Abstract

Project Code: **RTA5580009**

Project Title: **Materials Development for Sanitary, Wear and Reinforcement Applications (MatApp)**

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Objectives

1. To exchange research experiences among researchers from different universities, focusing on building up learning and research conditions, and producing young researchers in the fields of materials technology, polymer composites, rubbers, civil engineering and applied environmental science.
2. To develop new materials and materials relationships between structure, properties and processing for sanitary, wear and reinforcement applications.

Methodology, Results and Summary

This research was referred to as as ***"Materials Development for Sanitary, Wear and Reinforcement Applications (MAT-APP)".*** This research project comprised of three parts from 11 researchers from four universities under the research project "Materials Development for Sanitary, Wear and Reinforcement Applications *(MAT-APP)"* are listed as follows;

1. Anti-microbial performance for plastics and rubbers (APR): This part focused on anti-microbial performance for plastics and rubbers using various anti-microbial agents (anti-bacterial, anti-fugal and anti-algae) and polymer systems (LLDPE, LDPE, PP, PVC, PLA, wood/PVC composites, wood/PLA composites, silicone rubber, and natural rubbers) as well as introduction of reinforcing fillers (i.e. carbon black, silica and wood flours). The antimicrobial agents used included 2-hydroxypropyl-3-piperazinyl-quinoline carboxylic acid methacrylate (HPQM), 3-iodopropinyl-N-butylcarbamate (IPBC), 3-(4-isopropylphenyl)-1, 1-dimethylurea (Isoproturon) and N^2-*tert*-butyl-N^4-ethyl-6-methylthio-1,3,5-triazine-2,4-diamine (Terbutryn) triclosan and silver-substituted zeolite (Zeomic). The effects of thermal and accelerated UV ageing, natural weathering and soil ageings were also considered. *Staphylococcus aureus*, *Escherichia coli*, *Chlorella vulgaris*, and *Phormidium angustissimum* were used as the main testing microbial. Changes in chemical, physical, mechanical and morphological properties of materials were analyzed and extensively discussed. The general results suggested that the anti-

microbial agents acted different depending on chemical structures of polymer matrices, the stronger the matrices (also from higher reinforcements) the lower the releasing rates of the anti-microbial agents. The releasing mechanisms involved concentration gradient, changes in matrix surfaces, usually cracks due to environments and oxidations. Addition of reinforcing agents also prohibited and reduced abilities to kill the microbial.

2. Wear behaviors in composite materials (WCM): This work focused on improvements of wear resistance and friction coefficient of polymer based composite materials. The materials systems used were wood/PVC composites, Polyether ether ketone (PEEK) / hexagonal boron nitride (h-BN) composite coating via flame spray coating process, Al-bronze/PEEK/PTFE coating, natural rubber with fly ash based filler, fly ash/phenolic resin. The effects of testing conditions (load, testing speed), h-Bn content and particle size, and type of counter-face materials were of interests. The selected results suggested that the microhardness and degree of crystallinity could be improved with h-BN particles. The addition of h-BN particles into PEEK gave a lower specific wear rate and for higher content of h-BN added to PEEK coating resulted in a decrease in the friction coefficient. High applied load and high loading of h-BN in PEEK composite coatings provided good friction reduction while the composite coatings formed severe wear with grooves. In rubber compounds, bagasse fiber ash (BFA) was used as alternative and/or secondary filler in natural rubber (NR) compounds with a recommended loading of not greater than 15 parts per hundred rubber. In the hybrid filler system, BFA could be used to replace both PSi or CB filler up to 75% of the total hybrid filler (either BFA:PSi or BFA:CB) not exceeding 15 phr, without affecting the ultimate mechanical properties. For WPVC system, the work aimed to develop wood/PVC hybrid composite materials by incorporating synthetic fibers, namely E-glass, S-glass and carbon fibers. Three different wood flours were also considered, including *Xylia kerrii* Craib & Hutch. (XK), *Hevea brasiliensis* (HB) and *Mangifera indica* Linn. (MI). The results suggested that the addition of synthetic fibers significantly improved the flexural properties of WPVC composites, but only slightly affected their specific wear rate values, this effect being most pronounced with the incorporation of carbon fiber and when tested at longer sliding distance. The influence of different wood types showed no definite trend on the specific wear rates of the WPVC hybrid composites. Among different counterface materials used, a sandpaper counterface resulted in the highest specific wear rate, which involved a two-body abrasion mechanism. The results of this work indicated that S-glass fiber and XK wood were most suitable for co-reinforcing the wood/PVC composites in terms of wear-resistant applications.

3. Reinforcement applications in polymer materials (RAP): This research extended the reinforcement issues of different polymeric systems including thermoplastics (PP and PVC), wood/PVC composites (WPVC) and natural rubber and rubber composites (NBR and HNBR). The reinforcement techniques and techniques used included (i) filler reinforcement where carbon black, precipitated silica and bagasse ash fibers were used as aggregated fillers, and cotton short fibre as fibrillar filler and glass fiber reinforcements. In the case of fibre reinforcement, the curing behavior affecting anisotropic effect of reinforcement was monitored. Also, the bagasse fiber ashes were employed as a diluent in association with reinforcing filler (namely hybrid fillers); (ii) product designs where analytical and computational investigations were employed in WPC or WPVC materials before and after reinforcements, and (iii) the melt processability, rheological tests and the melt strength were examined for both plastic and elastomeric compounds. A reinforcement of hydrogenated acrylonitrile butadiene rubber (HNBR) by cotton fiber as natural reinforcing filler suggested that mechanical properties of rubber composites were improved dramatically by the addition of cotton fiber due to the enhanced hydrodynamic effect in association with crosslink density. Unexpectedly, with increasing fiber loading, the abrasion resistance decreases which was due to a poor interfacial adhesion between HNBR and fiber surfaces. The degree of fiber alignment was found to depend strongly on shear strain. The results demonstrate the importance of fiber alignment controllable efficiently by shear strain. Finally, the flexural and creep performances of strengthened wood/PVC (WPVC) composite members were investigated using a high carbon steel (HCS) flat bar strip adhered to the tension side and a carbon steel (CS) flat bar strip attached to the compression side. Good correlations of analytical, numerical and experimental results were obtained for the members before and after strengthening on the tension side, especially at initial displacements. The flexural and creep performances of strengthened wood/PVC (WPVC) composite members decreased with temperature. The final part dealt with measurement of melt strength of polymer and polymer composites using a newly designed experimental rig. The results suggested the drawdown forces changed continuously with changing roller speed. The changes in elongational flows were more sensitive to the changes in volumetric flow rate and roller speed in the circular die. The melt strength of polymer melt was found to reduce with addition of wood particles.

The summarized findings

The details of the work mentioned in the Methodology, Results and Summary parts are given in 28 publications in international refereed journals indexed in Thomson Reuters (ISI) and Scopus databases (see the list at the topic 2).

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