APPLICATION NOTE

Electrostatic Charging In Web Converting

Table of Contents

I. Introduction

Why Is It Important To Understand, Measure And Control Static Electricity In Web Coating, Converting, And Printing?

Statically charged materials on the converting machine, the web, or both may attract or repel the web to itself or to the machine. This material misbehavior can adversely affect the manufacturing process by causing jams and downtime, reduced productivity, and/or poor product quality.

Static on the web can attract contamination such as dust and other particulates, resulting in coating or printing defects.

Static shocks received by operators can cause dangerous physical reactions by the persons receiving the shocks, possibly resulting in injuries or death from moving machinery.

Static sparks in hazardous operations such as solvent-based coating or printing can cause fires and explosions, possibly resulting in injuries or death to people, destruction of the equipment or facility, and lost production.

Overall Review Of Static Generation, Measurement, And Continuous Control Of Static In Web Handling Operations

This document provides the reader with a review of web static charging mechanisms, web and machine factors most involved in static charging, typical locations of web static charging, and techniques to minimize web charging.

Generation and control of static in web converting depends upon many varying conditions in the web material, the converting machine, the surrounding atmosphere, and the static control measures used on the machine. It is impossible to predict and control all of these conditions because they can change without one realizing it until a statically caused event occurs. Changing conditions can alter the amount of static charge accumulation, so although static is under control today, it may not be under control tomorrow.

The keys to continuous static control are (1) the correct determination of critical areas of the machine to monitor for static charge accumulation, (2) application of static countermeasures and devices that prevent or control static charge accumulation, and (3) continuous electric field measurement in these critical areas using permanent fieldmeters, which are alarmed to warn or shutdown the operation when web static charge levels increase beyond predetermined set points.

II. How Electrostatic Charge Builds-Up on a Moving Web

Electrostatic Charging On A Web Converting Machine

Electrostatic charging can occur in several different ways, but for the purposes of this document, we will limit our discussion to contact and separation (triboelectric) charging between two surfaces. Triboelectric charging is a surface event that occurs when two surfaces are brought together and then separated or rubbed against each other (friction).

Different materials have different abilities to hold onto their free electrons (work function). During contact and separation of materials, one material will give up free electrons to the other, resulting in a net positive charge on one material and a net negative charge on the other material. Of the two materials, the material with the lower work function gives up electrons to the other material and becomes positively charged. The material with the higher work function takes electrons from the other material and becomes negatively charged.

Theoretically, if two surfaces are chemically and mechanically identical in structure and surface finish on an atomic or molecular level, then their work functions will be identical. When they are separated or rubbed together, no charge transfer will take place. Unfortunately, real materials are seldom completely pure, and they often have surface finishes and/or contamination that strongly influence their charging characteristics. Unwinding a roll of plastic sheeting can demonstrate this by sparking where the sheet separates from the roll, and by static attraction of contaminants to the sheet after separation. See Figure II-1.

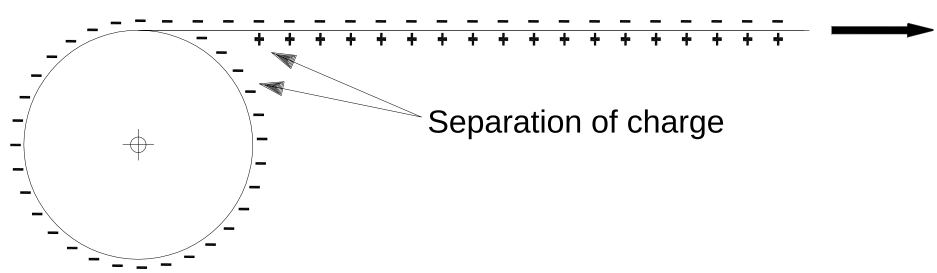

Figure II-1

Unwinding Roll of Plastic Sheeting

Table II-1 is a short triboelectric series that provides an indication of the order of some common materials. The way to use a triboelectric series is to note the relative positions of the two materials of interest. The material that charges positively will be the one that is closer to the positive end of the series, and the material closer to the negative end will charge negatively.

Asbestos	**most positive**
Glass	⇑
Nylon	
Wool	
Lead	
Silk	
Aluminum	
Paper	
Cotton	
Steel	
Hard rubber	
Nickel & copper	
Brass & silver	
Synthetic rubber	
Orlon	
Saran	
Polyethylene	
Teflon	⇓
Silicone rubber	**most negative**

Table II-1

Triboelectric Series

If only one surface has a significant electrical resistance while the other surface is a good electrical conductor, most of the charges still will not be able to return to their original surface. This again leaves an excess of positive charges on one surface and an excess of negative charges on the other. Under this condition, however, the surface charges on the conductor can freely move throughout the conductive body.

Unless this charged conductive body is able to obtain opposite polarity charges from ground to remain electrically neutral, it is isolated (a charged capacitor) and can become a static spark hazard.

Factors That Most Affect Triboelectric Charging

Contact Pressure: Increased pressure increases contact area by reducing the air gap between surfaces.

Contact Time: Increased contact time can increase charge transfer by enlarging the contact area.

Draining Velocity: The speed at which charges travel along the web toward recombination. It is relatively constant and independent of parting velocity, but is directly related to web front/back surface and bulk conductivity. Net charge builds on a web when parting velocity is greater than draining velocity.

Electric Field: The electric field generated at the location where the surfaces separate may provide enough force to affect the return of charges to their original surfaces.

Humidity: As humidity is increased, generally material conductivity increases, and charge accumulation decreases due to charge backflow.

Particulate Contamination: Dust and other particulates on surface layers affect surface chemistry and contact area, which affect charging.

Parting Velocity or Separation Speed: Affects the time electrons have available for returning to their original surface. Generally, the faster the surfaces are separated the more charge is left on the surfaces.

Slip (or Slide): Causes frictional charging due to relative motion between surfaces. This can also cause transfer of actual material from one surface to the other, which will affect charging as well.

Surface Hardness: Soft surfaces make contact that is more intimate and tend to cause more charging during separation.

Surface Layer Chemistry: Affects how charging takes place when surfaces of differing work functions contact each other.

Surface Roughness: Charge transfer decreases as surface roughness increases due to less contact area between the surfaces.

Temperature: Elevated surface temperatures usually result in increased charge transfer due to higher molecular energy levels as well as to decreased surface moisture films.

Locations Of Charge Transfer In Web Converting Machines

When the web is wound into roll form, the face and back are in contact. So charge transfer can occur during unwinding (see Figure II-1 for example). Surface chemistry and intimacy of contact are important factors here. Sometimes "charge balancing" is attempted by chemists who add surfactants and other chemicals to the surfaces to control front-to-back charging. In addition, the more intimate (greater) the contact between layers, the more charge is transferred. Intimacy is influenced by such factors as surface hardness, roughness, thickness, force concentration, and winding tension. Roll history (moisture changes, temperature changes, winding tension) can be an important factor because it may affect conductivity or contact area.

Corona discharge treatment (CDT) is applied to the web in some converting processes. CDT treatment is used to increase the web's ability to accept coating or printing layers. Because CDT purposely generates large quantities of ions to alter the web's physical characteristics, high charges are also left on the web, which then must be reduced or eliminated.

Webs and rollers exchange charge because of differences in material properties. The factors that we saw above translate into the following factors in a coating, converting, or printing machine:

Roller bulk conductivity and surface conductivity

Roller surface chemistry (material and contamination)

Roller surface roughness, texture, and venting

Roller/Web alignment and tracking

Roller/Web frictional drag (bearing failure)

Roller/Web intimacy of contact (surface hardness or compliance)

Roller/Web wrap angle

Web bulk conductivity and front/back surface conductivity

Web slip and weave

Web speed and tension

Web surface chemistry (material, antistatic agents, surfactants and contamination)

Web surface roughness and texture

Any other object that the web touches, such as turning bars, splice board, and the operator's hand, can also cause charge transfer.

High electric fields that occur at the separation of surfaces, such as at the nip of unwinding rolls or roller/web contacts, can result in corona discharges (glow). Corona discharges produce ions of both polarities that tend to reduce the overall web charge. Static control devices (passive or active ionizers) ionize air in order to control charges on the web by attracting opposite polarity air ions to neutralize the charges on the web.

Strong electric fields on insulating surfaces in the converting machine can charge ungrounded conductors (including people) by induction, especially at wind-up and delivery areas. These charged conductors could then release dangerous sparks to any other nearby conductor.

Typical Web Charging Scenario

If we select values of the above factors and hold them constant while allowing the web and roller to make multiple identical contacts, the charge that is transferred follows an exponential charging relationship versus time. The web charge density then gradually approaches equilibrium at velocity **V**.

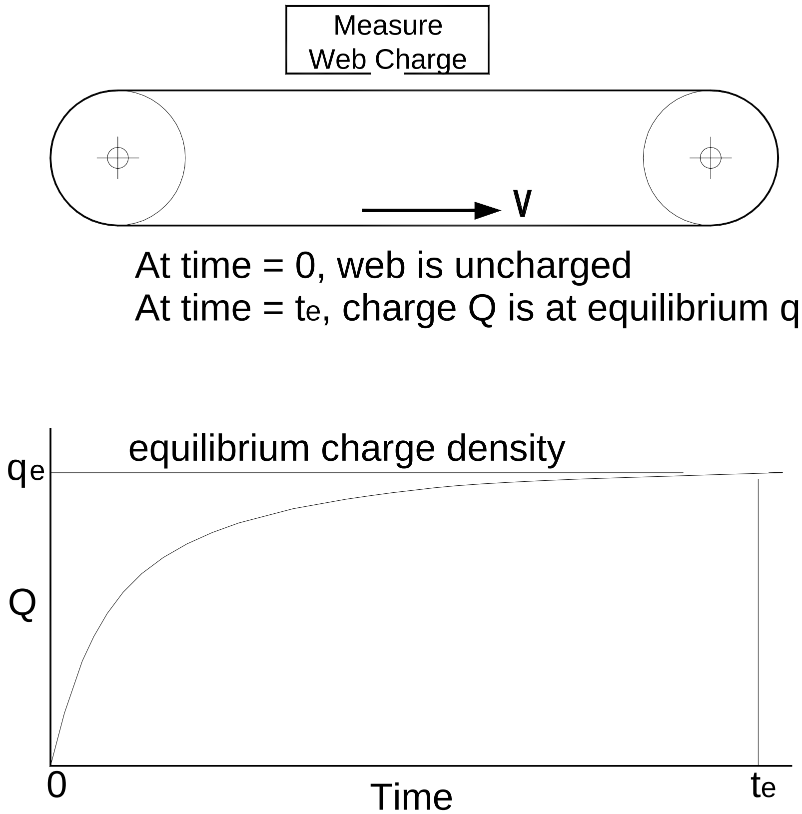

Figure II-2

Typical Roller/Web Charging Scenario

Techniques To Minimize Web Charge And How They Work

As much as possible, control the factors that govern charge transfer from objects (e.g. rollers, web laps) to the web. Usually, not all factors are known and/or controllable. Some general guidelines for reducing web charge transfer can be given, but they may be product and process dependent.

- Electrically ground all conductive machine parts including rollers (use conductive bearings and conductive bearing lubricants) to eliminate dangerous sparking from capacitive discharges to another conductor such as a person or metal. Please note that grounded conductive rollers cannot reduce charges of insulating web surfaces that pass over them! The purpose of grounding the rollers is to prevent the rollers from becoming highly charged.
- Maintain web-converting machines in excellent condition, making sure rollers are in alignment and turning freely.
- Use web substrates and coating materials that are conductive or dissipative, or can be made so before converting begins with the addition of antistatic agents.
- Use web substrates that were manufactured, wound, and packaged in environments with 50% or higher relative humidity (RH).
- Control RH in the web converting machine environment to 50-55%. Higher levels can cause iron and steel parts to rust, and may be uncomfortable to operators working in the area. In building areas with uncontrolled humidity, increased static charging is usually very dramatic during the winter when RH in heated buildings can frequently drop to less than 10%.
- If possible, avoid using pinch drive rollers. If they must be used, minimize the pinch roller pressure and tackiness.
- Reduce machine speed and web tension as much as practical.
- Increase web and roller surface roughness as much as practical.
- Clean machine rollers frequently. Web/roller electrification can be affected by previous products because of web material transfer to the rollers.
- Control drying conditions of web coatings to as low a temperature, and as high a relative humidity, as practical.
- Cover conductive rollers only with sleeves made of conductive or dissipative material. Large amounts of charge can be stored at the interface of resistive sleeve material and a conductor, which can be released in very hazardous sparks either spontaneously or when approached by a person (conductor).

Use passive and/or active ionization devices to reduce web charge density. If properly installed in the correct locations, it may be possible to initially control all static problems on the web-converting machine using ionization. Over time, though, the effectiveness of all these devices will degrade, and they will have to be cleaned, maintained, or replaced to return their effectiveness to original condition. The proper operation and effectiveness of ionization systems can be verified by continuous downstream monitoring using permanent installations of Advanced Energy Monroe 177A fieldmeters with Monroe 1036 fieldmeter probes.

The application note, *Electric Fields and Fieldmeters*, deals with the practical issues of measuring and interpreting electric fields with the Advanced Energy Monroe 265A and 282 handheld fieldmeters to determine where continuous monitoring is necessary.

III. Continuous Static Control

Control of static is not something that occurs once and can then be forgotten. It requires the implementation of continuous procedures such as charge neutralization using ionizers with electric field monitoring using permanent fieldmeters and probes to verify that the ionizers are working effectively.

Passive Ionizers

Passive ionizers connected to ground (e.g. tinsel, conductive brushes) rely on the electric field produced by the charge on the web to produce positive and negative ions by corona discharge. Passive ionizers feature points that concentrate the electric field to produce field strengths that, when they exceed the dielectric breakdown strength of air (30,000 volts per centimeter, V/cm), produce positive and negative air ions at the points. Passive ionizers rely on the electric field from the web to pull these air ions to the web to partially neutralize the charges on the web. Since passive ionizers rely on the electric field from the web to produce ionization, they are not very effective at field strengths below 1000 V/cm, but become very effective at higher field strengths. The effectiveness of passive ionizers also depends on point cleanliness and sharpness, number of points per unit area, distance from the web, web span length, and proximity to other conductors.

Electric Powered Active Ionizers

Electric powered active ionizers produce corona discharge ionization by applying a high voltage to geometrically arranged emitter elements. Ionizers made for reducing web charge use AC voltage, producing large amounts of both negative and positive air ions, or DC voltage producing only one polarity of air ion.

Various designs are used, depending upon the ionizer's purpose, but the high voltage emitter elements are usually needle points or thin wires. Operating details vary with different designs, but, as with passive ionizers, they rely on the electric field from the web to pull opposite polarity air ions from the emitter elements to the web for charge neutralization. Since they do not rely on the electric field from the web to produce ionization, they are effective at all but the highest field strengths. Some models use blowers or compressed air assistance to drive ions further distances toward the web. The effectiveness of active ionizers also depends greatly upon their design, their operating voltage, the web speed, point cleanliness and sharpness, web span length, distance from the web, and proximity to conductors.

Some electronic ionizers claim to be able to monitor the charge on the web. These ionizers monitor their own ion current. They provide an indication of the performance of the ionizer. They are not true monitors of the charges on web materials, and are not a replacement for electrostatic fieldmeters that are placed downstream of the ionizers to monitor web charging.

Radioactive (Nuclear) Powered Active Ionizers

Nuclear ionizers use radiation (α or β particles) that strip electrons from air molecules to make both positive and negative air ions. The air ions are attracted to the web by the electric field produced from the charge on the web. These ionizers usually can't produce as many ions per unit time as do electric powered ionizers. Since there is a specific amount of radioactive material in each device and radioactive decay occurs independent of process variables, the rate of ion production is not controllable and is independent of the amount of charge on the web. For example, Polonium 210, a Beta emitter, has a half life of 138 days, at which time its ion production is reduced by half.

Nuclear ionizers do not employ the use of high voltage to create air ions. Therefore, they do not create a threat of explosion or fire when used with solvents-based coating or printing applications.

Nuclear ionizers are a controlled device subject to licensing and regulation.

Key To Continuous Static Control

The keys to continuous static control are: (1) Correct determination of critical machine areas to (2) monitor continuously. Then (3) implement static control devices and continuous electric field measurement in these critical areas using permanent fieldmeters which are (4) alarmed to warn or shutdown the operation when web static charge levels increase beyond predetermined set points.

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