Flammability of natural fibre-reinforced polymeric composites

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Extensive studies have been carried out on the thermal decomposition and fire resistance of polymeric materials to reduce their high flammability. Although addition of flame retardant (FR) has proven to be effective in controlling the fire, some of them containing halogens, have negative effects on the environment and human health [1]. Thus, it is desirable to use an environment friendly fire retardant system for polymeric composites. Natural fibres are increasingly being considered as a group of alternative reinforcement materials in composites due to their certain inherent advantages, namely biodegradability and CO_2 neutrality, over the synthetic materials. Wool as a natural protein fibre is a less flammable material because of its relatively high content of cysteine (10 wt%), which is a sulphur containing amino acid, and nitrogen (15-16 wt%) [2]. It has also been observed that wool fibres produce char in an intumescent manner upon combustion. On the other hand, lignocellulose fibres, such as flax and kenaf, which are commonly thought as combustion sources in composites, the amount of lignin content can contribute to beneficial char formation and provide a thermal barrier. Therefore, the fire growth can be controlled by selecting suitable combination of materials in the composites. The char-forming tendency of the natural fibres can be increased with the addition of phosphorus based FR [3]. In particular, as a halogen-free intumescent FR, ammonium polyphosphate (APP) contains phosphorus and nitrogen, which can contribute to improved fire retardancy for polyolefin under combustion.

In this presentation, two different types of natural fibres, namely wool (animal-based) and kenaf (plant-based), have been selected to investigate their influences, in combination with suitable FR contents, on the flammability of thermoplastic polymer composites. Standard flammability test methods (e.g. cone calorimeter and UL-94) and thermogravimetric analysis have been employed to evaluate the fire performance and thermal decomposition of materials, respectively. The combined effects of wool and FR on effective char formation of the composites have achieved a significant reduction in heat release rate in the cone calorimeter test, Figure 1(a), and self-extinguishment after vertical flame application. The char structure formed during the cone calorimeter test has also been studied by scanning electron microscope (SEM), Figure 1(b). As an extension of research on wool, fibre surface has been chemically treated by amine phosphate and phosphoric acid in order to enhance the fire resistance - Fourier transform infrared spectroscopy and SEM have identified successful flame retardant treatment on wool surface. In each case, attention has been given towards maintaining/improving the mechanical properties.

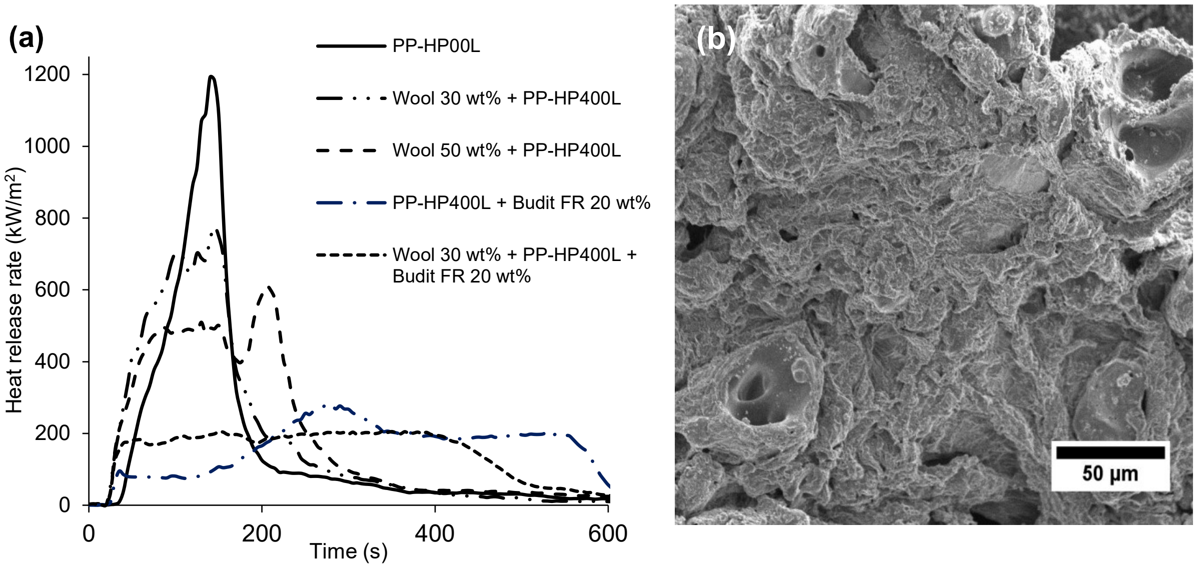

Figure 1 (a) Heat release rate curves of neat PP, wool+PP and wool+PP+APP composites, and (b) SEM image of char surface of wool+PP+APP composite after cone calorimeter test

In addition, the burning behaviour of thermoset polymer composites with long flax fibre has also been explored and compared with that of glass fabric reinforced composites. Although flax is more combustible than glass, similar fire reaction properties of flax and glass composites have been obtained due to intumescent char formed by the combination of flax and APP. Finally some results will be presented on the overall fire modelling of natural fibre composites, including combustion and structural damage under fire. It is shown that heat release rate simulated by Fire Dynamics Simulator package can match reasonably well with the experimental findings. The implications on possible structural damage will also be discussed using fire-induced damage prediction models [4].

References

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BIOGRAPHICAL SKETCH OF

PROFESSOR DEBES BHATTACHARYYA

Professor Debes Bhattacharyya is a **Distinguished Professor** in the Department of Mechanical Engineering and has been the founding Director of the Centre for Advanced Composite Materials at the University of Auckland. In 2016, he was felicitated as the Dr A P J Abdul Kalam Professor by SRM University in Chennai, India. He also holds an Adjunct Professor position at Washington State University, Pullman, USA. Professor Bhattacharyya was the Head of Mechanical Engineering Department from 1999 to early 2005. His research interest includes the mechanics and manufacturing of composite materials. He has held visiting positions at various universities in Australia, Canada, Germany, Hong Kong and the US, and has been awarded a number of international awards. He has delivered > 65 keynote/plenary/invited lectures at international conferences. He is currently the Editor (2) and Associate Editor (1) of three international journals and has served/is serving on the Editorial Advisory Boards of eight journals. Prof. Bhattacharyya has more than 450 scientific/technical publications including several edited/authored books and a number of book chapters. He has successfully implemented several international patents. He is a Fellow of the Royal Society, NZ and a Distinguished Fellow of the Institution of Professional Engineers NZ (IPENZ). He is a life member of ASME. For his international academic achievements he has been awarded an honorary 'Doctor of Engineering' (*honoris causa*) by the University of Southern Queensland, Australia. In 2012, he was awarded by IPENZ the Supreme Technical (John Cranko) Award for his professional contributions. He is a member of the Executive Council and past President of the Asian-Australasian Association of Composite Materials. He has done extensive consulting in New Zealand and overseas, and has chaired or served on many panels in New Zealand and Australia. He has been involved in the supervision of more than 110 postgraduate students including more than 60 PhD candidates. He has overseen 20 postdoctoral fellows/research associates. He has served as the Reviewer/Assessor for more than 35 international journals and organisations in Australia, Bulgaria, Canada, Hong Kong, Poland, Singapore & NZ. He has been the founding Director of Centre for Advance Composite Materials (CACM) until recently and has raised as the Principal Investigator more than $45M from both private and public sources in NZ and overseas – has established collaborative partnerships with several organisations in Australia, Canada, China, Germany and the US. He received a Teaching Excellence Award (sustained postgraduate supervision and teaching) from the Faculty of Engineering, The University of Auckland in 2013. He is involved as an international expert with Brain Korea 21+ program in advanced/nano-materials area (2014 – 19). For his overall achievements he has received several awards including two gold medals at the House of Lords, London, UK and Capitol Hill, Washington D.C., USA.