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FULL LENGTH ARTICLE

Application of Interval Type-2 Fuzzy Logic to polypropylene business policy in a petrochemical plant in India

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Abstract This paper presents a new approach to predict the quality of polypropylene in petrochemical plants. The proposed approach constructs four different models, based on a large number of data collected from a renowned petrochemical plant in India and uses it to predict the polypropylene quality. The quality of polypropylene depends on the indices such as melt flow index and the xylene solubility of the product and the parameters controlling these two indices are hydrogen flow, donor flow, pressure and temperature of polymerization reactors. Mamdani Interval Type-2 Fuzzy Logic inference systems are formed for first time. The model outcomes are compared with the collected plant data and a sequence of sensitivity analysis elects the most suitable model from them. Some sensitivity analyses are provided using Fuzzy C-Means Clustering to the models.

1. Introduction

Polypropylene is a versatile thermoplastic resin available in a wide range of formulations for engineering applications. Polypropylene (commonly called just PP) is a type of thermoplastic polymer resin. The chemical designation is $(–C_3H_6–)_n$. It is used both in industry and in consumer goods; it can be used both as a structural plastic and as a fiber as well. The structural plastic is often used for food containers, particularly those that need to be microwave safe and dishwasher safe. The melting point of polypropylene is very high compared to many other plastics, at 320 °F (160 °C). Polypropylene is also very easy to add dyes to and it is often used as a fiber in carpet

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Figure 1 House ware sector application: PP.

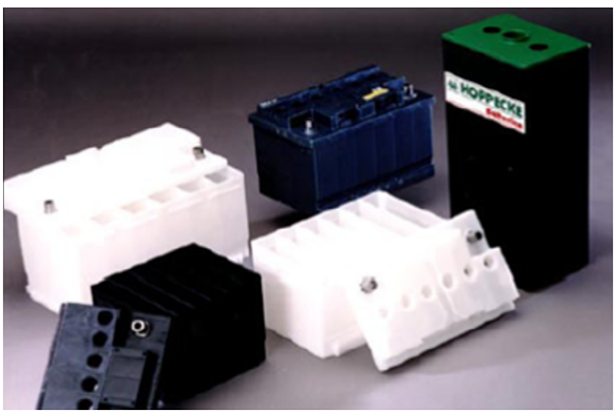

Figure 2 Battery sector application: PP.

Figure 3 Cast film application: PP.

Figure 4 Material development application: PP.

manufacturing that needs to be rugged and durable. Other benefits of PP are that it does not absorb water like other plastics, it does not deteriorate in the presence of bacteria, mold or other elements, and it is lightweight and very flexible. Rapid growth of PP as a novel material, touching all conceivable application areas and excelling in most of them, has helped industries in most sectors (including petrochemicals, electrical and electronics, consumer durables, packaging, storage, gasket and sealants, material handling and conveying, transportation and communication, furniture, footwear, personal care and health care, sports and entertainment) grow at a rapid pace. The global demand for polypropylene jumped from 6.4 million metric tons in 1983 to 38.6 million metric tons in 2004, with a growing rate as high as 5.8% from 2004 to 2009. Recently the world annual polypropylene production has increased from 52 million metric tons in 2008 to 69.1 million metric tons in 2013 and forecasts an annual increase on polypropylene global demand by 3.7% in the 2010–2014 time frame (Alshaiban, 2011). One can therefore expect a very booming market and bright future market for PP. All real-life applications of PP are shown in Figs. 1–4. The history of PP began in 1954 when a German chemist named Karl Rehn and an Italian chemist named Giulio Natta first polymerized it (Martin, 1954). This led to a large commercial production of the product that began just three years later (Sailors and Hogan, 1981). In last 60 years, the uses of PP have expanded rapidly in every aspect of life because of its versatility and affordability. The mean consumption rate of PP was about 10% per year in the recent past, and in application field this value is however way higher (Karger Kocsis, 1995). Depending on the end-users demand 3 types of polypropylene are produced (i) homopolymer, (ii) impact copolymer and (iii) random copolymer. Each type of polymer is produced in 4 different grades (3.5 MFI, 7 MFI, 10 MFI and 36 MFI) and these grades determine the quality of a polymer.

Application of polypropylene is based on its quality, which is controlled by its properties, such as melt flow index (MFI) and xylene solubility. To determine the quality of PP we, in this paper, have tried to form a mathematical model. The quality of the polymer depends on the products that are used to synthesize it (considered to be the input variables) and the characteristics of the final polymer (considered as the output variables). In classical logic approach an exact definition of mathematical model equations is needed to formulate a physical model and this approach requires an exact definition of the mathematical model equations to describe the phenomenon (Naderloo et al., 2012). But in practical field where the polymer is produced no such exact definitions have been followed and the variables take only linguistic values rather than some crisp values. One of the best methods to make a mathematical model from it, is to apply fuzzy logic approach just like how (Zhou et al., 2014) applied fuzzy programming to create an integrated model for sustainable municipal energy system