Final Year B.Eng. Research Projects
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The following project descriptions are subject to minor revision. If anyone is interested in further information, please email mpeasm@nus.edu.sg.

TH08 A pressure swing adsorption drying system for heat-sensitive products

Arun Sadashiv Mujumdar / Chua Kian Jon, Ernest

Freeze drying and vacuum drying are commonly used for drying of highly heat-sensitive products. Both are very expensive processes because of the need to maintain very low vacuum. A new laboratory-scale apparatus to dry heat-sensitive particulate materials has been designed and commissioned. Experiments are conducted by subjecting the vessel to prescribed cyclical variation of pressure (approx. 10-100 Pa) and temperature (approx. 25-60 deg C). A silica gel bed will also be installed for moisture adsorption to improve the dehydration process. Effects of various system parameters (e.g. amplitude, frequency of pressure swings, operating temperature, size of adsorption bed, product characteristics etc) on the dehydration kinetics, product quality and energy consumption will be studied. Potential scale-up criteria for larger scale units will be developed along with a techno-economic evaluation.

TH09 Hybrid Continuous and Intermittent Osmotic Convective Dehydration of Agricultural Products

Arun Sadashiv Mujumdar / Md Raisul Islam

Hybrid drying technologies are now becoming increasingly popular because of their improved energy efficiency and ability to produce enhanced quality products Continuous, intermittent or stepwise osmotic/microwave/convective drying modes can be used to dry several agricultural products. The impact of various drying conditions on drying kinetics and color changes as well as physical dimensions of these samples will be evaluated. The Hunter color scale parameters will be used to quantify the color changes. A titration method may also be used to study the ascorbic acid level of the dried products. With appropriate selection of osmotic pre-treatment, convective drying and microwave intermittence, it is possible to improve dried product quality and yet maintain high drying rates. This project involves an experimental investigation using an existing facility supported by simple mathematical modeling of the hybrid drying processes.

TH12 Novel Phase Change Materials (PCM) for Thermal Management of IC Packages

Arun Sadashiv Mujumdar

Phase change materials can store large amounts of heat without undergoing significant temperature change because of their high latent heats of fusion. This study is aimed at investigating the use of PCMs for active or passive electronic cooling applications with high power at the package level. Selection of the appropriate PCM and its geometric design are important aspects of the problem to be studied in this project. The main objectives of the experimental projects will be to investigate the use of PCMs as a passive thermal control technique (as a viable alternative to active forced convection cooling systems). Several different PCMs will be selected after defining the appropriate criteria. The PCM containers will be subjected to various transient heat loads to determine their heat storage characteristics. One additional possibility is to investigate PCMs field inside an aluminum matrix heat sinks for transient applications. This project will involve design and testing of a suitable test apparatus to measure transient temperatures and heat fluxes under various conditions of practical interest. It is possible that some of the experiments may be carried out in conjunction with Agilent Technology facilities, particularly for infra-red thermo-vision imaging of the temperature field.
This is an industrial collaborative project with Mr. Ravi Kandasamy, Agilent Technology, Singapore

TH13 Numerical Simulation of Thermal Characteristics of Phase Change Material (PCM) Based Thermal Management System for IC Packages.

Arun Sadashiv Mujumdar

To support the experimental project involving PCM-based thermal management of IC packages this project is aimed at evaluating numerically the heat transfer characteristics within a PCM container subjected to a range of steady and transient thermal boundary conditions. Since the melting temperature of the PCM is necessarily lower than the thermal boundary condition there is potential for development of free convection currents during the melting process. Free convective heat transfer is affected by the orientation and geometry of the PCM container. The objective of this computational project is to use commercial software such as FLUENT 6.0 to solve the governing conservation equations for mass, momentum and energy subject to various boundary conditions. Rates of heat storage (during freezing) and heat discharge during the cooling (freezing) process can be computed and compared with the experimental results of a companion FYP. Several different PCMs (including mixtures as well as PCMs separated from each other) will be tested.
This is an industrial collaborative project with Mr. Ravi Kandasamy, Agilent Technology, Singapore

TH14 An Innovative Spray Dryer Design for Production of Powders from Solutions

Arun Sadashiv Mujumdar / Huang Lixin

Spray drying is a very important industrial operation used to produce engineered powders from liquid feed stocks. It is found in numerous industrial sectors. The process consists of bringing a spray of liquid in contact with hot air in an appropriately designed chamber. The selection and design of spray atomizer, orientation of the drying air and the design of the spray chamber itself are known to affect the heat transfer performance of the dryer. Conventional spray dryers are vertical chambers with cylindrical symmetry. This project is designed to evaluate a novel horizontal design of a spray chamber to alleviate the problem of scale-up and permit operation as a two-stage process which is thermally more efficient. The computational fluid dynamic code FLUENT will be used to simulate the spray and drying gas interaction in various horizontal chamber designs. It is expected that the flow patterns within the chamber will be described by measurements in a small proto-type unit to be built. This project involves both simulation and experimental studies of flow patterns with and without spray.

TH15 Evaporation from Single Droplets

Arun Sadashiv Mujumdar / Huang Lixin

Heat and mass transfer from spherical droplets exposed to unsaturated heated gas is important in numerous industrial processes. The problem is also of fundamental interest. In this project we'll carry out experimental measurements of evaporation rates for a stationary droplet of a variety of fewer liquids, suspensions as well as solutions (of salts, sugars etc) with the idea of generalizing the heat and mass transfer rates as well as changes in the morphology of the dried particles. This information is critically important in fluid dynamic simulation of spray dryers. Aside from being able to predict the thermal performance of dryers, knowledge about the morphology allows more reasonable predictions of the quality of the dried products. If time permits it should be possible to use suitable software to predict heat and mass transfer from single as well as multiple droplets exposed to a drying gas. Experimental results will then be compared with the predicted ones.

TH16 Flow and Heat Transfer Characteristics of Unsteady Impinging Jets

Arun Sadashiv Mujumdar/Poh Hee Joo (IHPC, A* STAR)

Impinging jets are used extensively in industrial practice for heating, cooling, drying as well as chemical reactions owing to their highly favorable heat and mass transfer characteristics. They also find applications in biomedical engineering devices as well as in cooling of high density electronic components. It is often necessary to enhance their heat and mass transfer performance to even higher levels. Among the various active modes of heat transfer enhancement is the idea of

imparting oscillations to the jet as it issues from the nozzles. The direction of oscillation, its frequency as well as amplitude are expected to influence the impinging jet heat transfer rates. The nozzle design (e.g. round vs. non circular, laminar vs. turbulent etc.) also influences the thermal performance. The objective of this computational study is to quantify the effects of various key parameters on the flow as well as heat transfer rates at the impingement surface.

TH17 An experimental study to determine optimum drying conditions using a multimode heat pump dryer

Arun Sadashiv Mujumdar / Md Raisul Islam

Drying rate of any material depends on its internal thermophysical properties and the external drying conditions. Combined effects of drying air velocity, relative humidity and temperature govern the external drying condition. Convective heat and mass transfer coefficients between the flowing air and the drying surface depend on the air velocity. A heat pump can be used to control the relative humidity that affects the driving potential for evaporation of moisture. Other modes of heat input such as conduction, radiation, and microwave can also be used to supply energy for drying. Depending on the variation of thermophysical properties of the material during drying, external drying conditions and modes of heat input can be varied to obtain optimum drying conditions in terms of energy consumption and product quality. The objective of this study is to carry out an experimental investigation to determine optimum drying conditions for some selective materials under time varying convection, conduction and radiation heat inputs in a heat pump dryer. Comparison will be made with a mathematical model developed earlier.

TH18 Experimental study of vacuum and microwave drying of heat sensitive material

Arun Sadashiv Mujumdar / Md Raisul Islam

Drying is a coupled heat and mass exchange operation which also requires that the dried product meet certain pre-specified quality constraints. Efficient drying of heat-sensitive materials such as food and bio-products, medicines etc. still remains a challenge for researchers. Depending on the type of the heat sensitive material to be dried and the desired quality attributes to be achieved, it is necessary to maintain some specific drying conditions. If the required drying conditions are not maintained properly, color and quality of the food products and medicinal effects of the medicines could be diminished. Because of the use of low temperature of the drying air, products temperate also remain low. Moisture in the liquid phase migrates by diffusion from the bulk of the product to the exposed surface where evaporation takes place. As a result, the drying rate for the heat sensitive materials becomes considerably slow. The above mentioned limitation can be overcome if the boiling temperate of the moisture can be reduced to the permissible temperature of the product. Vacuum drying could be a potential option where the product will be dried at sub-atmospheric pressures in the presence of microwave or conduction heat sources. Microwave will generate heat volumetrically and as a result moisture will evaporate inside the product. This vapor can create an over- pressure and force the liquid moisture to the exposed drying surface. Consequently, significant improvement in the drying rate for heat sensitive materials can be achieved. In the present study, drying rates for some heat sensitive food products and medicines (e.g. tablets) will be investigated experimentally. A detailed parametric study will be carried out to determine optimal conditions for the heat and mass transfer operation.

TH26 An energy storage system using non-conventional phase change materials (PCM)

Hawlader M N A / Arun Sadashiv Mujumdar

A thermal energy storage system using phase change materials (PCM) enables storage of energy without a significant change in temperature of the system. The selection of appropriate phase change materials to suit the desired temperature range is important. A PCM storage system has been built with PCM for operation for low temperature applications. A concentric cylinder heat exchanger has been built and used for the measurement of energy addition and withdrawal rates from the system. This project will examine the effects of various parameters on PCM heat storage/ withdrawal rates for different PCMs both experimentally and numerically. Measurements of temperature and observation of the phase front movement would lead to a better understanding of the storage system. This is a continuation of an FYP completed last year.

TH49 Spray Cooling of Electronic Chips

Tay Ah Ong, Andrew / Arun Sadashiv Mujumdar

With the ever increasing processing power of IC chips, cooling of chips is becoming an important issue. Spray cooling of electronic components in which a spray of water is directed to a chip surface, has been shown to produce high cooling rates. In a project last year a test rig has been constructed for studying spray cooling of a chip. However, the test rig needs to be modified in order to obtain more accurate and reliable results.