation is used to identify the material from which the thermocouple is made. In the figure, the red-coated wire is indicative of an alloy called constantan, and the purple coating denotes another alloy called chromel. These wires are arranged to form two separate junctions. One junction, termed the reference junction, is situated in an equilibrium mixture of crushed ice and water. That junction is presumed to be at 0°C. The other junction is used to measure the unknown temperature. This setup produces a voltage which may be read by a millivoltmeter. If a temperature difference can be maintained without cost between the junctions, this setup provides an alternative energy source. The voltage output for this setup is in the range of 1-2 millivolts, a value so small that it has limited applications. In present-day setups, the ice-water reference junction is replaced by an electronic reference junction.

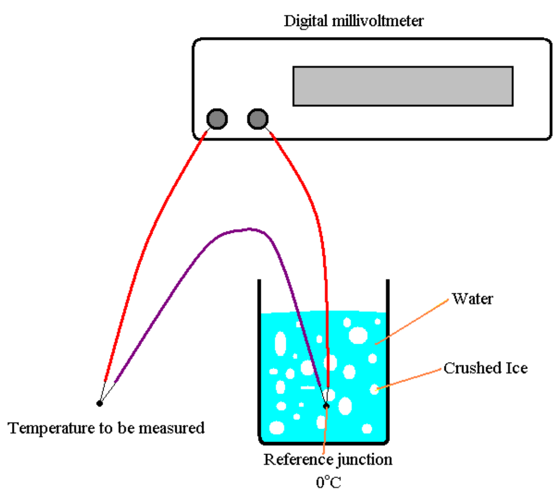

Fig. 6. 1 Typical thermocouple setup for temperature measurement

Suppose now that the thermocouple circuit displayed in Fig. 6.1 is revised in a manner that is shown in Fig. 6.2. Now, the two thermocouple junctions are both situated in the ambient environment, and the millivoltmeter is replaced by a D-C power supply. When the switch for the D-C power supply is in the off position, no current flows through the circuit, and the two thermocouple junctions are at the same temperature equal to that of the environment. When the power is switched on, the temperature of one of the thermocouples will decrease to a value below that of the ambient, while the temperature of the other will increase to be above the ambient. If an object were to be brought in contact with the colder of the two junctions, the temperature of the object might drop slightly. However, since the mass of the thermocouple junction would typically be very small, its capability to serve as a cooling device is limited. However, if a large number of junctions (*e.g.*, 100 junctions) were wired in series, a *thermopile* would be obtained. The massing of 100 cold junctions would be sufficient to create a significant cooling effect.

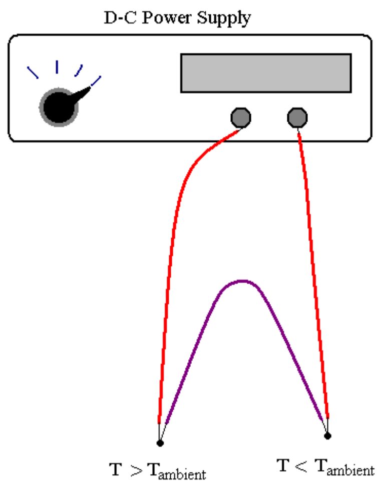

Fig. 6. 2 A setup for a thermoelectric cooler. To effect a significant cooling capability, it is necessary to use a cluster of many cold junctions.

In practice, it is convenient to package the concept displayed in Fig. 6.2 in the form of a chip. For example, an illustrative thermoelectric chip is displayed in Fig. 6.3. That figure shows a commercially available thermoelectric refrigerator. In that manifestation, the thermocouple wires are replaced by semiconductors. The bottom cover of the chip absorbs heat and is at a relatively low temperature, while the top cover rejects heat and is at a relatively high temperature.

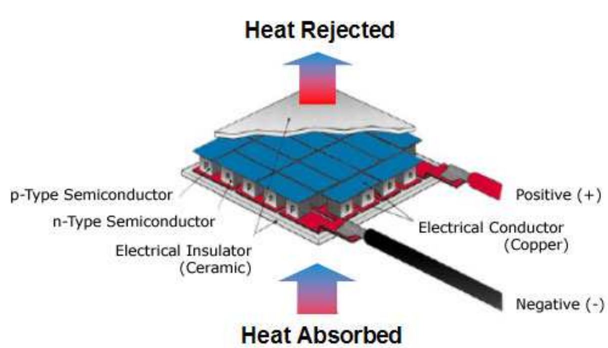

Fig. 6. 3 Off-the-shelf thermoelectric refrigerator