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A Perspective on various alkyl ketene dimer (AKD) application areas

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Abstract: Alkyl ketene dimer (AKD) is a common sizing agent, which is suitable for any kind of cellulose and its derivatives. To control of the penetration of liquids from paper surface is important by terms of printability and protecting the products from liquids. AKD sizing applications are becoming increasingly important in parallel with technologic development of industrial applications. It is necessary to examine the present state of the paper industry and the traditional practices in order to successful sizing. Pulp and paper industry, still major practitioner of the AKD, has the proper experience about AKD production and application. Besides that, there is growing interest about AKD applications certain area of engineering. This review is a brief outline showing experiments on AKD from researchers.

Keywords: AKD, alkyl Ketene Dimer

Çeşitli alkil keten dimer (AKD) uygulama alanlarına bir bakış açısı

Özet: Alkil Keten Dimer (AKD) selüloz ve türevleri için uygun olan yaygın bir iç tutkallama ajanıdır. Kâğıt yüzeyine veya tüm kâğıda sıvıların nüfuzunu kontrol etmek basılabilirdik açısından ve ürünlerin sıvılara karşı korunması açısından önemlidir. AKD tutkallama uygulamaları kâğıt uygulamalarının teknolojik gelişimine paralel olarak giderek daha fazla önem kazanmaktadır. Başarılı tutkallama için kâğıt sanayi ve geleneksel uygulamaların mevcut durumunu incelemek gerekir. Kâğıt hamuru ve kâğıt endüstrisi, AKD'nin hala en büyük uygulayıcısıdır, AKD üretim ve uygulama hakkında deneyime sahiptir. Bununla birlikte, AKD uygulamalarına mühendisliğin çeşitli alanlarında artan ilgi vardır. Bu derleme araştırmacıların AKD uygulama deneylerini gösteren kısa bir özettir.

Anahtar kelimeler: AKD, Alkil Keten Dimer

1. INTRODUCTION

Natural structure of the paper tends to absorb aquatic liquids because of their main components of cellulose and hemicellulose which contain hydroxyl groups. In order to prevent or retard the absorption of water, a procedure called sizing should be applied to the paper.

Sizing refers to the entire paper (internal sizing) or along the paper surface (surface sizing), control penetration of liquid. Surface sizing is applying to the hydrophobic chemicals to the outer surface of the paper at the dry end process (Latta, 1997; Neimo, 1999; Davison, 1992; Roberts, 1996; Roberts, 1997b; Hodgson, 1994). Internal sizing is defined as the process of gaining the resistance to water or other fluids to the cellulosic fibers during the wet end process (Crouse and Wimer, 1990; Eklund and Linström, 1991; Roberts, 1997a; Neimo, 1999; Hubbe, 2000; 2005; 2006a). Controlling the absorption of liquids is critical for both printability and specific purpose such as paper based biosensors.

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2. PAPER AND PAPER ADDITIVES INDUSTRY

Paper production is the subject of industrial application. According to Trademap 2014 data, while the global paper and paperboard imports was 156.7 billion dollars in 2009, increase to $ 173.7 billion in 2013 (ITC, 2015). Recycled fibers, which is another important fiber source is subject of important part of paper trade. The FAO data shows that, the total capacity of recycled paper and cardboard as seen 8.575 million tons in 2014 and it will reach 8.568 million tons in 2019 (FAO, 2015).

Such a large production should be considering both global and local aspect. Sectoral assessments need to see what the industry is so great. To evaluate the data in our country, it can be concluding that growth curve is similar with the global consumption.

By looking at the last five years of development; Turkey's paper and paperboard exports has increased in 2011, but experienced a slight decline in 2012. 1.1 billion dollars was exported paper and paperboard in 2013 (ITC, 2015). Meanwhile, Turkey's imports of paper and paperboard was 2.2 billion dollars in 2009, increase $ 3.1 billion in 2013. Report on the global paper in April 2015, during the first quarter of 2015 mixed paper per ton has declined to 120 dollars from 135 dollars (Linnenkoper, 2015). Istanbul Chamber of Industry, report that the production of paper and paper products in Turkey has increased 45.9 percent during the period 2006-2013. The highest share of imports is paper and paperboard with $ 2 billion (ISO, 2015).

For such a large amount of industrial production of pulp and paper, it is expected to improve the properties of the paper-enhancing additives. Referring to the global consumption, even if only in the North American paper industry is estimated to spend about 715 million dollars to the paper making additives (William and Scott, 1996). These additives are substances are retention aids (especially polyacrylamide) internal sizing agents (resin, ASA, AKD), fillers etc. With respect to the annual consumption of AKD with the promoters increased during 4 years (between 2010-2014 increased 265 tons (about 250.000$) to 764 tons 201 (about 720.000$) in Turkey (Pulp and Paper Industry Foundation Annual Report, 2015). In light of this data, AKD production will be increased in later years.

3. SIZING AGENTS

Since 1953, due to changes in paper production system, synthetic sizing agents are increased. AKD have been dominant in the market until recently. It is highly surprising that synthetic agent takes place of the rosin products such a rapidly way. Up to 1953, the rosin was the prominent commercial internal sizing agent and papermaking system was typically acidic until 1970s. The reason of this situation the use of rosin, the mechanism began to evolve at 1971, with aluminum sulfate as a retention aid. aluminum sulfate in aqueous solution, become aluminum ions which it holds the pH 4 to 5 range. (Strazdins, 1989).

Starting from 1970, the paper making system began to take place of the acidic to neutral or even alkaline systems. Neutral systems have many advantages. In alkaline system, fibers can be swollen more easily and pulp can be dried faster thanks to filler. Therefore, paper industry start production in a neutral and alkaline system inevitably. Naturally began to search for alternatives that can replace the rosin sizing. In 1953, the first synthetic sizing agent AKD's patent was taken by Hercules (USA Patent No. US2627477 A, 1953). For papermaking, AKD were developed by Hercules in 1956 (Davies et al., 1956). From now on AKD emerged the essential sizing agent for alkaline papermaking. On the other hand National Starch's received ASA as a new sizing agent patent (USA Patent No. US3821069 A, 1974). Nowadays, global paper industry uses AKD and ASA as a sizing agent mostly.

4. SIZING WITH AKD

There had been controversies about 'cellulose reactive sizing' terms. By the scientists on a large scale it is accepted that AKD forms covalent bonds with cellulose through ester bonds (Nahm, 1986; Lee and Luner, 2005; Davies et al., 1956; Roberts and Garner, 1984; Lindstrom and Soderberg, 1986; Odberg et al., 1987). The mechanism of sizing has been the subject of many studies (Garnier and Wright, 1998; Lindstrom and Soderberg, 1986; Odberg et al., 1987).

It is believed that mechanism occur three main steps. Firstly, AKD particles retain on the pulp fibers. Secondly, AKD particle spreading of a thick film layer. Lastly, β-keto ester linkage within cellulose and AKD. This β-keto ester bond have significant role in the sizing (Roberts and Garner, 1985; Garnier and Wright, 1998; Marton, 1990; Odberg et al., 1987). However, AKD can be reacted with water at the same time. In this case AKD hydrolyzed to ketone and occurs *β*–ketoacid which is an undesirable substance in papermaking process (Marton, 1990). To avoid *β*–ketoacid formation water–free condition systems should be developed.

5. VARIOUS APPLICATION OF AKD

AKD has been widely use in various fields. There are several studies concerning about modification of cellulose with AKD treatment. Also in biomedical devices which has disposable equipment's, is preferred the paper material because it is functional and inexpensive. Paper is suitable material for biomedical devices and researchers have been developed new technics to make papers compatible to their device. Therefore, the paper in this equipment treated with AKD to become suitable for use. Looking for low-cost devices for diagnosis, scientists are directed to do research with disposable paper for biochemical application (Li et al., 2012; Martinez et al., 2007). Some researcher tried to develop new method of AKD application. One of them is dissolved AKD wax in solvents, for example dissolving in n-heptane and dipping the paper in solution (Li at el., 2010a; Li et al., 2008; Shen et al., 2000; Seo et al., 2008). Dipping the filter paper to n-heptane-wax solution method can also be used to see the effect of AKD wax on the paper (Bildik et al., 2016). In another approach the ink jet printer was used to print AKD-heptane solution to the paper (Li et al., 2010a; Li et al., 2010b; Guan et al., 2014; Li et al., 2008).

Feasibility of successful implementation of AKD on paper, it is suggested that it could be applied also to the wood. However, researchers could not find any sizing effect both of the when they were blended with AKD and the UF-resin and AKD solution applied directly under vacuum pressure to the wood particles. Consequently, it is assumed that this could cause from failure of the application and in further studies application methods will be replaced (Hundhausen et al., 2009).

AKD cellulose interactions have been subject to new studies (Yan et al., 2016). Cellulose derivatives such as microfibrillated (MFC) cellulose and nanofibrillated cellulose (NFC) have potential as a polymer reinforcement material (Lee et al., 2014; Aitomäki and Oksman, 2014; Eichhorn et al., 2010; Dufresne, 2012). Modification of cellulose, MFC and NFC become important. The researchers became interested in cellulose derivatives and modification of their features with AKD (Yan et al., 2016; Song et al., 2012; Yoshida et al., 2012; Russler et al., 2012).

6. CONCLUSIONS

The successful results of the sizing application ensure that the use of AKD will be increased in future. AKD applications can be seen in all fields that use cellulose and its derivatives, especially in the paper industry. Cellulose surface modification necessary by means of controlling the penetration of liquid. AKD applications in various fields of engineering will take place promising developments in a short time

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