

Polyimide fiber paper research progress and performance introduction

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Abstract: The article introduced polyimide fiber paper and the paper-based composite materials applied in the nuclear industry, aerospace, military industry and general industry ; binding with the polyimide fiber performances to describes the polyimide fiber paper present research situation and difficulties under production.

Keywords: polyimide fiber paper, polyimide fiber, dispersion, shaping molding, heat treatment.

1 Foreword

At present,abroad study focused on the technical preparation of high performances Aramid paper. But now, there is fewer technical about polyimide fiber paper, one of the major factors in research is due to papermaking pulp technical barriers: 1960s DuPont began research polyimide fibers, but due to technical difficulties and with the maturity of Aramid fiber, and ultimately decided did not continue. Polyimide fiber has been reported in the former Soviet Union in the 1970s, but without further expansion of sales in the international market. Currently it is only used in military filed in Russia. As industrial high temperature filtration materials, Polyimide fibers can be only provided by one company named Evonic, which produces polyimide fibers marked P84; The other factor of polyimide paper fewer studies is that the performance of meta-aramid Nomex paper, produced by DuPont, can meet the needs of the industry at the time. Now, with the development of industrial, aviation, aerospace, shipbuilding, electronics and other fields, the radar cover, the second component force structure, insulated and other components, more and more polyimide composite paper are needed to stand higher temperature and higher-performance, which gradually occupies a pivotal position in the national defense material. In addition, it is also an essential material in electrical, electronics, telecommunications, environmental protection, chemicals and marine development and other areas ^[1]
^[2].

2 Application

Polyimide fiber paper and composite materials can be broadly used in many areas:

- 1) It can be used as aircraft, missiles, satellite broadband wave-transparent materials.
- 2) It can be made into a polyimide paper honeycomb material as a special structure . Such as aircraft wings, fairings, cabin door, linings, flooring, etc.
- 3) It can be used as high-temperature radiation resistant materials;
- 4) Applied to high temperature hoses, thermal protection materials, fire-retardant material hose radiation;
- 5) Insulating material. Transformers, terminal insulation at motors ;
- 6) Special filter material. It can be used for high-temperature filter materials, corrosion and other special circumstances.
- 7) Fire-retardant insulation material. Such as the fire service garment, theaters, hotels and other public facilities in the backdrop, wallpaper, spotlights retardant insulation protection.



Picture 1: all kinds of applications of polyimide paper

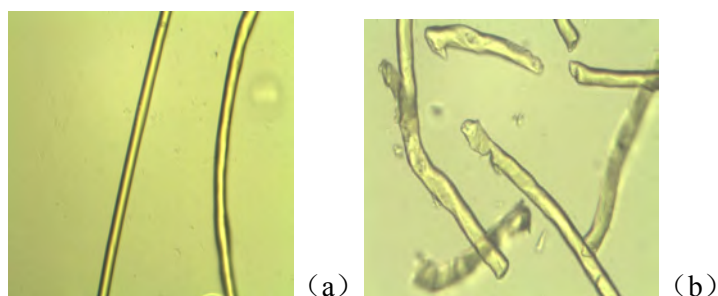
3 Performance and Situation

Polyimide (PI) is an excellent high-temperature insulating materials, it also has anti-oxidation, anti-radiation, hydrolysis, flame-retardant properties. So far, polyimide paper products are not available. The research on the polyimide fiber paper are at the laboratory stage, but the research on aromatic polyamide fiber paper of the same classification (ie, aramid paper) has made some achievements. However, due to the structure of aramide fiber itself, the aramid paper in insulating properties, heat resistance, and moisture absorption performances are inferior to the polyimide paper. Thus, the research on high temperature, high insulation polyimide fiber paper is the urgently needed for high-tech industries, which have exploring potential and market prospects^[3].

4 Polyimide fiber paper production difficulties

4.1 dispersibility polyimide fiber

As general PI fiber length is 3 ~ 10mm, which is much longer compared to plant fibers with 1mm ~ 2mm length, when the fiber dispersion process is easy to form flocculation group, because the fibers are dispersed unevenly in the paper forming process, it can form more weak points, resulting in paper strength and electrical properties is difficult to improve; on the other hand, PI strength of the fiber itself is relatively high, in fiber cutting process due to the high temperature caused a lot of fibers bonded together and forming a large number of fibers bundle, and difficult to disperse, we found that excessively beating will causes fiber cutting, resulting in the fiber structure defects, the fiber strength decreases, beating not sufficient and it can not achieve the purpose of dispersing the fiber bundles, so that the paper pulp will always having part of the fiber bundle, reducing the evenness of paper.



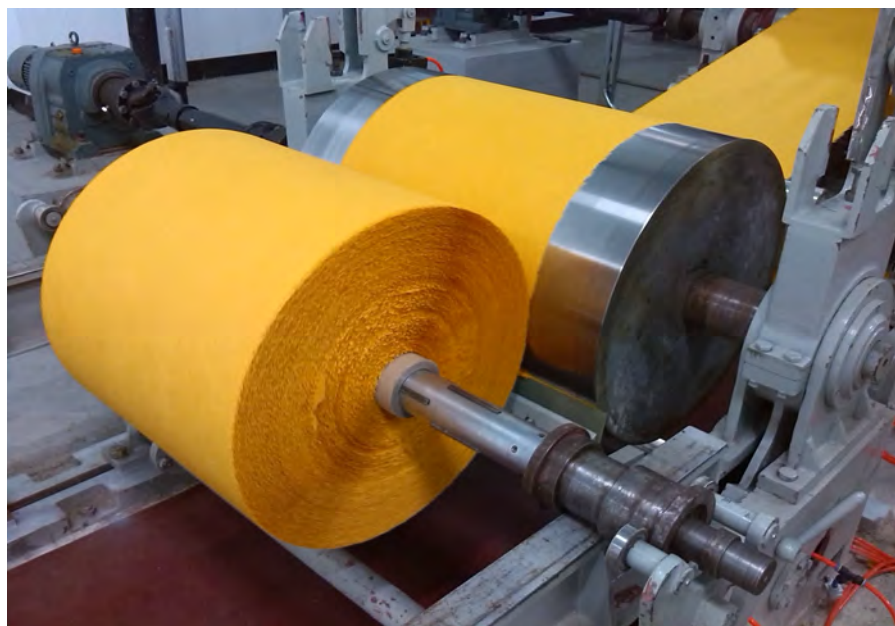
Picture2: PI fiber comparing before and after beating ($\times 400$)
((a) before beating, (b) , after beating)

As it can be seen from Picture2, fiber changes after beating. Figure (b) it is clear shows that: PI fiber after beating, the fiber surface has no sub-wire fluff, the fibers are cut at appears. During beating, fiber extrusion resulted in structural defects, reduce the strength of the fiber, there has the paper strength decreases and other issues. Polyimide as a synthetic fiber, different from plant fiber, whihc has poor hydrophilicity, so polyimide fibers do not disperse readily in water, and the fiber length also much longer than conventional plants fiber, at the slurry tank, pump, and pipes or other streaming device, it is easy to produce flocculation wound. PI fiber surfaces has no hydrophilic groups, which is not conducive to the fiber dispersibility in water. Characteristics of the fiber has become another factor restricting PI fiber paper base material properties [4].

4.2 polyimide fiber paper wet forming solution

PI fiber is different from plant fibers, PI fiber surface has no free hydroxyl groups, during the sheet drying period, there is no hydrogen bonding formed, there is no bonding between the fibers. After beating the fiber surface,PI is no sub-wire fluff, since the polyimide fiber surface is smoothy, resulting in poor connection between the polyimide fiber, so that its moldability also is poor. Traditional paper forming technology can not meet this requirement, it must adopt a new inclined wire forming technology.

From 1960s to 1970s,with the high-performance paper-based materials come out, developing of the wire forming technology. Using oblique wire molding can be effectively prevented that may occur when using long wire forming the "chase after the waves before the waves" phenomenon, as well as uneven phenomenon when using a cylinder shape, so that the polyimide fiber fiber evenly copy paper production, which is a key technology of polyimide paper production technology. Although the forming principle is similar,foreign researchers still meet the requirements of different products, developed various of structures oblique wire former, and put forward a comprehensive patent protection program, this technology is still blank in the domestic. In some Chinese patents, which has mentioned oblique wire forming technology, is not really obliquewire forming, just improved long wire forming molding [5], does not solve the polyimide sheet molding problems fundamentally. Therefore, the development of independent intellectual property rights inclined wire forming technology is very urgent. Changchun Hipolyking Co., Ltd. has been successfully resolved and mass production.



Picture 3: paper machine winder

4.3 stereotypical polyimide fiber paper is difficult to control

Heat treatment after forming the polyimide fiber paper setting process, due to the factors of the fiber geometry size, composition and other properties of the material on mutual restraint, in the heat treatment process, for the control of temperature, time, heat treatment and other factors is particularly important.

Since the process of pressing the sheets is under the air, the fibers will include the release of some water molecules, including small molecules, because it can not be successfully discharged, it will produce holes in the interior of the fibers, resulting in fiber structural defects, compared with PI fibers treated under vacuum environment, the fiber intensity should be reduced about 40% [1]. On the other hand, oxygen in the air may react under high temperature with the interior of the fiber molecular groups, destruction of the main chain structure, resulting in fiber strength and modulus decreased. The main factors affecting the paper tensile strength index is the fiber strength and binding force between fibers, the decreased of PI autogenous fiber strength will inevitably lead to anti-drop paper sheets index.

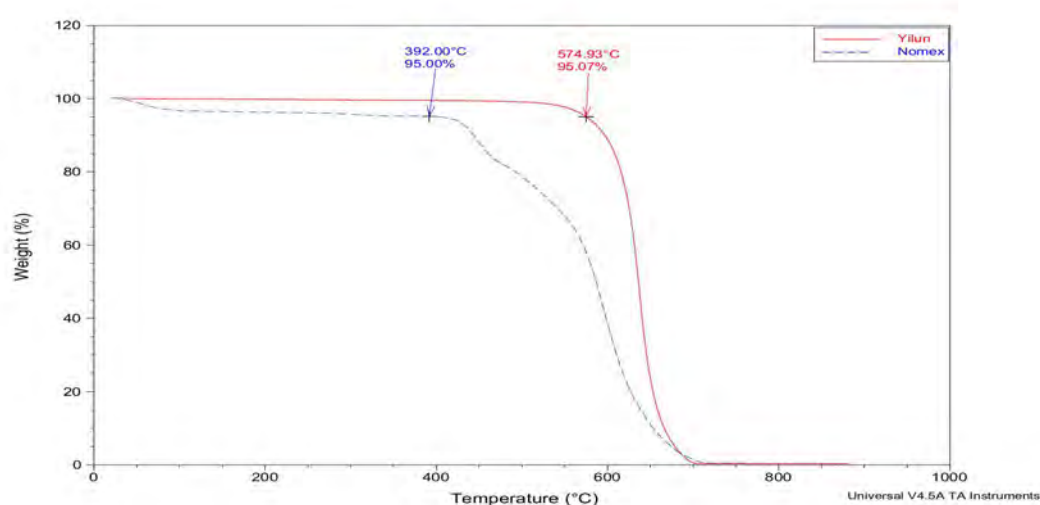
5 Polyimide fiber paper and aramid paper performance comparison

Table 1 polyimide fiber paper and aramid paper performance comparison

		polyimide fiber paper	aramid paper
Thickness/mm		0.08	0.08
Maximum operating temperature/°C		300	220
Thermal decomposition temperature/°C		570	392
LOI/%		38	29
Tensile strength /N	MD	85	78

	XD	65	64
Tear strength/mN	MD	1100	1200
	XD	1300	1325
breakdown strength	KV/mm	12	10

As can be seen from Table 1, polyimide paper sheet has 80 °C higher at the operating temperature than aramide paper , high thermal decomposition temperature is 178 °C higher than aramide paper, LOI index is 9% up than aramide paper.



Picture 4: TGA curve of Polyimide paper compared with Aramide paper

As can be seen from Picture 4, polyimide paper reach at 574.93 °C when the loss of weight 3.93%, while the weight of the aramid paper at 392.00 °C when the loss of 5%, so the polyimide paper can withstand higher temperature than aramid paper.

6 Conclusion:

The comparison with similar foreign products currently, abroad forming large-scale production capacity of only DuPont Nomex insulating paper products and Teijin company's products, but because of the polyimide paper and aramid paper is completely different, so compared to aramide paper, its main advantage: performance advantages, the heat resistance of polyimide paper, dielectric strength and mechanical properties better than aramid paper , as an insulating material will show longer life. In a short, polyimide paper will exhibit a higher cost-effective, in the international market will be located in a more favorable competitive position.

References

(See p228)