A THEORETICAL MODEL OF WATERLESS PLANOGRAPHY WHICH EXPLAINS SOME OBSERVED PHENOMENA

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Abstract: Observations of Waterless Planography are listed and the physical characteristics of these generalizations are described. The total of all forces that clean the plate is proposed and called the Tractive force. The influence of ink, plate and press properties on Tractive force are characterized. A test method for determining the combined influence is proposed. This method is used to show how some roller and ink properties effect Tractive force. Correlation is graphically demonstrated. Suggestions are made for improvements in ink and roller properties.

Introduction

The success of Waterless Planography depends upon the clean separation of ink from non-image areas, while at the same time the ink wets and transfers from the image. Certain general observations have been made of ink, plate and press properties which taken together control the limiting factors in Waterless printing. By defining these properties and describing their effects it is possible to produce a physical model for the process. With such a model as guide it is possible to predict the behavior of inks, plates and press and to make suggestions for their improvement.

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Observed Phenomena

1. The lower the free surface energy of the non-image areas of the plate the cleaner it will run.

2. The thinner the ink film the easier it is to run clean.

3. Smaller diameter form rollers run cleaner than large diameter form rollers.

4. Harder form rollers run cleaner than soft form rollers.

5. Higher tack inks run cleaner than low tack inks.

6. Inks with higher coherence work cleaner than those with lower coherence.

7. Non-polar inks work cleaner than polar inks.

Plate Properties

It is well known that Waterless printing plates employ low free surface energy materials in the non-image areas. Most commonly these are dimethyl siloxane polymers. The technology of Waterless plate manufacture is not a subject of this paper, but the nature of low free surface energy materials is germane. IMCON Waterless plates as described in 1994 TAGA paper by the author are used throughout.

Free surface energy is defined as the increase in free energy of a system when the surface is formed. In an ideal system liquid fills a box with a sliding cover. The interfacial tension between the cover and liquid is zero. When the cover is slid back uncovering an amount of surface, energy is added to the system. This is the free surface energy. Solids are also said to have free surface energy, although it is more difficult to employ an analogous ideal system. Solids are more easily treated by studying their heats of immersion. When a solid surface is immersed in a liquid heat is liberated. If the interfacial tension is zero the liberated heat is the surface free energy of the solid.

In practice this interfacial tension is near zero. The following is a list of published values.

Heat of Immersion at 25°C

Solid	ergs/cm^2	
	H_2O	n-C_6H_{14}
T_1O_2 (rutile)	550	135
Al_2O_3	400-600	100
SiO_2	400-600	100
$BaSO_4$	490	
Graphite	32	103
Teflon	6	47

A full treatment of the reasons for the difference in free surface energies of solids is not possible in this paper. It is useful to notice that the forces involved are Van der Wall, and Coulombic and can be treated by wave mechanics. Simply put, materials which have high dielectric, zero dipole and a very low order of chemical activity tend to have low free surface energies.

Besides the chemical nature the geometry of the surface influences free surface energy. The smoother the surface and the fewer the dislocations the lower the free surface energy.

The image of a Waterless plate should have high free surface energy. This is especially important when inks of high coherence are used. Such inks are not only repelled by low free energy surfaces such as silicone, but can be repelled by medium energy surfaces.

Temperature influences free surface energy. The lower the temperature the lower the free surface energy of all known materials, both liquid and solid.

In the printing process the form rollers transport ink to plate. In Waterless printing the inked form rollers also remove the ink from the non-image areas. The total of all forces acting on the non-printing area of the plate by the inked form rollers is called the Tractive force.

Tractive force is controlled by ink properties and ink/plate interaction. Press properties such as press geometry and speed influence Tractive force.

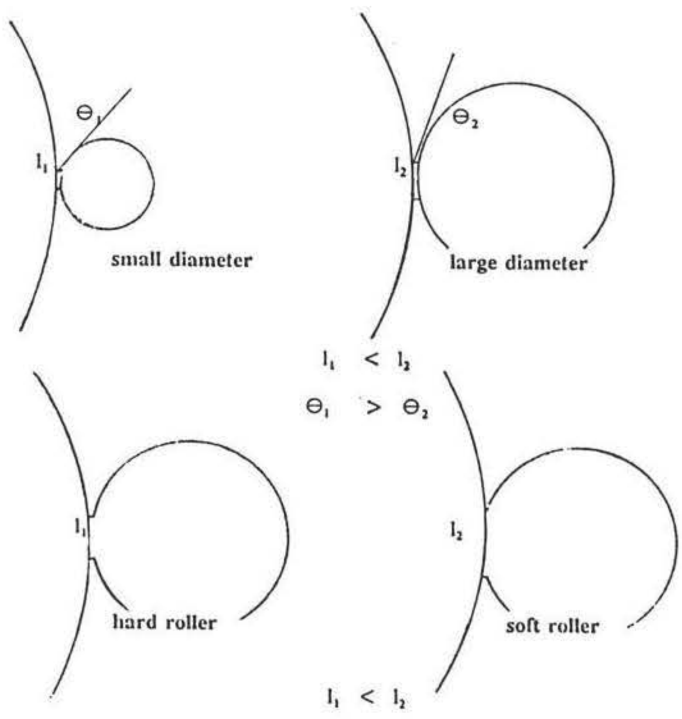
The volume of ink on the form rollers is an important parameter. The greater the ink volume the greater the amount of Tractive force necessary to clean the plate.

The following properties are directly proportional to Tractive force: Ink Tack
Ink Coherence

The following properties are inversely proportional to Tractive force:

Ink volume
Ink polarity i.e, interfacial tension between ink and plate.

FORM ROLLERS TOUCHING PLATE



Press Geometry

From the diagram it is observed that a smaller diameter roller wets a smaller area of the plate. Therefore less volume of ink needs to be acted on by Tractive force and the plate runs cleaner. The angle of contact is larger for a smaller roller thereby producing greater torque, which also increases Tractive force and the plate runs cleaner.

From the diagram it is observed that a harder roller contacts a smaller area of the plate. Therefore less volume of ink needs to be acted on by Tractive force and the plate runs cleaner.

Roller to Plate Pressure

The pressure between the form rollers and the plate effects the volume of ink. The area of contact is increased by increased pressure thereby increasing ink volume; however, the narrowed gap produced by increased pressure decreases ink volume. Therefore no simple relationship exits between Tractive force and roller pressure. It is likely that an optimum exits for each set of circumstances. An attempt was made in tests conducted for this paper to reach that optimum.

Ink Properties

Ink **tack** is defined as the resistance to the force of ink film separation. Tack results from the viscoelastic nature of the ink vehicle and the type and amount of pigmentation. The higher the tack the greater the Tractive force acting on the plate.

There are many devices which directly measure ink tack; the most common in the USA is the Inkometer.

Ink tack is a dynamic property. The higher the angular velocity of rollers the higher the tack.

Temperature influences tack. The higher the temperature the lower the tack.

Coherence is defined as the force of resistance to surface increase. It is the force that pulls the boundary layers of a liquid mass toward its interior. It differs from cohesion in that coherence is a property of bulk liquid whereas cohesion is a property of liquid surface.

Cohesion is defined as self adhesion. The work of cohesion is that required to produce two unit areas of interface from an unbroken column. It's unit of measure is surface tension. The difference between work of adhesion of a liquid for a substrate and its work of cohesion equals the spreading coefficient. Inks have both cohesion and coherence. The cohesion is most influenced by the polarity of the ink and is treated with ink polarity.

Coherence is not readily observable in materials of low viscosity and low internal structure. With materials of high viscosity and considerable internal structure such as printing inks, coherence is readily observable. It is an important property of Waterless inks. The higher the coherence the higher the Tractive force acting on the plate.

One way coherence can be observed is on a three roll mill. On such a mill the rollers run at different speeds; usually in the ratio of 1:3:9. Inks transfer from the slower rollers to the faster rollers. The higher the ink coherence the greater the transfer. In some cases complete transfer occurs; the slowest roller stripped completely clean.

Temperature influences coherence. As temperature increases coherence decreases. The temperature coefficient for coherence is notably less for high coherence inks than low coherence inks.

Inks of high specific gravity tend to produce higher Tractive force than inks of lower specific gravity. It would seem that as density increases coherence increases. High density pigments such as Titanium dioxide produce very clean working inks.

Ink polarity is defined as polarity due primarily to ink vehicle components which have chemically polar groups such as carboxyls and/or hydroxyls. Ink polarity decreases Tractive force. The reason for this is not immediately apparent, because polarity largely influences the interface between ink and plates and in most cases does not effect bulk properties.

Materials of low polarity wet the non-image better than high polarity materials. This being the case the work of unwetting the surface is less with low polarity materials. The resulting Tractive is thereby increased and the plate runs cleaner.

Tractive force can be expressed by the following formula:

$$T = \frac{KC \cos\Theta / \cos\Theta_1}{V\gamma A}$$

where

T = Tractive force

A = Area of plate being contacted

V = Ink volume

Θ = Form roller torque angle

Θ_1 = Inkometer roller torque angle

K = Ink tack (Inkometer reading)

C = Ink coherence

γ = Interfacial tension between ink and plate

It is understood that each variable contains some weighted constant of proportionality. At the present such weighted values are not known.

Coherence is considered to have the equivalent dimension of surface tension times volume. This being the case Tractive force reduces to the dimension of torque per unit area.

Test Methods

The best way to determine how well Waterless systems work is to print a controlled amount of ink at a controlled temperature. Qualitative results are easy to obtain; quantitative results much more difficult. It has been suggested that by increasing the temperature of the system incrementally quantitative results are possible. This is difficult to do consistently when the system temperature exceeds room temperature by more than a few degrees C. It is also true that ink properties change unproportionally with temperature (i.e., Tack changes faster than coherence). A more consistent method uses changes in ink tack. Ink tack is decreased by reducing vehicle viscosity until toning occurs. This method was used in the studies reported in this paper.

All tests were performed on a flat bed press. Inks were rolled out and applied by hand. IMCON Waterless plates were used with a standard GATF image. Ambient temperature was 25C°.

Pigments do not influence Tractive force as much as the vehicle. Pigments which are relatively non-polar make the best inks. Pigments which have some degree of polarity usually present no difficulty when good vehicles are used. Pigments of high polarity can present difficulties.

Examples

Non-Polar:	Carbon Black, Phthalo Blue, Pigment azos such as Diarylide Yellow, Naphthol Reds.
Some Polarity:	Azo salts such as Lithol Rubine Red, Permanent Red 2 B.
Polar:	Iron blue

Bulking agents such as silica and bentonite clays are used to increase structure, which increases Tractive force.

Vehicles

Vehicles made with polar solvents and resins soluble in such solvents are very difficult to make with sufficient Tractive force to print clean. Glycols and glycol soluble resins are examples.

Vehicles made with materials of intermediate polarity can create difficulties. Unbodied drying oils and some alkyds fall into this category.

Vehicles made with non-polar solvents and hydrocarbon resins make very suitable varnishes with high tractive force.

A useful test method for vehicle polarity is the alcohol number. This test uses a standard concentration of vehicles in Toluene (5 gms/50ml), which is titrated to a constant cloud point with ethanol. Temperature is held constant at 25°C.

The lower the alcohol number the lower the vehicle polarity.

Coherence properties of ink vehicles are increased by gelling agents such as Aluminum alcoholate or other poly valent metallic compounds. High molecular resins of suitable solubility are also used to increase coherence. Such materials must be used only in small amounts because such resins also tend to cause misting.

Surface active oils of very low polarity used in small concentrations increase Tractive force. Poly dimethylsiloxane oils are examples of such materials.

Experimental Data

A standard set of inks was made using the same pigment concentration (25% Carbon black), the same resin (Cyclised rubber), solvent (Hydrocarbon) and gelling agent. The ratio of resin to solvent was varied to produce inks of varying inkometer tacks.

Rollers of varying diameter and hardness were used to ink the plate with the same ink film thickness (1.5 mil). The tack was decreased until toning was just observed. This is reported as the Just Toning Tack.

Temperatures was constant at 25°C.

Roller Diameter	Durometer reading	Just Toning Tack
213 cm	45	11.5
200	35	19.0
152	35	18.5
113	45	10.4
113	30	16.2
108	70	9.0
66	25	21.0
63	45	8.3
35	70	6.9

It can be seen that the JTT is proportional to the diameter and inversely so with the durometer; the durometer having a greater influence than diameter. By graphing diameter/4 x durometer against JTT correlation can be seen.

<u>**Ink vehicles**</u> were made with different resins dissolved in hydrocarbon solvent. These were pigmented at the same level and adjusted in tack until just toning occurred on the press. The same roller was used and the same ink film the thickness (1.5 mil) applied. Temperature was kept at 25°C. Alcohol numbers were measured of the adjusted vehicles. Acid numbers were provided by the resin suppliers.

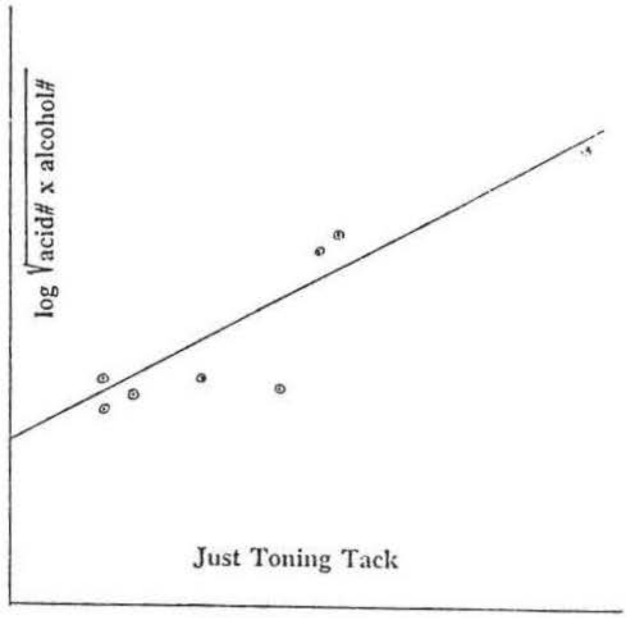
Resin type	Acid No.	Alcohol No.	Just Toning Tack
Cyclised rubber	2.0	34.9	14.0
Cyclised rubber&gel	2.0	30.8	6.9
Cyclised rubber& Coherence agent	2.0	23.0	5.0
Alphamethyl styrene	0.5	139.4	10.0
Hydrocarbon	1.0	24.1	9.0
Modified Phenolic	25.0	59.2	17.0
Rosin ester	13.0	81.5	16.0
Phenolic	30.0	250.0	30.0

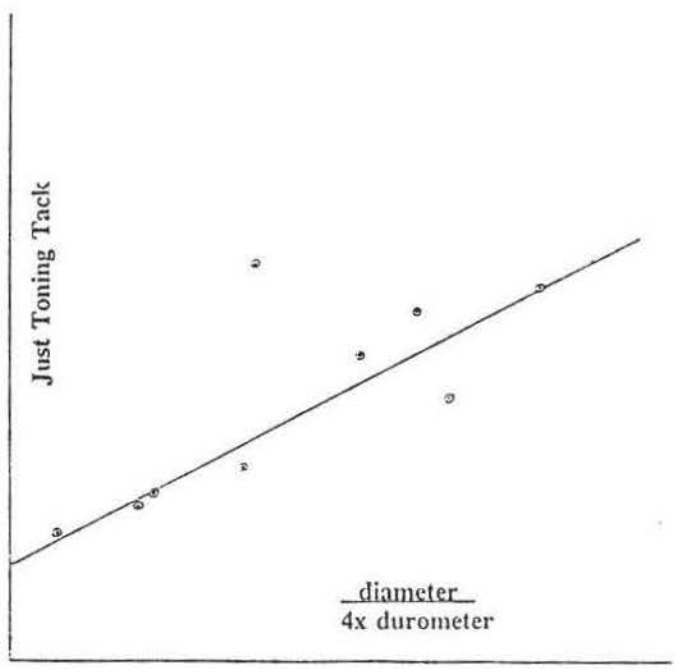
It is shown that the JTT is proportional with both acid number and alcohol number. A graph of log square root of the acid number times alcohol number shows the correlation.

Suggestions for Waterless Planography Improvements

The principal disadvantage of Waterless Planography is the lack of a controlling element. Wet lithography has fountain solution controls which compensate for variations in printing conditions. The concept of Tractive force suggests several such controls. If a form roller is run at a faster speed than the plate Tractive force is increased. This would allow the use of much lower tack inks, but plate wear would likely be a problem. Another device employs a roller which is coated with a tacky substance. This also increased Tractive force enough to allow the use of lower tack inks. The author has a U.S. patent for such a roller.

A better understand of ink coherence would lead to successful inks of lower tack. This would make Waterless a viable method for high speed publication such as Web Offset and Newspaper printing.


log √acid# x alcohol#
Just Toning Tack


Just Toning Tack
diameter
4x durometer

Conclusions

Tractive force, defined as the total of all forces acting on a non-printing of a **Waterless** plate by the inked form rollers, is shown to be equal to several interacting ink, plate and press properties. Test data supports the claim. Once the effects of Tractive force are known suggestions for ink and roller improvements can be made.

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