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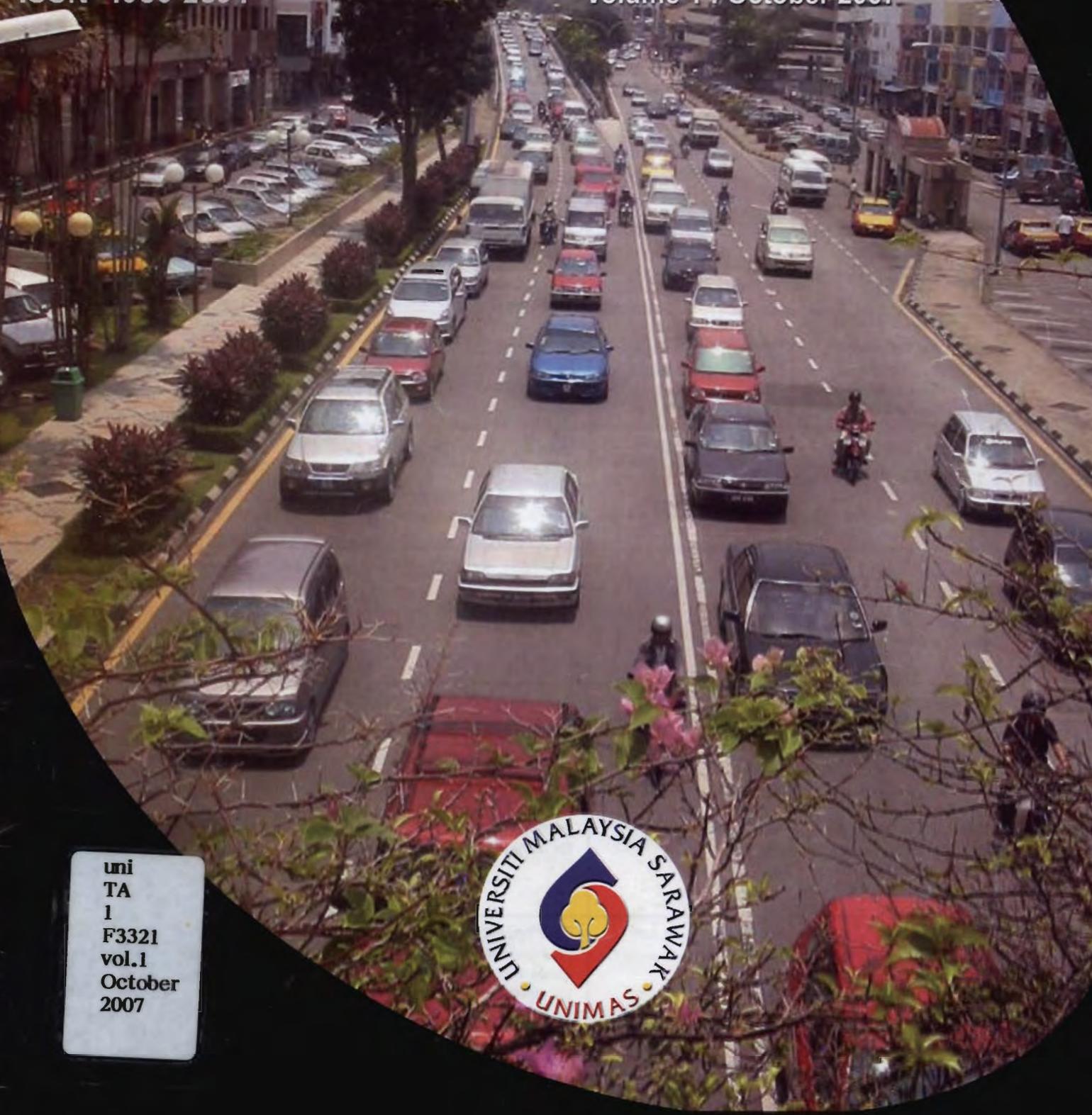
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Co-Editor: Ir. Dr. Andrew Ragai Henry Rigit

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Cover page: Urban Traffic Congestion (courtesy of Mohamad Raduan bin Kabit)

Hydro systems for Integrated Control of Flood and Low Flow for a River Basin in Sarawak

by
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Hydrosystems is a term originally coined by V.T. Chow to describe collectively the technical areas of hydrology, hydraulics and water resources (Mays and Tung, 1992). A study on hydrosystems is important in developing an integrated system that will optimize the control of flood and low flow in a river basin. Flooding is a common occurrence in Sarawak, particularly during the monsoon season between November to March every year (Memon and Murtedza, 1999). On average, the annual rainfall in Sarawak ranges from 3500 mm to 4000 mm. Since the hazard of flooding in Sarawak is quite high and with the growing momentum of economic development and urban expansion that exposed urban area to flood risk, it is important to the engineers and planners to have a mechanism that can estimate flooding frequency of a river basin. Malaysia as a whole has abundant water resources; yet, there are consistent problems of water shortage due to insufficient approach in sustainable development of water resources. Thus, it is also important to develop a mechanism that can estimate frequency of low flow of a river basin in order to establish a framework and the requirement for storing excess water that can be used during dry season.

Low flow and high/flood flow analyses had been well-documented in several water resources projects locally. However, what is lacking currently is an integrated-form of those data that can be "plug-and-play" by stakeholders. The significant of this project is therefore to develop an interface-based low flow and high flow frameworks to support decision making. Thus the 3 objectives of this project can be summarized as follows:

- 1) To develop a mechanism (by regionalisation) that can estimate flooding frequency from a river basin with the available data.
- 2) To develop a frame work and requirement for storing excess storm water which can be utilized during the dry season.
- 3) To develop an interface for integrated analysis of flood and low flow events in a river basin.

References

Mays L.W. and Tung T.K. Hydrosystems Engineering and Management. Pub. By McGraw-Hill. 1992.
Memon A. and Mohamed M. Water Resource Management in Sarawak, Malaysia. UNIMAS. 1999

A Separator with Inclined Multiple Angles Parallel Arc Coalescence Plates

by
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The proposed novel phase separator consists of a series of inclined multiple angles curved parallel coalescence plates to enhance gravity separation for coalescence of oil droplets, and coagulation of suspended solids (Fig. 1 & 2). It applies the principle of Boycott effect whereby the presence of inclined frustums medium promotes faster rising of oil droplets or falling of suspended solids and their coalescence and coagulation. The separator takes the shape of a rectangular tank to take advantage of constant laminar horizontal velocity, v_n as the fluid moves across the coalescence medium. The inlet of the separation system is equipped with a baffled distributor to direct uniform flow to the curved parallel plates to enhance oil-water-solids separation. Separator development shall be based on the principles of suspended solids sedimentation characteristics and oil coalescing (rising) characteristics. The ideal oil-liquid-solid phase separation unit is in the shape of a rectangular tank (Fig.1). In a rectangular tank, the flow enters the tank through a baffled inlet and horizontal velocity, v_n would be constant throughout (from entry to exit points). This allows heavier solids to settle more rapidly and lighter oil droplets to float to the surface. The introduction or presence of series of inclined multiple angles parallel arc coalescing plates further aids in the removal of oil droplets from wastewaters. The primary objectives of the proposed project are to:

- 1) Design/develop and
- 2) Carry out performance analysis on the novel oil-water-solids separator.

The novel invention is also aimed to produce effluents oil/grease and suspended solids concentration of 10 mg/L and 50 mg/L (and below), respectively so as to comply with the Malaysian Environmental Quality Act and Regulation allowable amount of oil/grease and suspended solids levels in sewage and industrial effluent discharges.

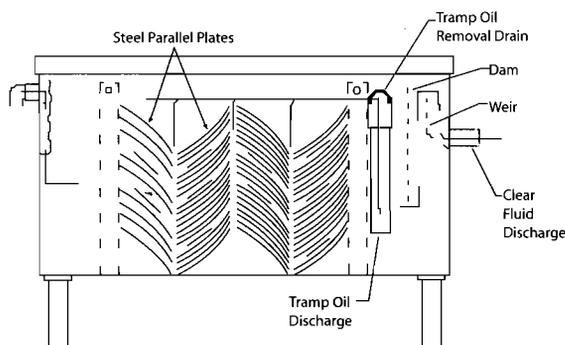


Figure 1: Inclined Multiple Angles Parallel Arc Coalescence Plates

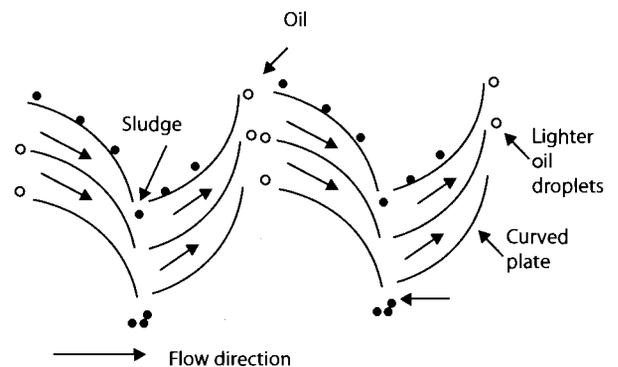


Figure 2: Oil-Water-Solid Separation Mechanism

Development of an Efficient Hybrid Solar Thermoelectric-Adsorption Cooling System

by

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Solar powered coolers are devices that used directly the solar energy radiated from the sun to produce cooling effect. Solar energy is environmental friendly, free and available adequately in almost every parts of world where people live. Everyone, including the poor living far away from the electricity grid such as rural areas, should find no difficulty in obtaining solar energy. The only cost of using solar energy is harnessing it from the sunlight [Abdullah & Leo, (2005), Lemmini & Errougani (2005)]. There are several ways of using solar energy for cooling, namely absorption cycle, adsorption cycle, vapour compression cycle and thermoelectric cooler. Among these technologies, adsorption and thermoelectric cooler has been chosen to be implemented in this research. In recent years, solar adsorption cooling system has witnessed an increasing interest in many fields due to the fact that this system is quiet, long lasting, cheap to maintain and environmentally benign [Dieng & Wang (2001), Abdullah & Leo (2005)]. Adsorption cycle powered by solar energy has been successfully used for ice making and cold production. For example, solar activated carbon-methanol adsorption ice maker (Li & Sumathy, 1999), zeolite-water solar cold storage system (Lu et. al., 2003) and carbon-ammonia solar refrigerator for vaccine cooling (Critoph, 1994). In our final-year student studies conducted recently at UNIMAS, a mini solar hybrid thermoelectric-adsorption cooler had been designed, built and tested. The coefficient of performance (COP) of the mini hybrid system is approximately 0.03 [Abdullah et. al. (2006) and Leo et al (2006)]. The initial result showed that it is feasible and very practical to extend and further improve this hybrid system [Leo et al. (2007) and Abdullah et al (2007)] for actual space cooling and refrigeration as proposed in the current study.

References

- Abdullah M.O. and Leo S.L., Feasibility of solar adsorption technologies for automobile air conditioning. Proceeding of ASME/ISEC2005, 2005 International Solar Energy conference, August 6-12, 2005, Orlando, Florida, USA.
- Abdullah M.O., Leo S.L., Teoh K. Y., Ting K.S., Tang C.H., Experimental Study of a Hybrid Solar Thermoelectric and Adsorption Cooling System, Applied Thermal Engineering, paper in review.
- Critoph R.E., An Ammonia Carbon Solar Refrigerator for Vaccine Cooling, Renewable Energy, Vol. 5, pp. 502 – 508, 1994.
- Dieng A.O. and Wang R.Z., 2001, Literature Review on Solar Adsorption Technologies for Ice-Making and Air Conditioning Purposes and Recent Developments in Solar Technology, Renewable and Sustainable Energy Review, Vol. 5, pp. 313 – 342, 2001.
- Lemmini F. and Errougani A., Building and Experimentation of a Solar Powered Adsorption Refrigerator, Renewable Energy, Vol. 30, pp. 1989 – 2003, 2005.
- Li Z.F. and Sumathy K., A Solar Powered Ice-Maker with the Solid Adsorption Pair of Activated Carbon and Methanol, International Journal of Energy Research, Vol. 23, pp. 517 – 527, 1999.
- Leo S.L., Teoh K. Y., Ting K.S., Tang C.H. and Abdullah M.O., 2006, Hybrid Solar Thermoelectric and Adsorption Cooling System, Paper presented at the International conference on energy and environment (ICEE2006) 28-30 August 2006. Universiti Tenaga Nasional, Selangor, Malaysia.
- Y. Z. Lu, R. Z. Wang, M. Zhang and S. Jiangzhou, Adsorption cold storage system with zeolite-water working pair used for locomotive air conditioning. Energy Conversion and Management, Volume 44, Issue 10, June 2003, Pages 1733-1743
- Leo S.L., Abdullah M.O., Hamid K. Ab. and Sulaiman M.Z., Hybrid Solar Peltier-Adsorption Cooler. Paper accepted to be presented at the International Conference of Engineering and ICT 2007 (ICEI2007), 27 to 29 November 2007, Malacca.
- Abdullah M.O., Ab Hamid K, Leo S.L. and Ngui J.L.. A study on Hybrid Solar Peltier-Adsorption Cooler. 1st Engineering Conference on Energy & Environment (EnCon2007) Conference. December 27-28, 2007, Kuching, Sarawak, Malaysia.

Performance of a Dielectric Barrier Discharge Plasma Actuator and Flow Simulations

by

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Since decades, the add of energy and gas injection are used for modifying subsonic airflows. In this way, electrohydrodynamic (EHD) actuators are studied since the middle of the 1990s, by using the flow induced by the movement of ions in the plasma area (mangier et al, 2006). This kind of control presents the advantage to have a very short response time and not to require mechanical moving parts. EHD actuators can be classified into three large groups based on the different electrical characteristics of the discharge (Sosa et al, 2006), namely (i) AC dielectric barrier discharge devices (DBD), (ii) DC unipolar coronas discharge based devices (UCD), and (iii) plasma sheet discharge devices (PSD). This study will look into the first group, DBD. Usual configurations of a DBD consist of planar parallel electrodes separated by a thin dielectric film, disposed in general in arrangements in the streamwise direction of an aerodynamic surface (Roth and Xin, 2006). These actuators use periodically excited electrodes, one of them air exposed while the other is encapsulated in a dielectric material. The dielectric barrier between both electrodes plays an important role in the stabilization of the discharge. The physical mechanisms responsible for the EHD effect in a surface DBD are not completely clear (Lagmich et al, 2006). Many parameters (dielectric thickness and permittivity, voltage waveform, amplitude and frequency) are known to affect the velocity of the generated flow but the scaling laws are not known and work is still necessary to quantify the EHD force and to understand the parameters for optimizing the force. Therefore, one of the objectives of this study is to illustrate how 2D fluid models of the discharge can help to understand and quantify the EHD force generated by surface DBDs, and to provide scaling laws.

References

- Lagmich Y., Callegari Th., Unfer Th., Pitchford L.C., Boeuf J.P., 2006, Modelling of Surface Dielectric Barrier Discharges for Flow Control: EHD Force and Scaling Laws, 2006 International Symposium on Electrohydrodynamics – Buenos Aires, p.71-74.
- Magnier P., Dong B.J., Hong D., Bauchire J.M., Hureau J., Pouvesle J.M., 2006, Dielectric Barrier Discharge for Airflow Control, 2006 International Symposium on Electrohydrodynamics – Buenos Aires, p.63-66.
- Roth J.R., Dai X., 2006, Optimization of the Aerodynamic Plasma Actuator as an Electrohydrodynamic (EHD) Electrical Device, 44th AIAA Aerospace Sciences Meeting and Exhibit, 9 - 12 January 2006, Reno, Nevada.
- Sosa R., Arnaud E., Artana G., 2006, Study of induced flow by a sliding discharge, 2006 International Symposium on Electrohydrodynamics – Buenos Aires, p.83-86.

Investigation of Physical, Mechanical and Acoustic Properties of Wood Polymer Composites (WPC)

by
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The satisfactory use of wood depends on the proper treatment because specific uses of wood require it to be treated in a certain way prior to put it in service. Chemical impregnation of wood enhances specific properties such as decay resistance, dimensional stability, hardness and resistance to weathering. The enhancement of these properties is dependent primarily on the chemical used and impregnation of these substances into wood. Considerable interest has been manifested in wood impregnation and many monomers have been studied: vinyl monomers; such as epoxy resins, urethane and phenol formaldehyde. This technique is of growing interest in developing countries and considerable efforts are made to produce wood polymer composites based on local tropical woods. The wood will be impregnated, grafted, acylated, acetylated before dimensional stability measurement. The analysis on wood will include acoustic emission testing, dynamic mechanical thermal analysis, light microscopy, Scanning Electron Microscope (SEM) and decay resistance test. This study embarks on the following objectives i.e. to identify Malaysian wood species suitable for wood polymer composite, to determine the strength through several non-destructive testing (NDT), to determine the thermo mechanical properties through dynamic mechanical thermal analysis and to develop wood polymer composite from the properties.

The Effects of Malaysian Atmosphere on the Durability Aspects of Epoxy-Resin Concrete

by
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The deterioration of a material depends on how and what extend it interacts with its surrounding. Durability is one of the main concerns in designing, and mostly in maintaining structural integrity of a structure to last its service life. Malaysian unique tropical climate can be a hazard to many concrete structures as high temperature and high humidity can affect the chemical interaction between concrete's alkaline nature and the surrounding. Thus, the deterioration of concrete is related to its durability as it is exposed to conditions such as UV radiation, temperature, rain and wind. Epoxy resin is resin formed by the chemical reaction of epoxide groups with amines, alcohols, phenols and others. Epoxy resin concrete are used in many advanced countries in many applications including aircraft, aerospace and composite reinforcing concrete products. The technology that applies epoxy resin includes repair and appraisal works in civil engineering particularly as reinforcement in concrete. Previous researches had considered epoxy concretes exposed under 4 seasons' climate and results show significant parameters of the exposure had affected the strength properties of the concretes. The objectives of this research are;

- 1) To construct a correlation between atmospheric and wet-dry condition with durability of epoxy resins concrete
- 2) To predict durability from the permeability, porosity and shrinkage testing.
- 3) To compare atmospheric exposure with laboratory conditions

Thus, there is a need to understand the behavior of epoxy resin concrete under Malaysian climatic stress. When the behavior of strength is understood, durability of design and repair works for structures with epoxy resins can be predicted.

Estimation of Parking Pricing Model to Mitigate Congestion at Congested Business Districts (CBDs)

by
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Transport Demand Management (TDM) is used as one of the strategies to mitigate urban traffic congestion. Parking Pricing Strategy is one of the major inputs in TDM that is used to formulate strategies to effectively alleviate traffic congestion at Central Business Districts (CBDs). The effect of such strategy can be estimated by using Parking Pricing Model. Previous researches had shown that the availability of parking facilities significantly affect the congestion level at CBDs. However, the effectiveness of TDM depends on the accuracy of the Parking Pricing Model used. Currently, there is no research being carried out to estimate the Parking Pricing Model for Malaysian Road Condition. Furthermore, previous researches had indicated that the traffic condition in Malaysia especially at Congested CBDs is significantly different than the traffic condition in the Western Countries. Thus in this study, Parking Pricing Model for Malaysian scenarios will be estimated. In this study, Stated Preference Survey will be employed where extensive data collection shall be carried out from selected study areas. The data will then be reduced accordingly and analyzed by using Multinomial Logit Model software to develop the parking pricing model. Subsequently, the estimated Parking Pricing Model will be used to estimate travel pattern behaviours (*mode choice and demand elasticity*) in order to devise effective and comprehensive TDM strategies that are capable to reduce traffic congestion at CBDs in Malaysia and therefore increase national productivity as a result.

Improvement on Particle Image Velocimetry Analysis on Simple Soil – Structure Interaction

by
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It is very important to attain accurate measurement of displacement in geotechnical model testing. New methods have always been searched for especially those which introduce minor disturbance to the models. In this project, a new method (Particle Image Velocimetry (PIV)) to observe displacement of geotechnical structures will be used. PIV is a relatively new technique in geotechnical engineering. The method has been widely used in fluid mechanics experiments (Adrian, 1991). Figure 1 shows a typical PIV set up for fluid analysis; meanwhile, figure 2 shows a proposed set up for this project. Unlike analysis on fluid, analysis on soil like sand requires no tracer particles and laser sheeting to illuminate the

tracers as sand particles themselves are traced in PIV analysis. Several pioneering works have been published; i.e. White (2002), White et al. (2003); on using this technique in geotechnical testing. Prior to this new method, displacement measurement on plane models has been performed by observing movement of target markers which are embedded into the soil. The disadvantage of this method is that the markers introduce disturbance to the models. Unlike this conventional method, PIV reduces disturbance on plane model to none, as in this method no target markers are involved. According to White et al., the method measures velocity of patches of texture which are tracked from sequence of digital images. PIV also proves to be useful when observing displacement behavior during any selected events (i.e. serviceability state) and within short duration of a geotechnical test. Therefore, deformations at much lower strain can be made compared to the conventional technique which normally requires measurement to be performed after failure. This project is an initial step in setting up the analysis equipment and computer program, as a ground to move on into more sophisticated analysis. Soil-structure interaction is an area which can benefit from this new technique and in this proposed work, interaction and displacement of simplified soil-foundation model will be observed and measured via PIV analysis using a freeware computer program prepared for PIV analysis in fluids (MatPIV (Sveen, 2004)). In addition, improvement on the MatPIV program will be performed to suit the geotechnical testing environment. This shall involve computing works using MatLab. This MOHE (Fundamental Research Grant Scheme) funded research shall involve works from setting up of equipment for PIV analysis and soil modeling to analyzing and processing digital images of soil models under various loading conditions. Currently, the project is at its equipment designing stage. The research group would like to invite those who are interested to join the group as postgraduate student (for Masters level degree).

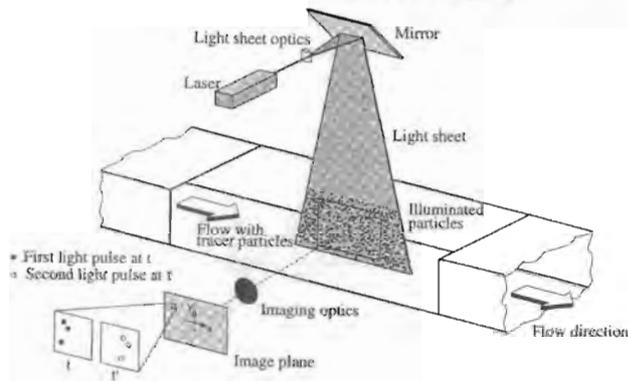
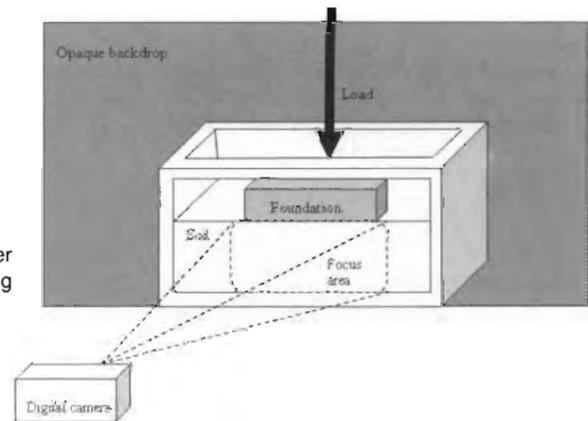


Figure 1: A typical set-up for a PIV recording in a wind tunnel experiment (Raffel, Willert & Konpenhams, 1998)

Figure 2: Proposed set up for soil PIV recording. No laser sheeting required as soil particles are now acting as tracers.



References

- Adrian, R.J. (1991), Particle Imaging Techniques for Experimental Fluid Mechanics, Annual Review of Fluid Mechanics, Vol. 23, pp. 261-304.
 White, D.J. (2002), An Investigation into the Behaviour of Pressed-in Piles, Ph.D. Thesis, University of Cambridge.
 White, D.J., Take, W.A. and Bolton, M.D. (2003), Soil Deformation Measurement Using Particle Image Velocimetry (PIV) and Photogrammetry, Geotechnique, Vol.53, No. 7, pp. 619-631.
 Sveen, J.K. (2004), MatPIV1.6, <http://www.math.uio.no/~jks/matpiv/index.html>.
 Raffel, M., Willert, C.E. and Konpenhans, J. (1998), Particle Image Velocimetry: A Practical Primer, Springer Verlag, Berlin.

The Determination of Optimum Mix Proportion for Foamed Concrete Used as Road Base on Soft Soil

by

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This research is part of an ongoing effort to produce strong foundation on soft soils using concrete as the base. The main objective is to produce lightweight concrete, with density as low as 1000 kg/m³, but having adequate strength within the range above 15 N/mm². There are several methods available to produce concrete which is light weight but in this study foaming agent is applied. The fundamental issue is to investigate the mix proportion that can produce such concrete that is light yet strong for use as road base. Several attempts have been made using mix proportion meant for normal and high performance concrete. Some experiments have been done at the preliminary stages and the results have not been very encouraging. Amongst problems faced is instability of the foam after casting, segregation of mixes, brittleness of hardened concrete, determining the appropriate amount of foam and achieving lightweight density. At present, results from the self-compacting (SC) mixes, added with foam, showed a more positive outcome than other mixes. The hardened concrete is strong, stable and light. However, there are still some more investigations to be done before any conclusive reporting can be done. The design aspect of the foundation, floatability, optimum strength and density, use of fly ash and recycled plastics are few areas to pursue in the near future. The study now narrows down to adopting the SC mixes as a basis to determine the optimum mix proportion for foamed concrete to be used as road base on soft soil.

A Cost-Effective Recycling/Treatment System for Metal-Cutting Fluids

by

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The proposed research project is in answer to "Waste Management and Recycling" of spent metal-cutting fluids at source through recycling/treatment process. It is of a pollution prevention or rather waste reduction nature, specifically research on in-process recycling of metal-working fluids system suitable for all machining settings, a rather neglected segment of pollution prevention research by source reduction. The escalating coolant waste disposal cost driven by tougher environmental law has been the primary concern for nearly all facilities involved in machining operations. Undoubtedly, a low coolant-related cost could be detrimental to the survival of a machining facility. The proposed cost-effective three-stage recycling system consists of:

- 1) negligible operational and minimal maintenance costs oil-coolant-solid gravity phase separation unit for removal of O&G and suspended solids (TSS) from coolant.
- 2) filtration-aeration process, and
- 3) pasteurization-cooling process, is perhaps the most powerful system, i.e., more efficient and cost-effective than the existing conventional on-site and mobile recycling systems.

Figure 1 illustrates proposed Three-Stage Recycling System for Metalworking Fluids. The problem lies with the fact that the present on-site and mobile recycling technologies of metal-working fluids are unsatisfactory, i.e. far from attaining optimization of coolant life, yet using more toxic substances such as bactericides and fungicides. If successful, the proposed research on more efficient, more cost-effective, and minimal maintenance metalworking fluids on-site recycling system will provide an alternative recycling system that leads directly to the acceptance of a new approach by machining industry.

Oil & Grease (O&G) Removal: Experimentally, the system attained approximately 83% of O&G removal efficiency. The effluent oil concentration, C_o was found to be directly proportional to influent flowrate, Q_i . Q_i can be expressed as a function of C_o for different influent oil concentration, C_i by a series of power equations to estimate the required flowrate, Q_{10} for a given C_i to achieve desired C_o of 10 mg/L. Different power equations $Q_{10} = 22.851 C_i^{-1.6225}$ and $Q_{10} = 166.19 C_i^{-1.4314}$ were obtained through curve fitting exercises to express the Q_{10} for co-current and counter current flow, respectively. Q_{10} for counter current flow was found to be 18.6 times higher than co-current flow, indicating that co-current flow required a lower flowrate to achieve C_o of 10 mg/L. At $C_i = 100$ mg/L, counter current flow achieved 15% higher oil removal as compared to co-current flow.

Total Suspended Solids (TSS) Removal: It was experimentally demonstrated that the system was capable of removing >85% TSS (including particles) from the coolant. The effluent TSS, C_o was found to be directly proportional to influent flowrate, Q_i . The influent flowrate, Q_i can be expressed as a function of effluent TSS concentration, C_o for different influent TSS levels, C_{ss} by a series of power equations to predict the required flowrate, Q for a given influent TSS level to achieve the desired effluent levels between 50 and 150 mg/L. Power equations $Q_{50} = 3423.6 C_{ss}^{-2.8525}$ and $Q_{150} = 63688 C_{ss}^{-2.9533}$ express the required flowrate needed to achieve effluent TSS level, C_o of 50 mg/L and 150 mg/L, respectively. The smallest removable particle size, d can be predicted for different influent flowrate, Q using power equation $d = 85.664 Q^{0.7338}$ ($R^2 = 9448$). The system is capable of removing solids particles with diameter ≈ 2.92 mm design flowrate of $1.0 \times 10^{-5} \text{ m}^3/\text{s}$.

The proposed system will substantially cut-down coolant-related cost (i.e., coolant waste disposal and virgin coolant concentrate costs) by optimizing coolant life. More importantly, the proposed system is applicable to all large and small machine operating shops. The proposed system is comparatively more cost-effective than any other system currently available in the market, yet producing better recycled quality. The proposed system requires negligible operation cost and minimal maintenance cost.

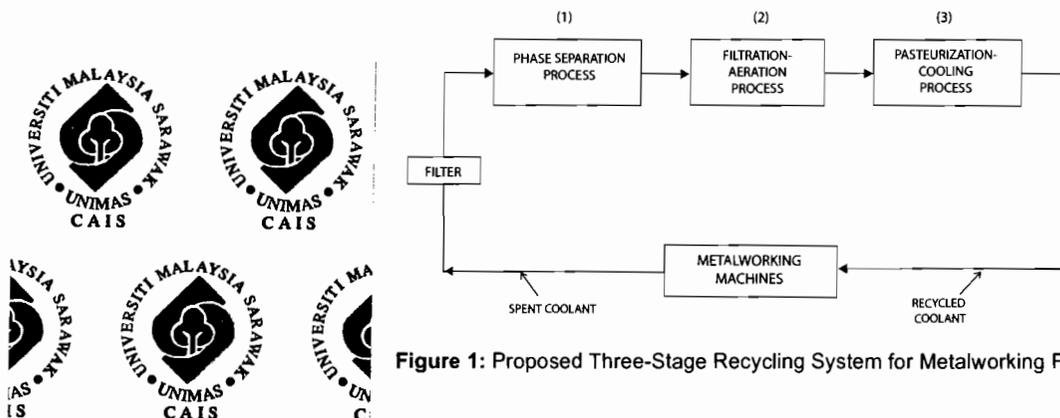


Figure 1: Proposed Three-Stage Recycling System for Metalworking Fluids

Patents

Apparatus and Method for the Separation of Oils & Solids in a Liquid (PI20070094)

Awards

Silver Medal - High Performance Oil-Water-Solid Separator,

Malaysia Technology Expo, 6th Invention & Innovation Competition, 29th-31st Mar 2007, PWTC, KL

Bronze Medal - Phase Separation System with Inclined Parallel Coalescence Plates,

IPTA R&D Expo, 30th Sep - 2nd Oct 2005, PWTC, KL

Journal Papers

Law, P.L., Ngu, L.H., Wong, K.K. and Rahman, A.A. (2006), "Development and Performance Tests of a Separator for Removal of Physically Emulsified and Free Oils from Waters", *Journal of the Institution of Engineers, Malaysia (IEM)*, Vol. 67, No. 2, pp 10-19.

Ngu, L.H., Law, P.L. and Wong, K.K. (2004), "A Study on Flow Characteristics of a Vertical Perforated-Pipe Distributor in a Circular Separator", *Journal of Civil Engineering (IEB)*, Vol. CE 32, No. 2, pp 121-132.