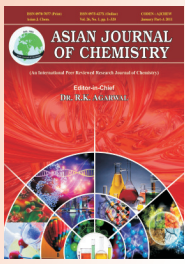
Asian Journal of Chemistry; Vol. 26, No. 16 (2014), 5100-5104

ASIAN JOURNAL OF CHEMISTRY

http://dx.doi.org/10.14233/ajchem.2014.16339



Effect of Dispersants on Dispersion of Glassfiber Suspensions

QING CHEN, ZHAO-FENG CHEN*, CHENG-DONG LI, WANG-PING WU, FRED EDMOND BOAFO and BIN-BIN LI

Super Insulation Composites Laboratory, Nanjing University of Aeronautics and Astronautics, Nanjing 210016, P.R. China

*Corresponding author: Fax: +86 25 52112626; Tel: +86 25 52112909; E-mail: zhaofeng_chen@163.com; chenqingbla@163.com

Received: 12 September 2013; *Accepted*: 11 November 2013; *Published online*: 28 July 2014; AJC-15639

Glassfiber core material used as the insulation filler of vacuum insulation panel was successfully fabricated by wet method. The quality of glassfiber suspensions dispersion could affect glassfiber distribution of the core material and the thermal insulation performance of glassfiber vacuum insulation panels. The effects of the mean length of glass fibers and dispersants on glassfiber suspensions dispersion were investigated. The dispersion characteristic of glassfiber suspensions was analyzed by the absorbance and sedimentation rate. The results showed that the absorbancies of glassfiber suspensions under the optimal concentration of the three types of dispersants were 0.344, 0.703 and 0.663, respectively. The optimum addition amounts of hydroxyethyl cellulose, hydroxypropyl methyl cellulose and sodium hexametaphosphate were 0.008, 0.012 and 0.04 %, respectively. The glassfiber suspensions with sodium hexametaphosphate had a complete dispersed characteristic.

Keywords: Dispersant, Dispersion, Glass fiber, Suspensions, Absorbance.

INTRODUCTION

A vacuum insulation panel (VIP), which consist of a micro-porous core structure, a thin gas tight envelope bag and getter or desiccant, is the most energy-efficient thermal insulation material is available in the market today. At present, the thermal conductivity and thickness of vacuum insulation panel with glassfiber core material are as low as 0.0015 W/(m·k) and 5 mm, respectively, which have about 1/10 lower thermal conductivity and 1/7-1/10 lower thickness than those of the conventional thermal insulation materials[1-4]. In recent decades, vacuum insulation panels are the key materials in the fields of high-end areas of energy, such as aeronautics, astronautics, warships, submarine, missile launcher wall and aircraft downtime wall[5,6].

Core material provides strength against the external atmospheric pressure and particularly determines the thermal insulation performance of vacuum insulation panels[7,8]. At present, glass fiber is widely used as the core material for vacuum insulation panels. Glassfiber core material produced by wet process includes the following steps: providing suspensions of glass fibers; dewatering the suspensions to form a wet-laid mat; drying and cutting the mat[9]. In glassfiber suspensions, the van der Waals force between glass fibers plays a major role which can attract glass fibers coupled together and tangled with each other intricately because of high aspect ratio of glass fiber[10]. The glass fiber flocculation can seriously affect the distribution structure of core material after forming and the direction of heat transfer in the fibrous material. Dispersing media can be effectively used to disperse the fibers in water. A source of supply of a suitable dispersant, such as cellulose, is connected with water when the dispersant and water are mixed together to form a viscous dispersion[11]. Thus, the dispersion characteristic of glassfiber suspensions is the key technology. However, relatively fewer research works on glass fiber suspensions for vacuum insulation panels core material are found in literatures. To resolve the problem of flocculation in glassfiber suspensions for vacuum insulation panels core material, the effects of the mean length of glass fibers and the dispersants on dispersion characteristic of glassfiber suspensions were investigated in the present paper.

EXPERIMENTAL

The centrifugal glass fiber was manufactured by Suzhou V.I.P. New Material Co., Ltd. Hydroxyethyl cellulose (HEC), hydroxypropyl methyl cellulose (HPMC) and sodium hexametaphosphate (SHP) were supplied by Shangdong Head Co., Ltd.

Morphology and microstructure of the glass fibers were observed by scanning electron microscopy (SEM, Hitachi S-4800). The glass fiber block with 2 g weight was cut into horizontal and vertical geometries according to the average length of glass fiber, which was about 38 mm. Afterwards, a

concentration of 0.2 % glass fiber suspensions was prepared at 2890 r/min speed beating for 1000 r by using a GBJ-A fiber standard dissociation device. All components were dissolved in deionized water. The aspect ratio of the best cutting samples were drawn according to the data measured by fifty points (fibers) before and after cutting, respectively. The experiments were conducted at pH = 3.5 ± 0.05 adjusted at room temperature by additions of sulfuric acid. The pH was measured before and after the experiment by means of pH meter (PHS-25 C).

The best cutting samples were added with three different dispersants uniformly and the addition amount of dispersants was 0.004, 0.008, 0.012, 0.02, 0.03, 0.04, 0.06, 0.08 and 0.1 % of its total amount, respectively. After 5 min standing, the absorbancies of supernatant liquid of the suspensions were observed by UV-1800 spectrophotometer (Shimadzu Corporation) under 968 nm absorption peak. The sedimentation height of glassfiber suspensions were measured every 5 s in 300 mL glass beaker for free settling.

RESULTS AND DISCUSSION

The SEM micrograph of glass fiber is shown in Fig. 1. The glassfiber vacuum insulation panel core material are stratified randomly and entangled with each other. The mean diameter of glass fiber was about 2.5 μm while the average length of glass fiber was about 38 mm.

Cutting and aspect ratio of glass fiber: The size of fiber block was prepared according to the average length of glass fiber. Table-1 shows the different cutting methods on the fiber mass area. Obviously, with the decreased of fiber block size, the fiber mass area and the mean length of glass fibers in suspensions decreased too. The percentages of fiber mass area

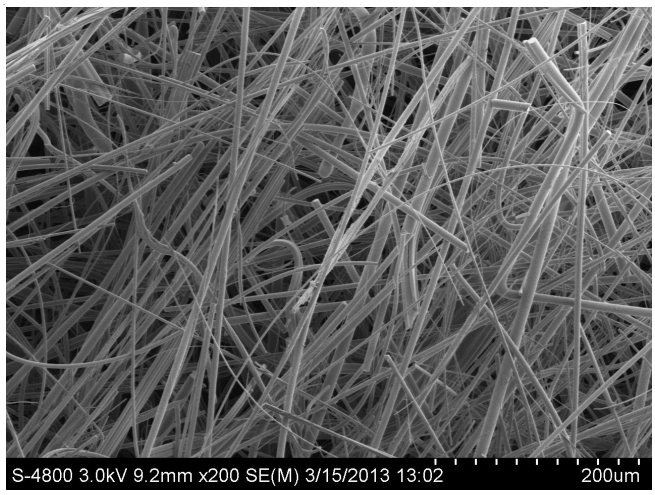
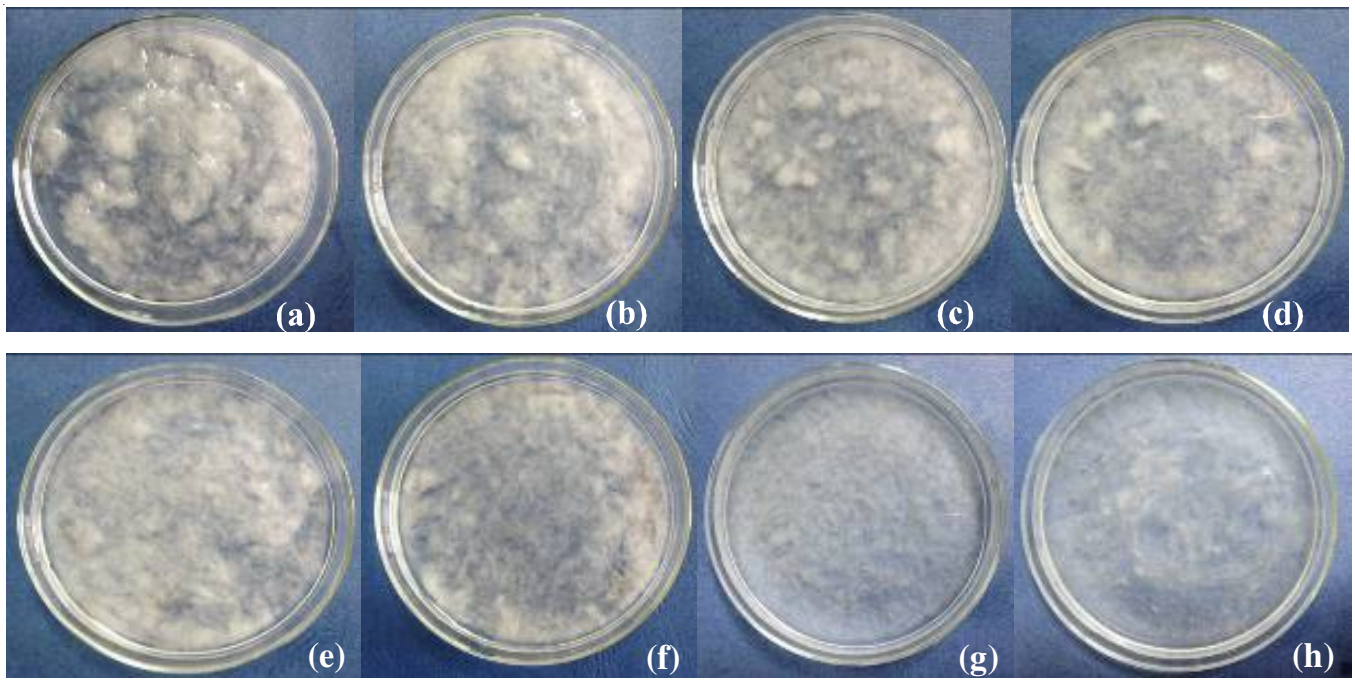


Fig. 1. SEM micrograph of glass fiber

in the suspensions before and after cutting were 72.6 and 2.4 %, respectively. At the same time, the mean length of glass fibers decreased from 38 to 12 mm. It is noticeable that the dispersion degree of glass fiber after cutting is significantly higher than that of glass fiber before cutting.

Fig. 2 shows the effect of different fiber-block sizes on glassfiber suspensions. The size of fiber block (a) was 80 mm × 80 mm; after beating the suspensions appeared dense and continuous glass fiber flocculation. Sample (a) showed a poor dispersibility. The dispersion of the fibers in samples (d), (e) and (f) were better than that of the fibers in samples (b) and (c). Samples (g) and (h) showed better dispersion with less tiny fiber content and no significant flocculation. Comparing samples (d), (e), (g) and (h); samples (d) and (g) were rectangular cotton-block and samples (e) and (h) were square cotton-



(a) 80mm×80mm (b) 40mm×80mm (c) 20mm×80mm (d) 20mm×40mm
(e) 20mm×20mm (f) 10mm×40mm (g) 10mm×20mm (h) 10mm×10mm

Fig. 2. Effect of different fiber-block sizes on glassfiber suspensions

TABLE-1
EFFECT OF DIFFERENT CUTTING METHODS ON THE FIBER MASS AREA

Number	Fiber block size (mm)	Fiber mass area (%)	Mean length of glass fibers (mm)
a	80 × 80	72.6	38
b	40 × 80	52.7	30
c	20 × 80	48.1	26
d	20 × 40	14.9	23
e	20 × 20	16.2	16
f	10 × 40	15.4	13
g	10 × 20	2.4	12
h	10 × 10	4.7	13

block. The fiber mass area of samples (e) and (h) were higher than that of samples (d) and (g). Thus, the square cotton-block after beating showed a better dispersion because the rectangular cotton-block in the water experienced more shearing force than that of the square cotton-block. Hence, the dispersion of rectangular cotton-block after beating was better than that of the square cotton-block.

The measured average length of uniformly dispersed glass fiber in sample (g) was 12 mm. Fig. 3 shows the aspect ratio of fibers before and after cutting. It was shown that the aspect ratio of glass fiber before cutting was 3-20 and present a discrete distribution. After cutting, the aspect ratio of glass fiber was main 0.5-4, which showed a decrease. According to the crowding number formula[12]:

$$N_{crowd} = \frac{2}{3} C_v \left(\frac{l}{d} \right)^2 \quad (1)$$

where N_{crowd} is the crowding number, C_v is the suspensions concentration, l is the length of the glass fiber and d is the diameter of the glass fiber. When the aspect ratio of glassfiber suspensions at the same concentration is reduced, the crowding number of the fiber can effectively reduce consequently. Hence, the possibility of glass fiber forming agglomerates in suspensions would be reduced.

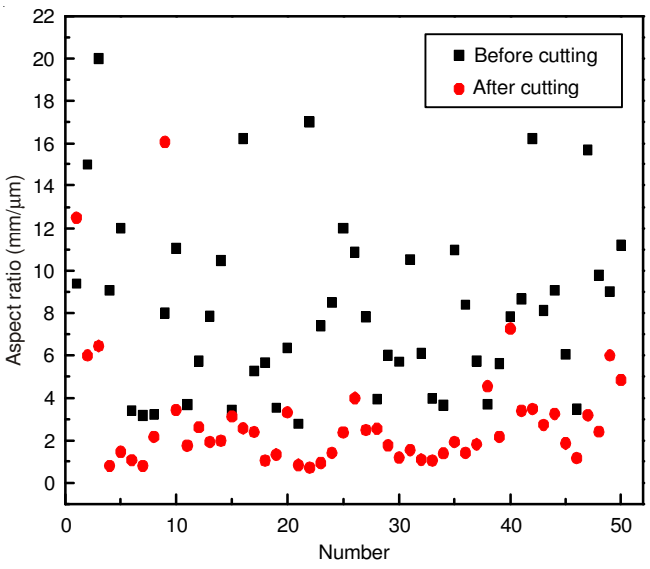


Fig. 3. Diagram of aspect ratio of glass fibers before and after cutting

Dispersion characteristic of glassfiber suspensions: Sedimentation rate and the absorbance of suspensions are indirect but provide a simple way to measure the dispersion of glassfiber suspensions. Generally, the slower the fiber sedimentation rate, the longer the fiber suspension in the suspensions and the better the dispersion of the suspensions. When light passes through the suspensions, because of the scattering and absorption of light of the intertwined glass fibers, the incident light can not pass through that part of the suspensions. According to the Lambert-Beer law[13]:

$$A = \log\left(\frac{I}{I_0} \right) = -\log T \quad (2)$$

where A is the absorbance, T is the transmittance, I_0 is the incident light intensity and I is the transmitted light intensity. From eqn. (2), it is shown that the higher the absorbance, the weaker the transmittance of suspensions. The lower the absorbance, the stronger the transmittance of suspensions and *vice versa*.

Fig. 4 shows the influence of dispersants amounts on the absorbance of glassfiber suspensions. The absorbance was 0.041 when there was no dispersant. In the low concentration of 0.012 %, the maximum value of the absorbance of suspensions with hydroxypropyl methyl cellulose was 0.703, which showed a better dispersion than that of hydroxyethyl cellulose and sodium hexametaphosphate. In other words, glass fiber show a good dispersion in high absorbance and form reunite in low absorbance according to the eqn (2). With the increase of concentration, the viscosity of the suspensions with hydroxypropyl methyl cellulose get bigger which results in weakening the dispersion of hydroxypropyl methyl cellulose whiles enhancing the thickening ability. The mobility of suspensions became worse and the absorbance of glassfiber suspensions slowed down and tended to be stable[14]. In the high concentration of 0.04 %, sodium hexametaphosphate showed enhanced dispersion. The absorbance of suspensions with sodium hexametaphosphate was 0.663 which was higher than that of hydroxypropyl methyl cellulose. While the suspensions with hydroxyethyl cellulose kept a very low absorbance at its optimum amount relatively (0.344 at concentration of 0.008 %).

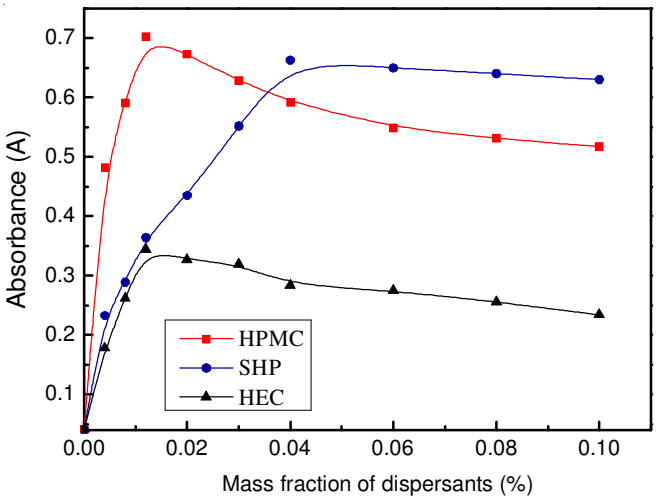


Fig. 4. Influence of dispersants amounts on the absorbance of glassfiber suspensions

Fig. 5 shows the diagrams of adsorption of three dispersants at the surface of glass fibers. The hydroxyethyl cellulose is a kind of nonionic surfactant while hydroxypropyl methyl cellulose is a kind of water-soluble organic polymer. Fig. 5a indicates that when hydroxyethyl cellulose was added to the suspensions, the consistency of suspensions increased[15]. It was observed that the glass fiber could not dispersed better in high consistency suspensions. As for hydroxypropyl methyl cellulose, Fig. 5b depicted that hydroxypropyl methyl cellulose attached to the surface of the fiber, forming a thin lubricating film equivalently. As a result, the fibers slide over each other without tangles and the fine glass fiber content decreased slightly[16]. In this way, it explained that high concentration of hydroxypropyl methyl cellulose makes low absorbance of suspensions in Fig. 4. Thus, hydroxyethyl cellulose had a less affect on dispersion of glassfiber suspensions than that of hydroxypropyl methyl cellulose.

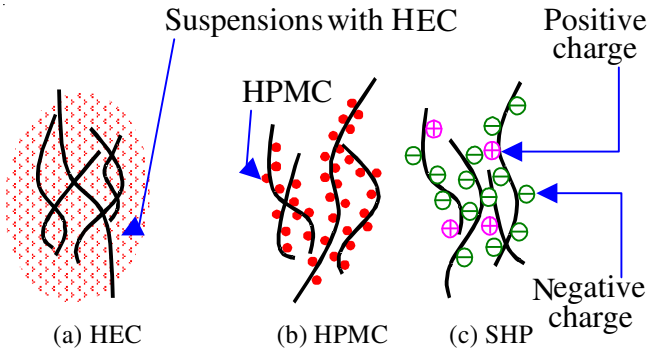


Fig. 5. Diagrams of adsorption of three kinds of dispersants on the surface of glass fibers

The glass fiber surface contains a lot of anionic group[17]; it could easily adsorbed charged H^+ from water molecules. In this way water molecule polarized, so that its positive end faced the interior of the fiber, whiles the negative end was toward the outside fiber. Therefore the glass fiber was negatively charged. Because of sodium hexametaphosphate is one kind of anionic dispersants, the negatively charged fibers produced specific adsorption to sodium hexametaphosphate when sodium hexametaphosphate was added to the suspensions. The negative charge on fiber surface changed to a more negative direction, making the fibers repel each other and dispersed stability as shown in Fig. 5c[18].

Fig. 6 indicates the sedimentation height of fiber suspensions added in optimal amounts of three kinds of dispersants. The sedimentation heights of suspensions with hydroxyethyl cellulose and hydroxypropyl methyl cellulose were 110 mL and 100 mL, respectively, which were much higher than that of sodium hexametaphosphate of 75 mL. It was illustrated that the suspensions with sodium hexametaphosphate had a relatively gentle subsidence rate at the same time because of its highly dispersed suspensions.

The settlement state diagrams of glass fiber in the solution are shown in Fig. 7. The fibers in Fig. 7a have a serious reunion phenomenon which cause the glass fibers to form a layered structure mat. Fig. 7b shows that it is typical of the dispersed fibers settling in suspensions. Less flocculation made fibers more dispersed and formed a uniform structure. Such results

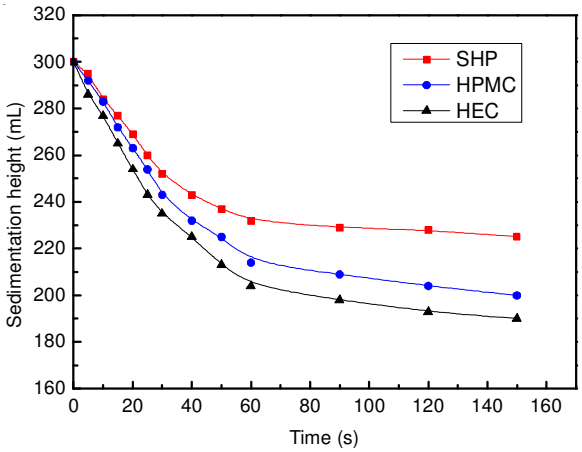


Fig. 6. Sedimentation height of fiber suspensions added in optimal amounts of three kinds of dispersants

suggest that the higher the ratio of fibers dispersed into single proportion, the slower the settling time[11]. Hence, Fig. 7a show a higher sedimentation height and higher reunion fibers than these of Fig. 7b at the same time.

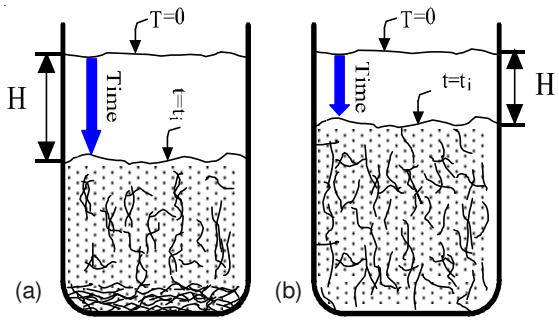


Fig. 7. Settlement state diagrams of glass fiber in the solution (a) settlement of reunion fibers (b) settlement of dispersed fibers

Conclusion

Cutting process made the glassfiber suspensions well distributed and less continuous flocculated. The optimum addition amounts of hydroxyethyl cellulose, hydroxypropyl methyl cellulose and sodium hexametaphosphate were 0.008, 0.012 and 0.04 %, respectively. The glass fiber suspensions with sodium hexametaphosphate at concentration of 0.04 % had a high and stable absorbance 0.663 and had the best dispersion, the minimum suspensions sedimentation height and the slowest sedimentation rate. The dispersion of the glassfiber suspensions prepared with hydroxypropyl methyl cellulose was better than that of the glassfiber suspensions prepared with hydroxyethyl cellulose.

ACKNOWLEDGEMENTS

This work was supported by Funding for Outstanding Doctoral Dissertation in NUAA (BCXJ13-10), Funding of Jiangsu Innovation Program for Graduate Education (the Fundamental Research Funds for the Central Universities, CXLX13_149), the Combined Innovation Fund of Industry-University Research in Jiangsu province (SBY201220136) and Taicang city (TCCXY1207), and the Sixth Major Talent Peak Achievement of Jiangsu Province (2011-JZ-016).

REFERENCES

1. Y.G. Wen, X.R. Wang and J.B. Yang, 9th International Vacuum Insulation Symposium, London, UK (2009).
2. C.D. Li, Z.C. Duan, Q. Chen, Z.-F. Chen, F.E. Boafo, W.-P. Wu and J.-M. Zhou, *Mater. Des*., **50**, 1030 (2013).
3. X.B. Di, Y.M. Gao, C.G. Bao, Y. Hu and Z. Xie, *Vacuum*, **97**, 55 (2013).
4. C.D. Li, Z.F. Chen, F.E. Boafo, Q. Chen, J. Zhang, J.-M. Zhou, X.-L. Ye and C.-Y. Li, *Dry Technol.*, **31**, 1084 (2013).
5. K. Araki, D. Kamoto and S. Matsuoka, *J. Mater. Process. Technol*., **209**, 271 (2009).
6. M.A. Tahir, H.V. Tafreshi, S.A. Hosseini and B. Pourdeyhimi, *Int. J. Heat Mass Transfer*, **53**, 4629 (2010).
7. H. Simmler, S. Brunner and U. Heinemann, Thermal Insulation Summary, IEA/ECBCS Annex 39 (2005).
8. M. Alam, H. Singh and M.C. Limbachiya, *Appl. Energy*, **88**, 3592 (2011).
9. Z. Chen, Z.F. Chen, T.Z. Xu, J.L. Qiu and J.M. Zhou, *Appl. Mech. Mater*., **121**, 181 (2012).
10. D.J. Shaw, Introduction to Colloid and Surface Chemistry, p. 217 (2000).
11. O.J. Rojas and M.A. Hubbe, *J. Dispers. Sci. Technol.*, **25**, 713 (2005).
12. C.T.J. Dodson, Fiber Crowding, Fiber Contacts and Fiber Flocculation, Pulp and Paper Centre, Internal Report (1995).
13. F.C. Strong, *Anal. Chem*., **24**, 338 (1952).
14. http://www.sxdaneng.com/en/PageView.Asp?id=213&Cid=106&Lid=51.
15. Y.W. Zhang, Q.R. Jin, J.X. Zhao, C. Wu, Q. Fan and Q. Wu, *Eur. Polym. J*., **46**, 1425 (2010).
16. H.F. Reims, Handbook of Paper Science, vol. 1 (1989).
17. Y.P. Lu, M.Q. Zhang, Q.M. Feng, T. Long, L.-Ou and G.-Zhang, *Nonferrous Met. Soc. China*, **21**, 208 (2011).
18. J. Larry, A Tappi Press Anthology (1991).