A new method for testing the adherence between foil and substrate

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ABSTRACT

An increasing number of currencies is provided with an Optically Variable Device (OVD) as a counterfeit deterrent. The device is applied by using foil technology and adhered to the substrate with a hot melt adhesive. The adherence is generally tested with an adhesive tape. Apparently, this practical test suffices, but the question arises if a method exists with a larger potential for standardisation. A feasibility test with the IGT printability tester, using a highly viscous pick up oil shows promising results. This paper presents the testing method, shows a few preliminary results and discusses their relation with the foil application method.

Keywords : foil adherence, IGT printability tester

1 INTRODUCTION

An increasing number of currencies carry an attached OVD foil as a counterfeit deterrent. These measures are not restricted to the higher denominations, the low Euro (€) denominations, for example, are provided with a continuous foil stripe. The OVD stripe or patch may comprise various security features and, additionally, the striking colour changes with angle of observation present an attractive feature for the general public to distinguish between genuine and counterfeit. The security foil – stripe or patch – is adhered to the paper by hot melt technology. The complex layered foil structure is shown in the figures 1a and 1b. The hot melt 6 adheres the layers 3, 4, and 5 to the security substrate (paper in general).

1 - Foil carrier
2 - Release coat
3 - Top lacquer
4 - Al evaporated layer in which the holographic grating – the security structure – is embossed
5 - Chemically deposited protecting layer
6 - Adhesive

Figure 1a; the layered structure of a security foil. The total thickness on paper (the layers 3, 4 and 5) ranges between 3 and 5 micron. The carrier has a thickness of 19 micron. The adhesive layer of 5 gr/m^2 corresponds to a thickness of 5-6 micron.

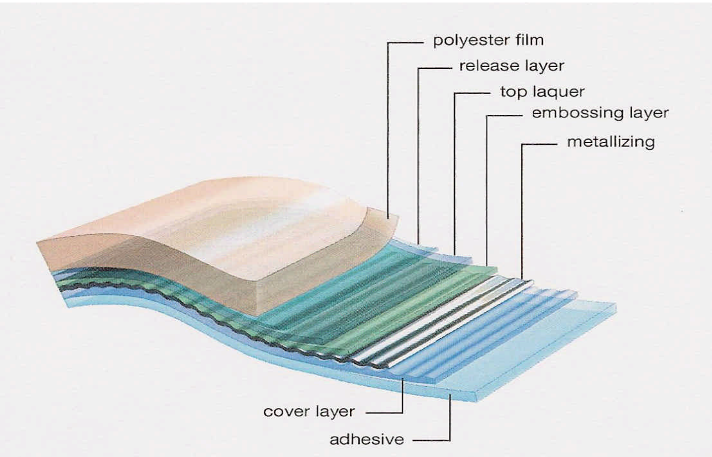


Figure 1 b; a cut away view of an OVD foil

The surface roughness of currency paper is illustrated by a profile scan in figure 2. The surface roughness exceeds the total thickness of the layers 3, 4, 5 and 6. At first glance the question may arise if adherence by hot melt technology is possible at all. But it must be realised that the vertical scale and horizontal scale differ a factor of 1000. Still the delicate foil has to be adhered to a relatively rough substrate.

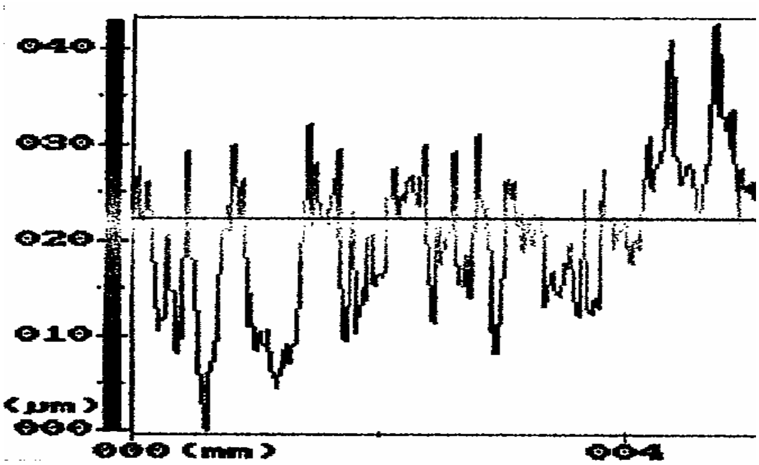


Figure 2; currency paper surface scanned with a laser profilometer.

The two foil application methods in use in the security printing industry are:
- Laminating (Kurz, Gietz, Bobst) where the foil is first gently positioned on the substrate, subsequently the foil is ironed with a light pressure and as a last step the carrier foil is peeled off.
- Rolling (Steuer) where the paper, together with the foil, is squeezed between two heated processing rollers.

2 A RULE OF THUMB FOR PRESSURE AND DWELL TIME?

Intuitively we realise that, for a short dwell time t, a high pressure p is required. Subsequently, we realise that heat is diffusing through foil and adhesive to the paper substrate. Let us assume that the diffusion coefficient D is linearly related to the pressure p:

$$D = C.p$$

The so-called diffusion length L_D characterises the diffusion processes. This length is defined as the square root of the product of diffusion constant and time:

$$L_D = (D.t)^{½}$$

The dimension of L_D is length and in fact L_D indicates that a certain temperature is reached at a depth L_D. The laminating and rolling process differ, but the temperature needed for the hot melt to do its work is identical. This implies that:

$$L_{D(Rolling)} = L_{D(Laminating)} = (D.t)^{½}$$

This leads to the rule of thumb:

p.t = constant.

3 LAMINATING

The majority of the suppliers to the currency industry and the currency printers are using the laminating technology as supplied by Kurz.

In general, this technology can be described as follows:

- position the foil gently on the paper substrate,
- then iron the foil with a light pressure during a certain time, and
- finally, peel off the carrier.

A relatively low pressure of 0,38 MPa and a long dwell time of 420 msec at a temperature of 150°C are the characteristic parameters.
The development of Kurz has resulted in the de la Rue Giori 'Optinota' for sheet fed applications at 10 000 sheets per hour and a MHS machine for web fed applications at 100 m/min.
The moving shim type machines like Gietz and Bobst with an output of 5000 sheets per hour are based on the same principle.

4 ROLLING.

The Foil jet rolling process, as developed by Steuer, uses temperatures of about 235°C and a short dwell time of 3 msec. The paper is squeezed together with the foil between two heated processing rollers. The pressure can be approximated using our rule of thumb from section 2, and amounts to 50 Mpa.
The rolling process reduces the thickness of the final structure of paper and foil adhered by 5 – 15 micron.

An upper roller is heated and the hot melt is activated during the relative short dwell time. The upper roller transports the foil; the lower roller transports the paper. The different coefficient of friction between upper roller and foil, and lower roller and paper results in stress strain on foil and paper, when the hot melt adhesive fixes foil and paper together. This stress strain may damage the delicate optical structure and may thus introduce a decreased resistance against wear.

5 THE ADHERENCE TEST

The adherence of hot melt foils is generally tested with the so-called TESA test. Adhesive TESA tape is carefully pressed over foil and paper and then, with a jerk, suddenly ripped of. The hot melt adhered foil should not show any damage as a result of this test.
This is a very empirical and practical test; but the question may be raised if an alternative test method can be contrived that leads to a better description and a standardisation of the results?
Considering the above, it is suggested by IGT to apply the IGT testing equipment for the pick up testing of coated offset papers. A pick up oil with an extremely high viscosity has been selected, and it has been a pleasant surprise to observe that this tacky and viscous oil can be distributed with the regular laboratory distributor equipment. The distributor roller is subsequently mounted on the IGT tester.

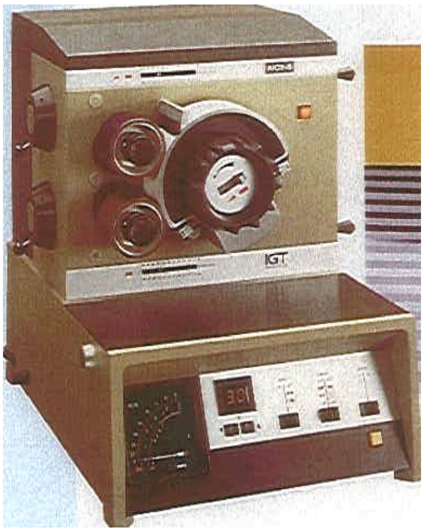


Figure 3; the IGT tester.

The foil–paper combination is stretched on the main body in the centre. Pressure and speed are then selected and fixed. The oil is so tacky that the coating of a normal offset paper is ripped off completely.

For the feasibility test the following samples were submitted:

- Windowed thread or Stardust
- LEAD
- Notes from Canada, Hungary and Rwanda

Conditions for all the trials were identical:

Ultra High Viscosity H 1900	
Pressure	625 Newton
Speed	1 m/sec

After the test, tiny pieces of foil were detected on the roller coated with the pick up oil. The foil images under test have been photographed[1] and the results are shown below.

The test results can be divided into the following four categories

1. No visible damage
2. Appearance of a few tiny holes
3. Flakes are missing
4. Serious damage

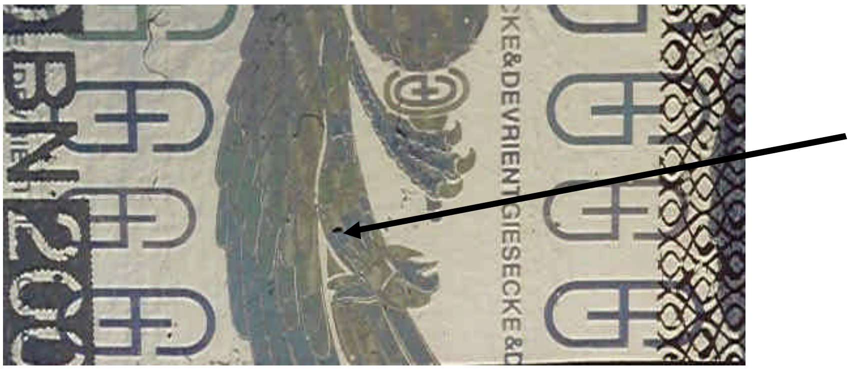
Category 1 – No visible damage

Hungary, 10 000 Forint. Substrate has been pre coated with a primer.

[1] Photographs by Rudolf L. van Renesse

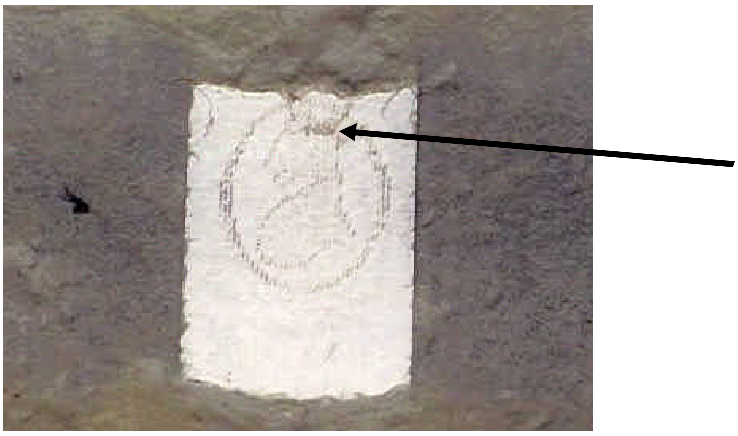
Category 2 – Appearance of a few tiny holes

Demo note G&D, LEAD sample. Applied with Kurz MHS technology.



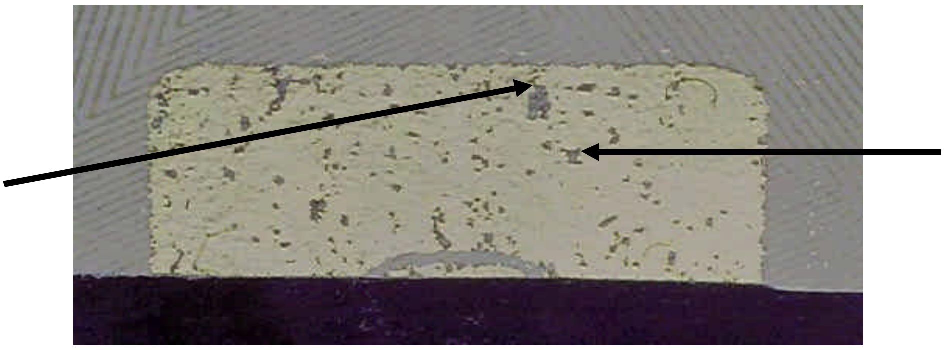
Demo note G&D, LEAD sample. Kurz MHS technology

Category 3 – Flakes are missing

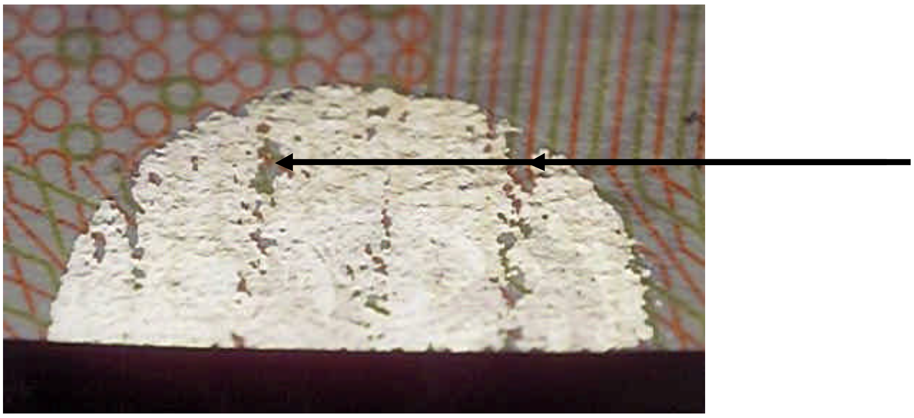


Stardust extra wide, sample note Portals/de la Rue.

Category 4 – Serious damage



Optical Security Device Canada. Cold foil technology



Rwanda banknote, hot stamp process.

6 DISCUSSION AND CONCLUSION

Caution should be exercised regarding conclusions. The sample size is small, and the foil application method is not yet known with full certainty. However, the method with the high viscous pick-up oil results in considerable differences in category of damage and those different categories are possibly related to differences in the foil technology and application technology. It is known that the Canadian OSD surface structure differs from the holographic foils due to the applied hot melt technology. The samples shown in category 1 and 2 are adhered to the paper with the laminating technology. It is assumed that the foil on the Rwanda banknote is applied by the rolling technology.

In this respect a follow up has to be considered where - based on a controlled input - the optimum pick up conditions can be established. Pressure, speed and viscosity of the pick up oil are important parameters for the optimalisation. But just as important is the handling of the image before and after the test; the determination of the debris on the counter roller covered with viscous oil, categorising the damaged image, etc.
Once this optimum is determined the method can be used as an objective quality test for the adherence of foil to paper or other substrates, where the quality range comprises the four levels indicated above.