ADVANCED SURFACE DESIGN OF POLYESTER FILMS AND ITS APPLICATION TO MAGNETIC RECORDING MEDIA

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ABSTRACT

This paper briefly overviews the recent surface design for the purpose of achieving the good windability of polyester films and its application to the substrate films for the magnetic recording media.

One example is concerning the application to the films for VHS video tapes. The authors found it is quite important to remove the air layer from between each layer of the wound films in order to get a good roll formation in the VHS tape production process and we were successful in solving the roll formation problem by introducing a unique technology.

The other is concerning the application to the films for high density magnetic recording tapes such as 8 mm video or professional video, for which one of the requirement to the substrate films is to achieve quite a smooth surface and a good windability at the same time. The authors made it possible and were successful in reducing cost by introducing the dual surface film manufacturing technology and a technology to form fine and minute protrusions on the surface of the film and their combination.

INTRODUCTION

Polyester films such as Polyethylene-terephthalate(PET) are widely used in applications such as magnetic media, electric and electronic devices, photographic films, metallized films and packaging. They are chosen for these uses because of their excellent mechanical, thermal and chemical properties.

Pure polyester films without any other ingredients have quite a smooth surface, and hence the friction coefficient is so high that it is quite difficult to wind such films into a roll formation due to the blocking phenomena. It necessary to make the film surface rougher in order to get a good windability. The easiest way to achieve this is to add filler particles into the polyester matrix in the polymerization process and these particles form protrusions on the surface of the film, which in effect reduce the real contact area in film to film contact(Refer to Figure 1). But the protrusions will not be formed simply by adding particles into the polymer. Polyester films are produced in general in such process as follows;

melting-extruding -cooling -elongation in MD and TD- thermosetting

and the small particles added in the polymer matrix in the polymerization process are squeezed into the close vicinity of the surface of the film for the first time in this elongation process.(Refer to Figure 2)

It is natural that the rougher the surface gets, the larger the added particle size gets or the larger the quantity of the added particle gets, and in proportion the lower the friction coefficient becomes.(Refer to Figure 3) And the friction coefficient of the films has to do with the film thickness and the elasticity of the films. Even when the roughness of the films is the same, the thinner the film becomes and the lower the elasticity becomes, the higher the friction coefficient between the film surfaces becomes. As is understood from Figure 4, the friction coefficient of polyethylene 2.6-naphthalene di-carboxylate (PEN) film with the Young's modulus of 7000 N/mm2 is lower than that of PET film with the Young's modulus of 5500 N/mm2, when the surface roughness and the thickness of the film is the same. Judging from the above facts, it is necessary to make the film surface rougher or to make elasticity of the film higher so as to get as good a windability for thinner gauge films as that for thicker films.

One of the most important uses of polyester films is the substrate films for magnetic recording media, for example, video tapes, audio tapes, floppy disks, data cartridges and so on. Most important characteristics of the recording media is the electro-magnetic conversion property, which is mainly influenced by the surface roughness of the magnetic layer and the distance or spacing between the surface of the magnetic layer and the magnetic head.(Refer to Figure 5) The relation between the spacing d(μ m) and the output loss Ls(dB) is represented as follows(Ref.1);

$$Ls(dB)=-54.6 \times d/\lambda$$

where

λ stands for the wavelength of the recorded signal(μ m).

The larger the spacing gets or the shorter the recorded wavelength in accordance with the high density recording the higher the output loss gets(Figure 6). Schematic structure of the video tape is depicted in Figure 7. The important factor which gives direct influence to the spacing between the magnetic head and the surface of the tape is ,not to mention, the surface roughness of the magnetic layer. The surface roughness of the magnetic layer is determined by the surface roughness of the base film as well as the dispersion of the magnetic pigment and the degree of the surface finishing of the coated magnetic layer. The thinner the magnetic layer for higher density magnetic recording, the larger the influence of it becomes.

As mentioned at the beginning , protrusions are formed on the surface of the polyester films so as to promote handling and these protrusions and the electromagnetic conversion properties has a trade-off relationship with each other. It can be said that it is the concern of all the base film manufacturer how they could supply smooth base films with reasonable prices without damaging the electro-magnetic conversion properties in the magnetic recording field where a rapid progress continues to take place.

Here two examples of recent development will be presented.

BASE FILM FOR VHS VIDEO TAPE

Figure 8 gives the rough idea of the production process of PET films for VHS tapes and shows the summary of issues on each process. Recently the first priority is placed on reducing cost, and the process speed both of tape manufacturing and of the duplication of movie software is raised to the upper extremity to several hundred to a thousand meter per minutes. Under such circumstances what draws people's attention is that the output of such products does not increase and rather gets lower with the increase of speed due to the worse roll configuration of coated webs and of the slit pancakes in tape manufacturing process and of pancakes in the duplicating process. In more detail ,it is a phenomena a portion of the web or the tape edge jumps out of the web roll or the tape pancake. This phenomena belongs to another roll formation defect different from the blocking problem caused by the bad slippary of films already set forth at the introduction.

According to our detailed survey this phenomenon is ascribed to the surface design. Figure 9 shows the surface topography of bad base film design and good one in this respect, and it becomes clear that the surface topography of good base film shows a rather larger number of higher protrusions.

At the beginning of the VHS tapes, some twenty years ago, fine particle preparation and refinement technology was still premature and people were obliged to resort to natural but crushed particles, for example, Calcite, China clay, Kaolinite and so on and one of the defects those natural particles had in nature was the large distribution of the particle size. On the other hand, when it comes to improving the electro-magnetic conversion properties, it is indispensable to remove the extra large particles as much as possible. Such requirement has boosted the related technology up to the stage as it is today. That is, small particle crush technology, classifying technology, dispersion technology has advanced to a great extent, furthermore preparation technology of artificially synthetic particles with small size-distribution has advanced a great deal.
As a consequence people are able to get easily synthetic particles with uniform size distribution and they have started using them as main filler particles for VHS.

The phenomenon of film roll edge irregularity is found to be peculiar to the PET films which contains, as a main particle, such particles as have small size-distribution. From this knowledge we proposed a hypothesis that the quantity of the trapped air gets larger in between the film surfaces because of the difficulty of the air to escape due to the lack of high protrusions and the pressure between the films gets higher, and so that the films becomes easier to shift laterally. In order to verify our hypothesis we made a simulation test on the roll film edge irregularity, as depicted in Figure 10 by preparing a film containing only a small quantity of large size synthetic particles with narrow size distribution. This quantity of particles was limited within the range which is considered not to degrade the electro-magnetic conversion properties. And the easiness of air escape from between the film surfaces was also measured with using the Digital Bekk Roughness meter supplied by Toyo Seiki Co. Ltd.(Refer to Figure 11).The measurement of the roll film edge irregularity was conducted by using the Re-winder made by ASAKA Co.Ltd. ,which was altered so that the running film edge position could be detected (Refer to Figure 12).

As a result we were successful by adding a small quantity of large synthetic particles in greatly increasing the speed of the air escape(Refer to Figure 13) and in reducing the roll film edge irregularity to the same level as those of films using the natural particles with large size-distribution (Refer to Figure 14). The effect of large particles of new film design, confirmed in simulation, was also confirmed by the tape manufacturer(Refer to Figure 15).

BASE FILM FOR HIGH DENSITY MAGNETIC RECORDING TAPE

Recent development of magnetic recording media is so remarkable that the volume recording density is around seven times as high as that ten years ago(Refer to Figure 16). This has been achieved by the contribution of the following factors altogether;

the decrease of recording wavelength
the narrow track pitch
the thinner tape

The requirement to the base films is getting severer with the advancement of higher density recording. As is mentioned in the introduction, the shorter the recording wavelength becomes, the smoother the surface roughness of the magnetic layer should be(Refer to Figure 6). In the case of metal evaporation tape surface roughness of the base film should be as smooth as possible because the thickness of the magnetic layer is so thin in comparison with the coating type tape that the film surface gets nearly the same as that of magnetic layer(Refer to Figure 17). On the other hand the decrease of the tape thickness for the purpose of miniaturization of the cassette size and the longer recording time directly leads to the decrease of the base film thickness. Both of these requirements makes the base film even more difficult to wind (Refer to Figure 3,4) and in fact it was almost impossible to wind those films designed with using the conventional technology. To be more concrete, the smooth surface and the low stiffness leads to the high friction coefficient, which causes the local blocking of films and bump-shaped defects, and which causes the roll film edge irregularities and local wrinkles due to the bad air escape, in the winding process of the film manufacturing plant.. Consequently we could not get a film of good role formation, which leads to the higher production cost.

Dual surface film due to the co-extrusion technology has been proposed in order to solve this problem(2,3). This technology is to get a film which has different surface roughness on either side by extruding separately the different polymers for smoother side and the rougher side using two extruders(Refer to Figure 18). Availing ourselves of this technology it becomes possible to get low cost and good formation role films by improving the handling of films while keeping smooth the surface for the magnetic coating.

Figure 19 shows the roughness profile of example base films, produced by this co-extrusion technology, for metal coating type tape and for metal evaporation type tape. On the surface of the smoother side of base film for the metal evaporation tape there is formed a thin coating layer with super fine peaks on it, which not only work well to reduce the friction coefficient between the head and the surface of the magnetic layer but also function to reduce the friction coefficient of films to get a good roll formation(Table 1).

Such surface design technology using super fine peaks as is depicted above will be inevitable in winding thin base films that will be used for data storage tapes and what not which is expected to grow in line with the progress of multi-media .

CONCLUSIONS

New surface design technology is described concentrating mainly on the polyester films for magnetic recording media. Taking advantage of such new technology and the conventional one, Teijin's polyester films could be applicable to a wide variety of area.

We are confident that Teijin will be able to supply thin gauge and good handling films by combining leading edge surface design technologies and Teijin's unique and highly elastic PEN film.

REFERENCES

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2. JP77141611
3. JP93329997

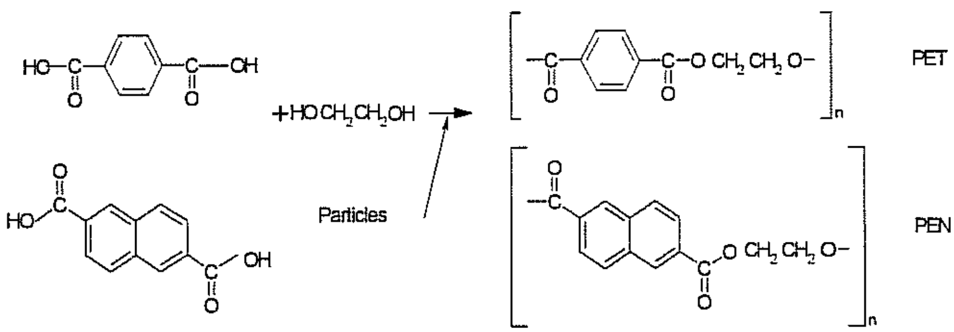

Figure 1. The Schemes of the Polymerization of Polyesters for Film Application.

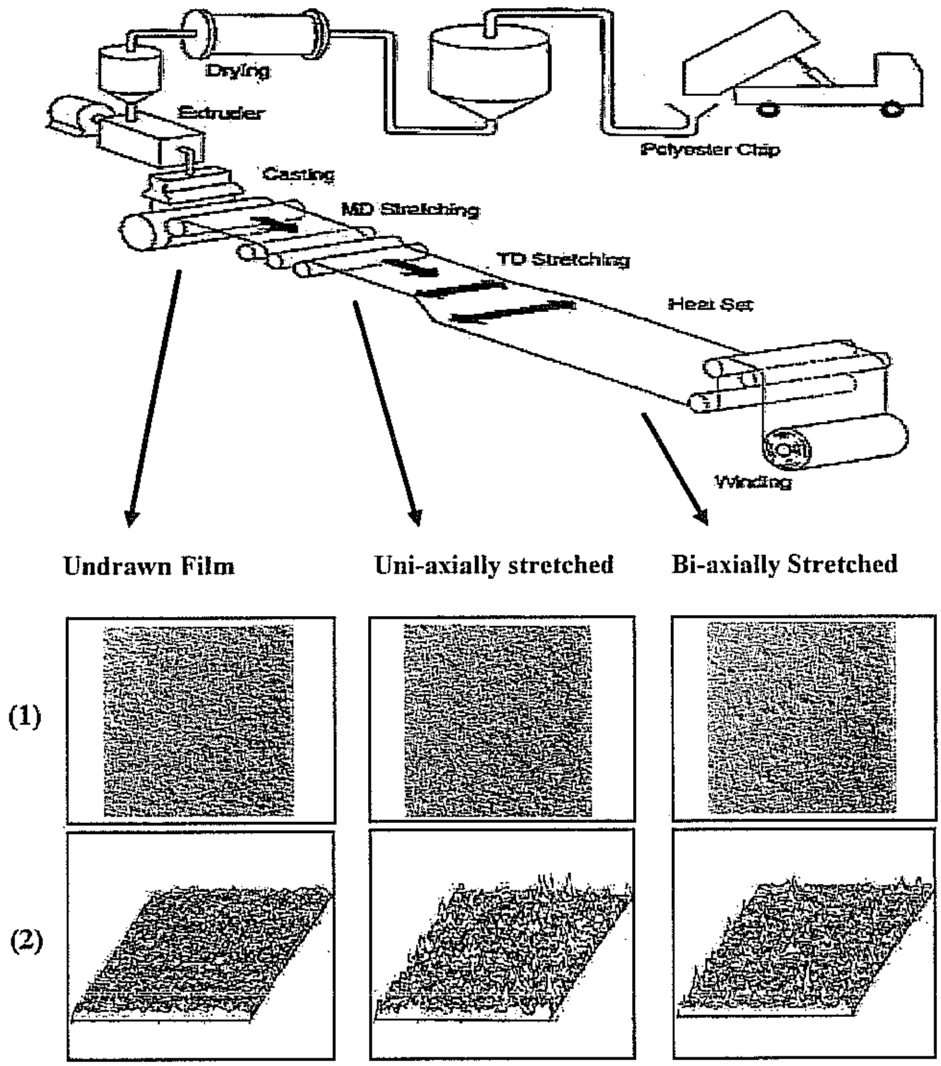

Figure 2.Process of the film manufacturing and the surface change of the film at each process.
(1) Photographs of the Film Surface
(2) 3-Dimentional Surface roughness of the film Measured by WYKO Roughness Meter

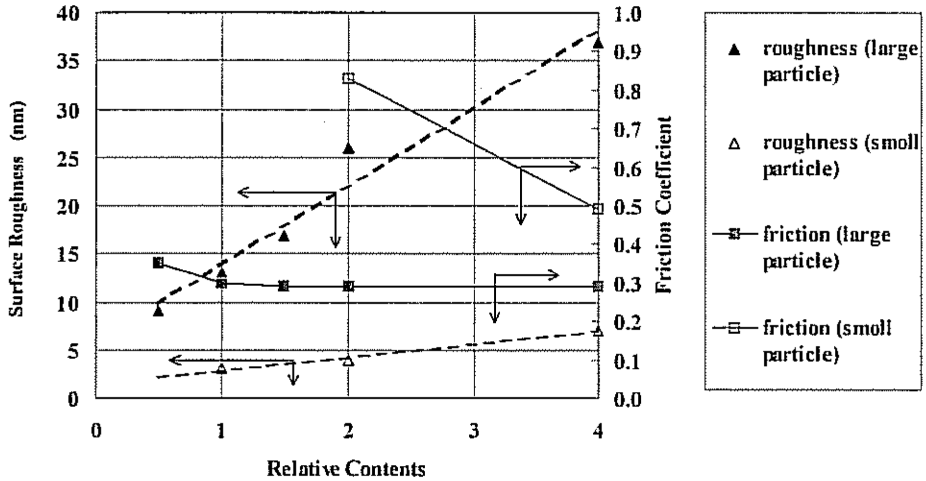

Figure 3. The Effect of Particle Content and Size on Surface Roughness.

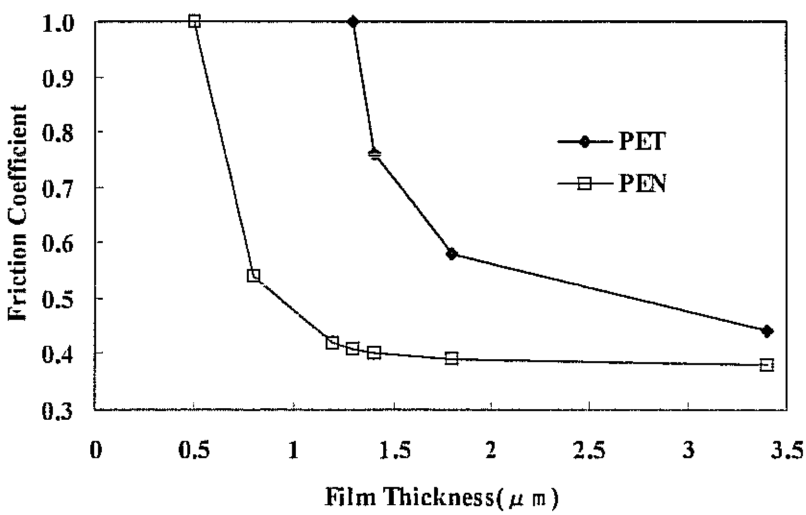

Figure 4. Friction Coefficient vs Film Thickness.

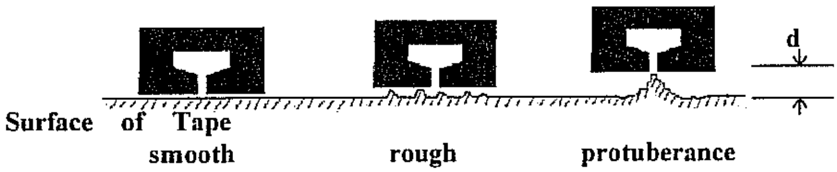

Figure.5 The Distance Between the Magnetic Head and the Tape.

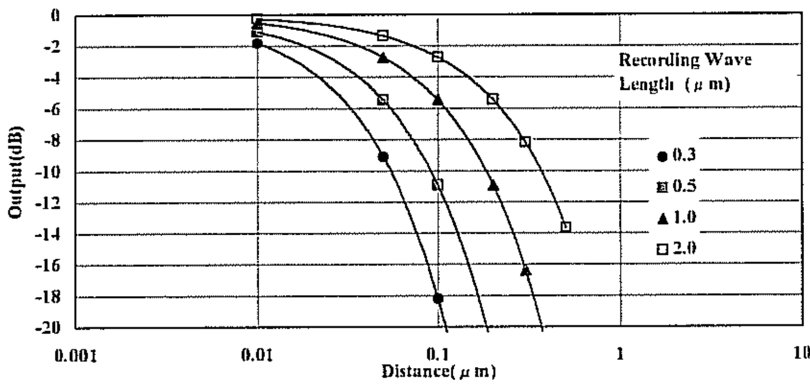

Figure 6. Output Loss

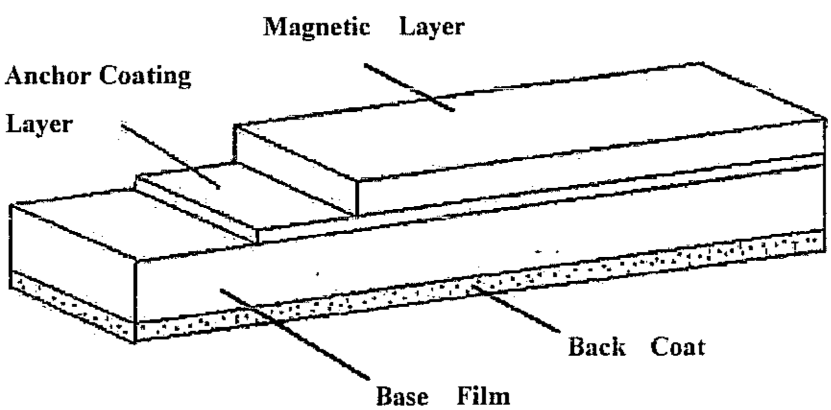

Figure 7.The Structure of a Magnetic Recording Tape.

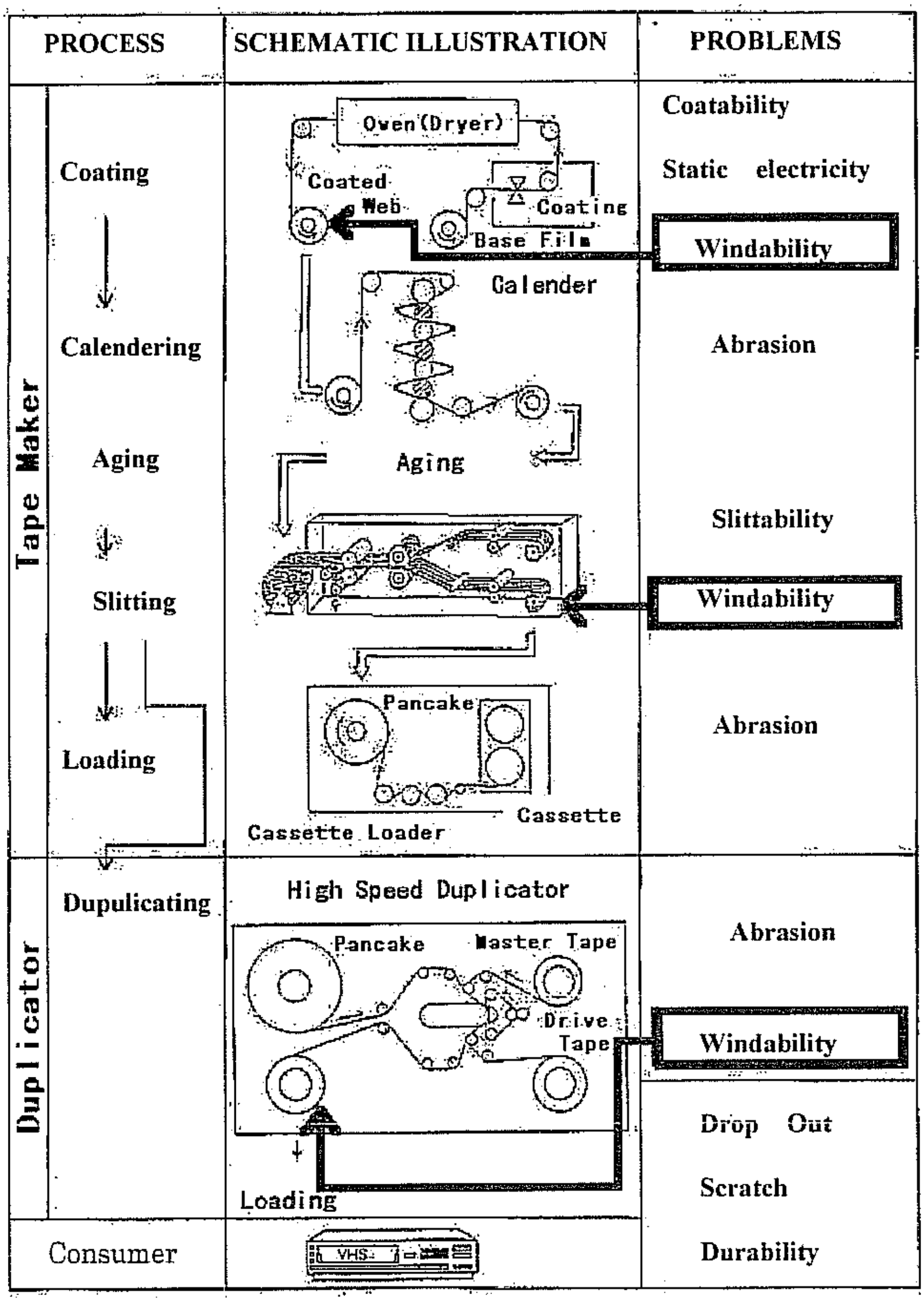

Figure 8. Production Process of Magnetic Tape and Summary of Possible Problems.

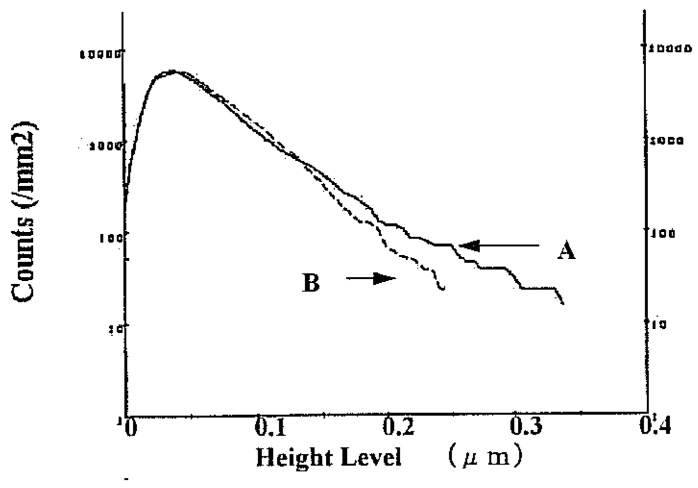

Figure 9. The Surface Topography of Base Films.
A; Good Windability
B; Bad Windability

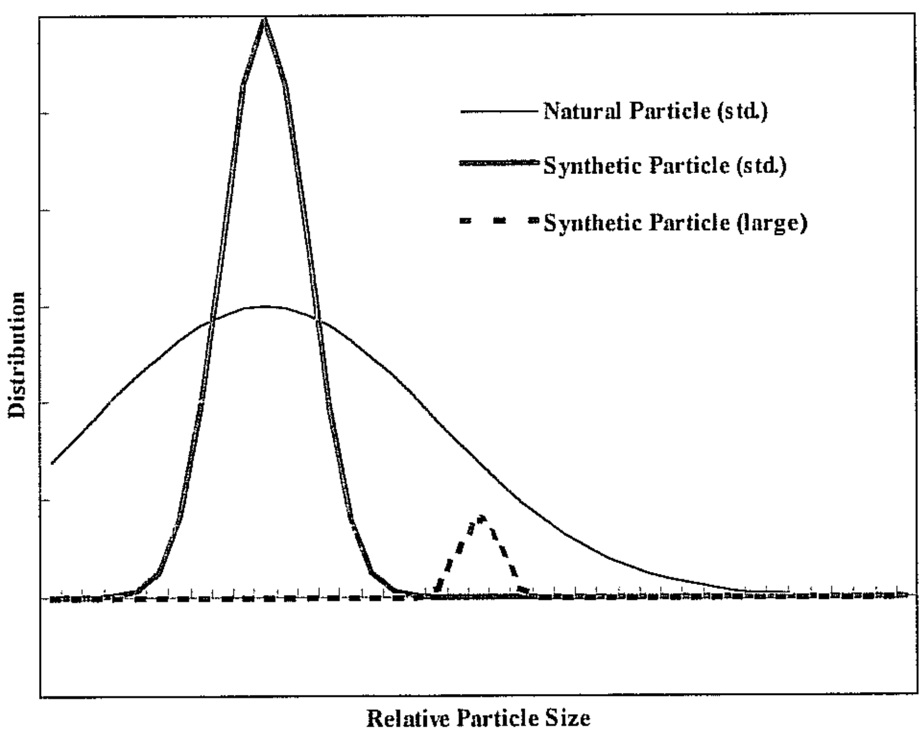

Figure 10. Image of Particle Size Distribution.

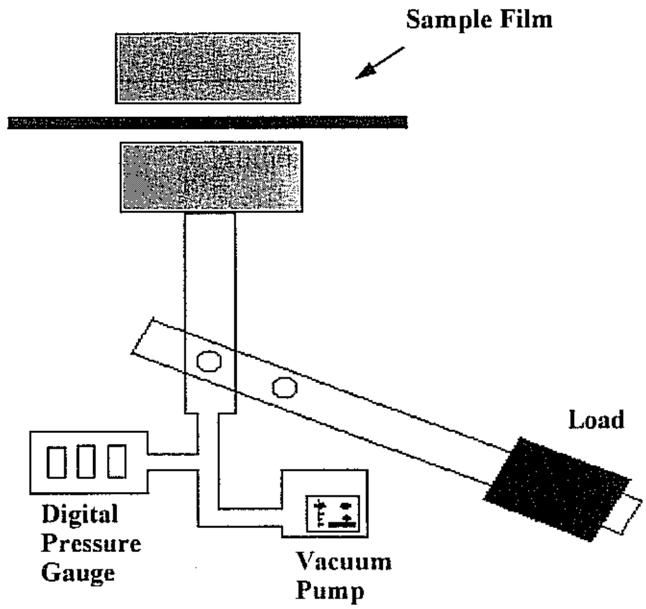

Figure 11. **A Schematic Illustration of the Digital Bekk Roughness Meter.**

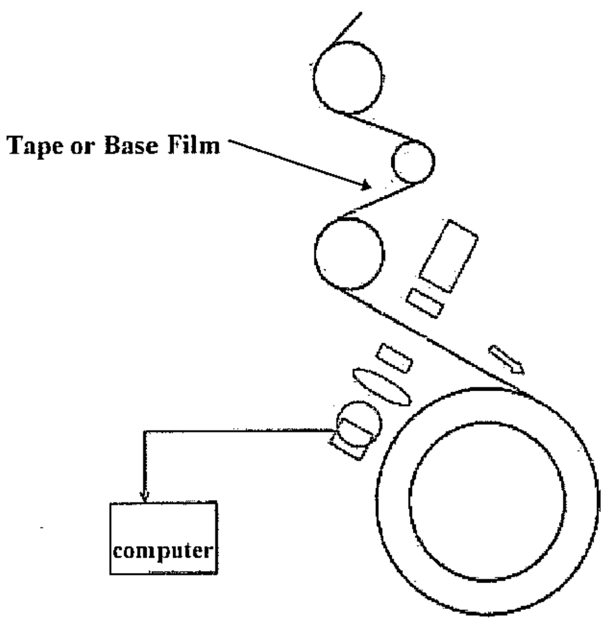

Figure 12. A Schematic Illustration of the Windability tester.

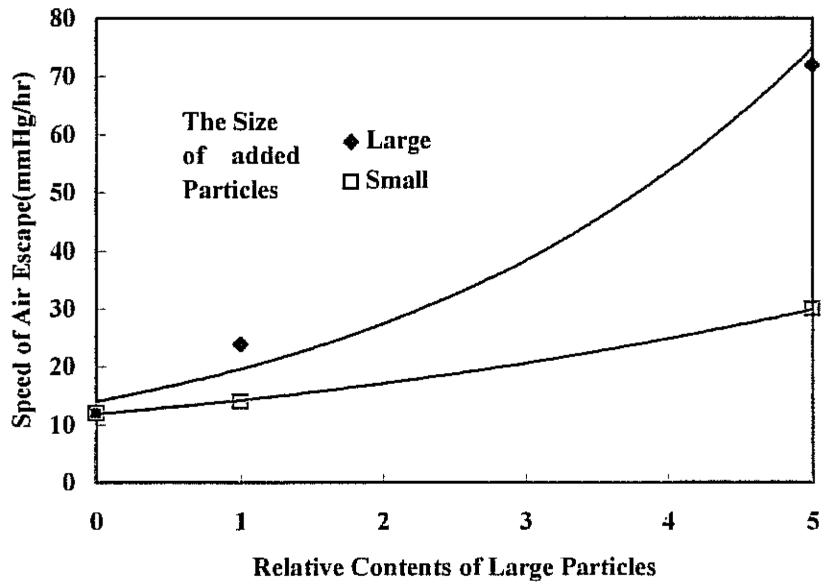

Figure 13. Speed of Air Escape vs Large Particles Contents.

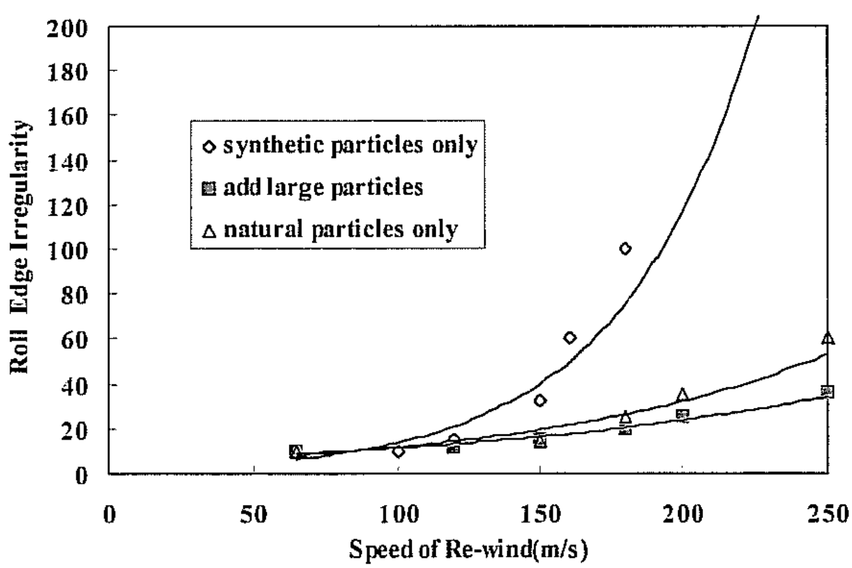

Figure 14. Irregularity of Wound Roll Edge vs Winding Speed.

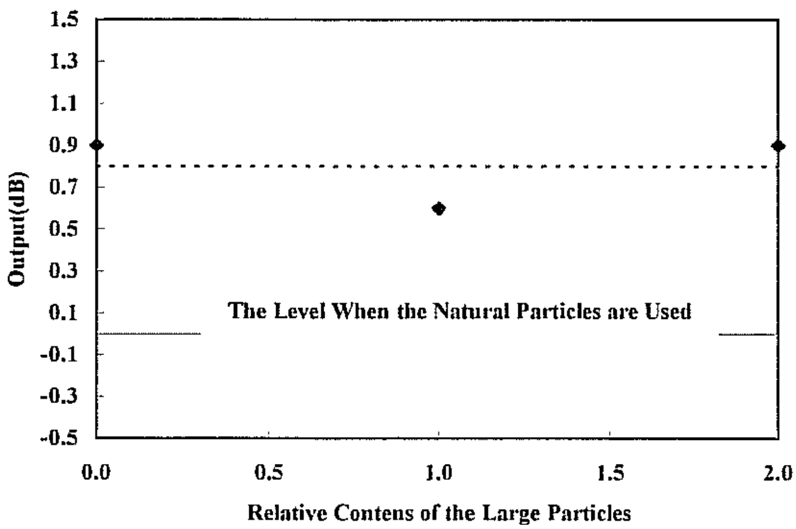

Figure 15. Electro-Magnetic Conversion Property of the Tapes, which Use the Base Film with Small Quantity of Large Particles in it.

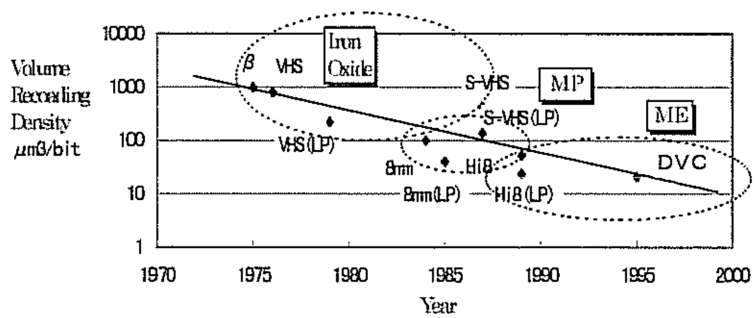

Figure 16. Progress of Recording Density.

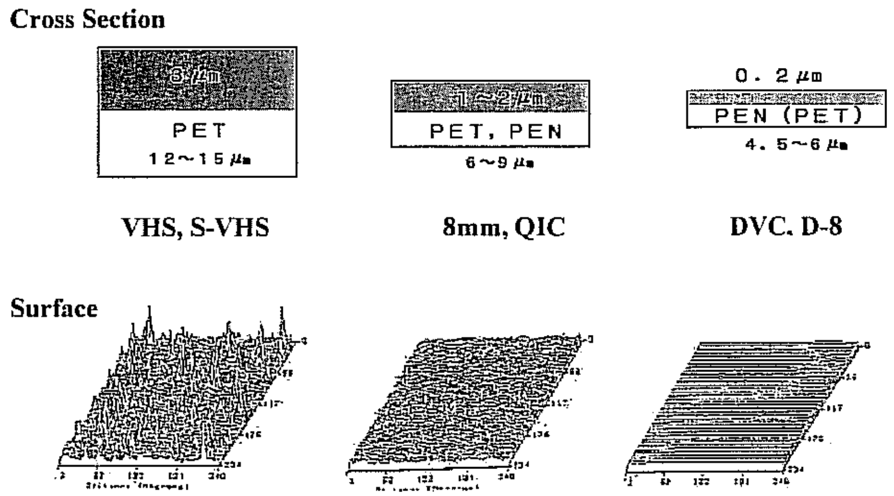

Figure 17. The Cross Section of Tapes and the Required Surface to the Base Film for Each Application.

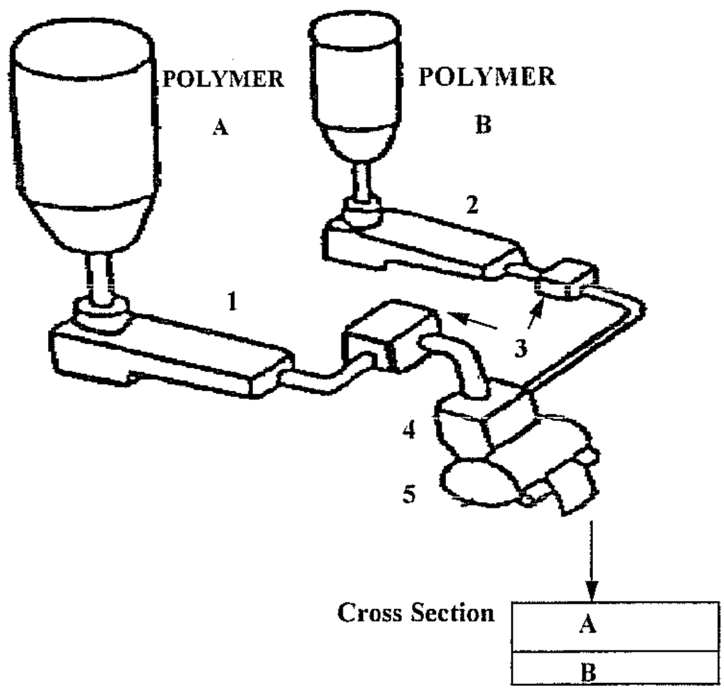

Figure 18. Co-extrusion Technique.
1;extruder 2;co-extruder 3;filter 4;die 5;casting

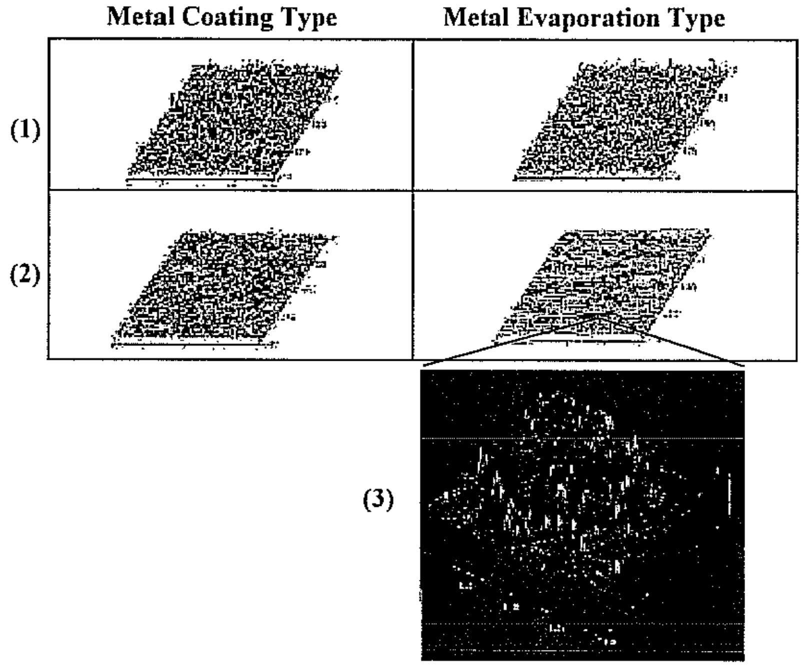

Figure 19. The roughness Profile of the PEN film Produced by Co-extrusin Technology.
(1)3-D Topography of the rougher side by WYKO
(2) 3-D Topography of the smoother side by WYKO
(3) 3-D Topography of the smoother side of the base film for metal evaporation tape measured by Atomic Force Microscopy

Base Film Structure	Double Layer	Double Layer	Single Layer
Under Coating	Coat	Non-Coat	Coat
Friction Coefficient	0.29	0.41	0.9<

Table 1-Friction Coefficients of the Base Film for Metal Evaporation Tape