Analysis Method

An attempt is made in the present study to use well known magnetic hysteresis-related concepts to help in the understanding of the Feeding Properties of printing blanket composites. A short glossary of terms relating to magnetic hysteresis, mainly as defined in Encyclopaedia Britannica, is presented in Annex A.

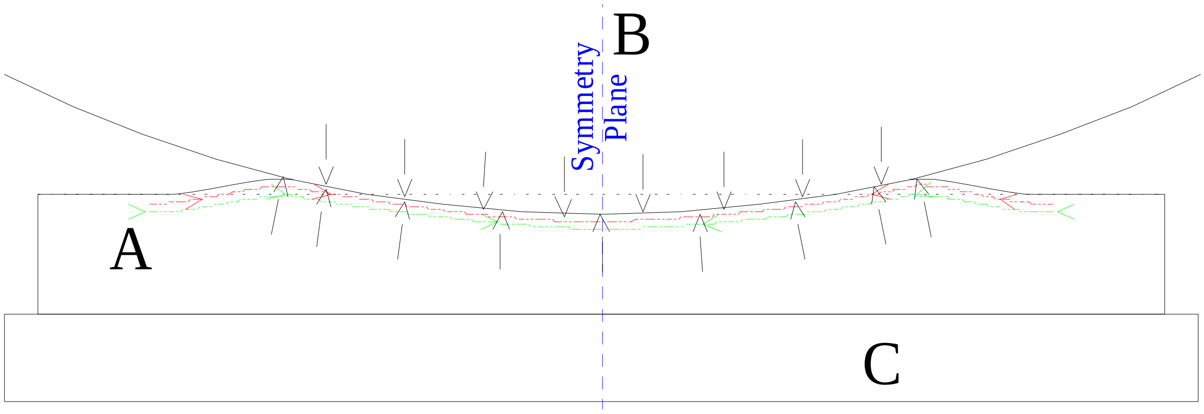
Magnets and magnetism related phenomena are acknowledged to be best studied and understood with the help of Quantum Mechanics, necessary at the atomic and the subatomic levels, where the granular nature of matter can no longer be ignored. As from the Relativity Theory onwards, modern science requires that an increasing number of Dimensions be considered, which are not easy for the human mind to grasp.

But for the layman it is enough a challenge to realize that in most technological fields, in-depth study of materials behaviour will involve several Variables which often interrelate with each other to some degree.

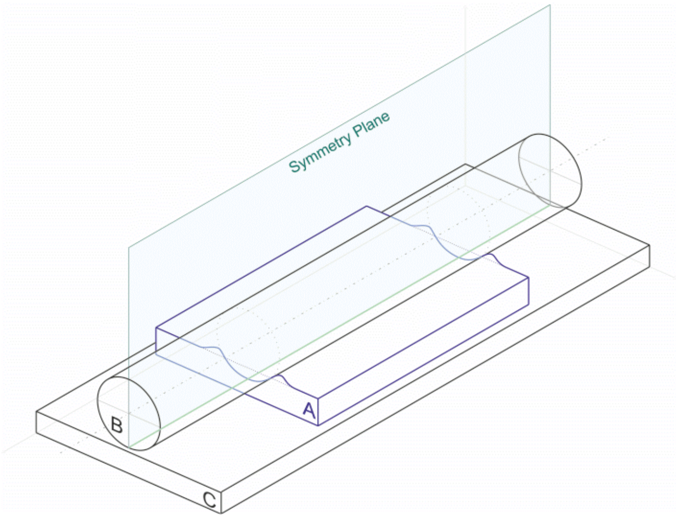
Basic steps as laid down by the Scientific Method remain unchanged, but organic-chemistry-based materials demand that a generous amount of time and database collection work be carried before any successful behaviour interpretation or further steps may be attempted. And as materials use chemical compounds closer to that common to living beings - such as natural rubber - observation and data base building times will tend to grow somehow, in a similar way to those required for bird watching observation, or scientific wild life study.

Compression Scheme and Rubber Reaction

Let us consider a uniform thickness, rectangle shaped, flat solid rubber format A seating on a horizontal flat steel block C. Solid rubber is incompressible but deformable. When a compressive force is vertically applied on the rubber surface by the descent of a steel cylinder B, exerted by an area segment of its lateral surface, rubber particles displaced due to local thickness reduction must reach a new equilibrium position and a *field of compressive plus tensile reaction force* develops.



The above image depicts a rather simplified variant of current offset printing conditions.



Steel cylinders' height is bigger than the width of rubber format A and both cylinder bases overhang from the rubber format A. The resulting frontier perimeter of the steel / rubber interface is composed by the two generatrix segments of the lateral cylinder surface - where the two bulges are formed in compensation of the rubber volume displaced by the cylinder - and completed by the two circumference segments of the rubber format lateral edges which are also in contact with the cylinder.

The steel/rubber frontier segments defined by the cylinder generatrix lines define an indentation compression condition, while the two circumference segments of the rubber format define a deflection compression condition.

The field of reaction forces created by the cylinder on its descent into the rubber block has a symmetry defined by the generatrix line of the cylinder that indents deeper into the rubber. We can say that line forms a *domain wall* and establishes a border between two distinct domains, the field of reaction forces of *each domain being just the mirror image of the other*.

Let us now assume that, keeping the same pressure on the rubber block, the cylinder is dragged leftwards, perpendicularly to its axis over the rubber block. (The cylinder is being slid instead of being rolled.) Some rubber particles, originally subject to the domain field of forces on the left side will have to sneak under the domain wall, joining now the domain field of forces on the right side. As the particles change from one domain to the other they must adapt themselves to the varying stress conditions they are being submitted as shown in Domain_wall_vectors.png and Barkhausensprung.gif.

Changing a particle from one domain to another demands a certain amount of energy, meaning the particle will also have a correspondent reaction. As the domain wall moves sideways, the potential energy stored by that particle increases until it becomes big enough for the particle to sneak under the domain wall and to join the adjacent particles to which it is structurally linked but from which it had been brought apart by the initial descent of the domain wall.

When the particle finally changes its position from one domain to the other its reaction is quite sudden - usually acknowledged in the Printing Industry as Rebound, re-baptised here as **Whip Reaction** - and it may be sufficient to contribute to a very minute movement, that is usually described as rubber **Feed Properties**.

A number of factors and compression scheme variations influencing the rubber behaviour, namely in what concerns hysteresis, whip reaction and feeding properties are dealt as annexes to the present document.

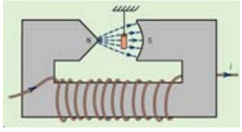
ANNEX A

Reference Concepts

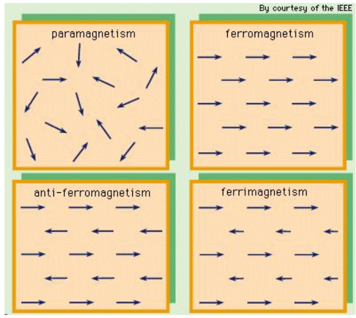
Magnetism

Phenomenon associated with the motion of electric charges. This motion can take many forms. It can be an electric current in a conductor or charged particles moving through space, or it can be the motion of an electron in atomic orbit. Magnetism is also associated with elementary particles, such as the electron, that have a property called spin.

Diamagnetism



Kind of magnetism characteristic of materials that line up at right angles to a nonuniform magnetic field and that partly expel from their interior the magnetic field in which they are placed.

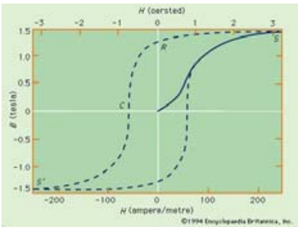


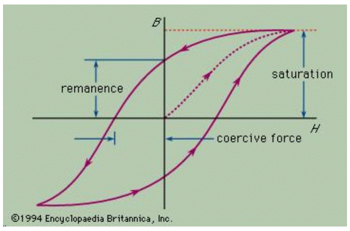
Paramagnetism

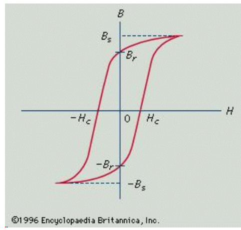
Kind of magnetism characteristic of materials weakly attracted by a strong magnet. Most elements and some compounds are paramagnetic. Strong paramagnetism (not to be confused with the ferromagnetism of the elements iron, cobalt, nickel, and other alloys) is exhibited by compounds containing iron, palladium, platinum, and the rare-earth elements.

Magnetic Hysteresis

Lagging of the magnetization of a ferromagnetic material, such as iron, behind variations of the magnetizing field.







When ferromagnetic materials are placed within a coil of wire carrying an electric current, the magnetizing field, or magnetic field strength H, caused by the current forces some or all of the atomic magnets in the material to align with the field. The net effect of this alignment is to increase the total magnetic field, or magnetic flux density B. *The aligning process does not occur simultaneously or in step with the magnetizing field but lags behind it.*

If the intensity of the magnetizing field is gradually increased, the magnetic flux density B rises to a maximum, or saturation, value at which all of the atomic magnets are aligned in the same direction. When the magnetizing field is diminished, the magnetic flux density decreases, again lagging behind the change in field strength H. In fact, when H has decreased to zero, B still has a positive value called the remanence, residual induction, or retentivity, which has a high value for permanent magnets. B itself does not become zero until H has reached a negative value. The value of H for which B is zero is called the coercive force. A further increase in H (in the negative direction) causes the flux density to reverse and finally to reach saturation again, when all the atomic magnets are completely aligned in the opposite direction. The cycle may be continued so that the graph of the flux density lagging behind the field strength appears as a complete loop, known as a hysteresis loop. The energy lost as heat, which is known as the hysteresis loss, in reversing the magnetization of the material is proportional to the area of the hysteresis loop. Therefore, cores of transformers are made of materials with narrow hysteresis loops so that little energy will be wasted in the form of heat.

Hysteresis (Loop)

All ferromagnetic materials exhibit the phenomenon of hysteresis, a lag in response to changing forces based on energy losses resulting from internal friction. If B (magnetic flux density) is measured for various values of H (magnetic field strength) and the results are plotted in graphic form, the result is a loop of the type shown in the accompanying figure, called a hysteresis loop. The name describes the situation in which the path followed by the values of B while H is increasing differs from that followed as H is decreasing.

With the aid of this diagram, the characteristics needed to describe the performance of a material to be used as a magnet can be defined. B_s is the saturation flux density and is a measure of how strongly the material can be magnetized. B_r is the remanent flux density and is the residual, permanent magnetization left after the magnetizing field is removed; this latter is obviously a measure of quality for a permanent magnet. It is usually measured in webers per square metre. In order to demagnetize the specimen from its remanent state, it is necessary to apply a reversed magnetizing field, opposing the magnetization in the specimen. The magnitude of field necessary to reduce the magnetization to zero is H_c, the coercive force, measured in amperes per metre. For a permanent magnet to retain its magnetization without loss over a long period of time, H_c should be as large as possible. The combination of large Br and large H_c will generally be found in a material with a large saturation flux density that requires a large field to magnetize it. Thus, permanent-magnet materials are often characterized by quoting the maximum value of the product of B and H, $(BH)_{max}$, which the material can achieve. This product $(BH)_{max}$ is a measure of the minimum volume of permanent-magnet material required to produce a required flux density in a given gap and is sometimes referred to as the energy product.

Magnet

Any material capable of attracting iron and producing a magnetic field outside itself.

Reference: http://www.britannica.com

Magnetic Field

Region in the neighbourhood of a magnet, electric current, or changing electric field, in which magnetic forces are observable.

Magnetic fields such as that of the Earth cause magnetic compass needles and other permanent magnets to line up in the direction of the field. Magnetic fields force moving electrically charged particles in a circular or helical path. This force - exerted on electric currents in wires in a magnetic field - underlies the operation of electric motors. Around a permanent magnet or a wire carrying a steady electric current in one direction, the magnetic field is stationary and referred to as a magnetostatic field. At any given point its magnitude and direction remain the same. Around an alternating current or a fluctuating direct current, the magnetic field is continuously changing its magnitude and direction.

Magnetic fields may be represented by continuous lines of force or magnetic flux that emerge from north-seeking magnetic poles and enter south-seeking magnetic poles. The density of the lines indicates the magnitude of the magnetic field. At the poles of a magnet, for example, where the magnetic field is strong, the field lines are crowded together, or more dense. Farther away, where the magnetic field is weak, they fan out, becoming less dense. A uniform magnetic field is represented by equally spaced parallel straight lines. The direction of the flux is the direction in which the north-seeking pole of a small magnet points. The lines of flux are continuous, forming closed loops. For a bar magnet, they emerge from the north-seeking pole, fan out and around, enter the magnet at the south-seeking pole, and continue through the magnet to the north pole, where they again emerge. The SI unit for magnetic flux is the weber. The number of webers is a measure of the total number of field lines that cross a given area.

Magnetic fields may be represented mathematically by quantities called vectors that have direction as well as magnitude. Two different vectors are in use to represent a magnetic field: one called magnetic flux density, or magnetic induction, is symbolized by B; the other, called the magnetic field strength, or magnetic field intensity, is symbolized by H. The magnetic field H might be thought of as the magnetic field produced by the flow of current in wires and the magnetic field B as the total magnetic field including also the contribution made by the magnetic properties of the materials in the field. When a current flows in a wire wrapped on a soft-iron cylinder, the magnetizing field H is quite weak, but the actual average magnetic field (B) within the iron may be thousands of times stronger because B is greatly enhanced by the alignment of the iron's myriad tiny natural atomic magnets in the direction of the field.

Magnetic Pole

Region at each end of a magnet where the external magnetic field is strongest.

Magnetic forces cannot be traced to unit magnetic poles of submicroscopic size in direct contrast to electric forces that are caused by actual discrete electric charges, such as electrons and protons. Indeed, magnetic forces themselves also fundamentally arise between electric charges when they are in motion. See also magnetic dipole.

Magnetic Dipole

Generally, a tiny magnet of microscopic to subatomic dimensions, equivalent to a flow of electric charge around a loop.

Electrons circulating around atomic nuclei, electrons spinning on their axes, and rotating positively charged atomic nuclei all are magnetic dipoles. The sum of these effects may cancel so that a given type of atom may not be a magnetic dipole. If they do not fully cancel, the atom is a permanent magnetic dipole, as are iron atoms. Many millions of iron atoms spontaneously locked into the same alignment to form a ferromagnetic domain also constitute a magnetic dipole. Magnetic compass needles and bar magnets are examples of macroscopic magnetic dipoles.

Magnetic Resonance

Absorption or emission of electromagnetic radiation by electrons or atomic nuclei in response to the application of certain magnetic fields.

A particle of matter that is spinning about its own axis or moving in an orbit around some external point acts like a gyroscope: it resists forces that tend to change its state of motion. The measure of this resistance is the mechanical angular momentum, which depends on the mass of the particle, its size or that of its orbit, and the angular velocity (the number of revolutions per unit time). The angular momentum is represented by a vector directed along the axis of rotation. An electric charge in such motion creates a magnetic field with strength and direction represented by a magnetic vector denoted μ. This vector, which is proportional to the magnitude of the charge (instead of the mass of a particle), measures the tendency of the charge's axis of rotation to align itself in the direction of an external magnetic field. The motion of a particle that has both mass and charge is characterized by both of these vectors, which will be collinear but may be oppositely directed, depending on the sign of the charge.

Faraday's Law of Induction

Faraday found that (1) a changing magnetic field in a circuit induces an electromotive force in the circuit; and (2) the magnitude of the electromotive force equals the rate at which the flux of the magnetic field through the circuit changes. *The flux is a measure of how much field penetrates through the circuit.*

Magnetic Flux Density

Total magnetic field including also the contribution made by the magnetic properties of the materials in the field.

To illustrate the meaning of flux, imagine how much water from a steady rain will pass through a circular ring of area A. When the ring is placed parallel to the path of the water drops, no water passes through the ring. The maximum rate at which drops of rain pass through the ring occurs when the surface is perpendicular to the motion of the drops. The rate of water drops crossing the surface is the flux of the vector field ρv through that surface, where ρ is the density of water drops and v represents the velocity of the water. Clearly, the angle between v and the surface is essential in determining the flux.

Reference: http://www.britannica.com

Magnetic Saturation

When the ratio between magnetic energy and thermal energy is large enough to align nearly all the dipoles with the field, magnetization approaches a saturation value.

Refer to 3rd paragraph of http://www.britannica.com/EBchecked/topic/357334/magnetism/71543/Induced-and-permanent-atomic-magnetic-dipoles#ref113953 - The forces opposing alignment(...)

Saturation Flux Density

Measure of how strongly the material can be magnetized (B_s).

Remnant Flux Density

It is the residual, permanent magnetization left after the magnetizing field is removed.

Remanence

When magnetic field strength H = 0, the magnetic field constitutes what is termed the residual flux density, and the retention of magnetization in zero field is called remanence.

Coercive Force

When the external field is reversed, the value of B (magnetic flux density) falls and passes through zero at a field strength known as the coercive force.

Further increase in the reverse field H (from H = 0) sets up a reverse field B that again quickly reaches a saturation value S . Finally, as the reverse field is removed and a positive field applied, B traces out the lower broken line back to a positive saturation value. Further cycles of H retrace the broken curve, which is known as the hysteresis curve, because the change in B always lags behind the change in H. The hysteresis curve is not unique unless saturation is attained in each direction; interruption and reversal of the cycle at an intermediate field strength results in a hysteresis curve of smaller size.

Domain

The French physicist Pierre-Ernest Weiss postulated a large-scale type of magnetic order for ferromagnets called domain structure. According to his theory, a ferromagnetic solid consists of a large number of small regions, or domains, in each of which all of the atomic or ionic magnetic moments are aligned.

If the resultant moments of these domains are randomly oriented, the object as a whole will not display magnetism, but an externally applied magnetizing field will, depending on its strength, rotate one after another of the domains into alignment with the external field and cause aligned domains to grow at the expense of nonaligned ones. In the limiting state called saturation, the entire object will comprise a single domain.

Domain Wall

It was suggested in 1907 that a ferromagnetic material is composed of a large number of small volumes called domains, each of which is magnetized to saturation. In 1931 the existence of such domains was first demonstrated by direct experiment. The ferromagnetic body as a whole appears unmagnetized when the directions of the individual domain magnetizations are distributed at random. Each domain is separated from its neighbours by a domain wall. In the wall region, the direction of magnetization turns from that of one domain to that of its neighbour. The process of magnetization, starting from a perfect unmagnetized state, comprises three stages: (1) Low magnetizing field. Reversible movements of the domain walls occur such that domains oriented in the general direction of the magnetizing field grow at the expense of those unfavourably oriented; the walls return to their original position on removal of the magnetizing field, and there is no remanent magnetization. (2) Medium magnetizing field. Larger movements of domain walls occur, many of which are irreversible, and the volume of favourably oriented domains is much increased. On removal of the field, all the walls do not return to their original positions, and there is a remanent magnetization. (3) High magnetizing field. Large movements of domain walls occur such that many are swept out of the specimen completely. The directions of magnetization in the remaining domains gradually rotate, as the field is increased, until the magnetization is everywhere parallel to the field and the material is magnetized to saturation. On removal of the field, domain walls reappear and the domain magnetizations may rotate away from the original field direction. The remanent magnetization has its maximum value.

Refer to http://upload.wikimedia.org/wikipedia/commons/7/79/Barkhausensprung.gif

Barkhausen effect

Series of sudden changes in the size and orientation of ferromagnetic domains, or microscopic clusters of aligned atomic magnets, that occurs during a continuous process of magnetization or demagnetization. The Barkhausen effect offered direct evidence for the existence of ferromagnetic domains, which previously had been postulated theoretically.

Heinrich Barkhausen, a German physicist, discovered in 1919 that a slow, smooth increase of a magnetic field applied to a piece of ferromagnetic material, such as iron, causes it to become magnetized, not continuously but in minute steps. The sudden, *discontinuous jumps* in magnetization may be detected by a coil of wire wound on the ferromagnetic material; the sudden transitions in the magnetic field of the material produce pulses of current in the coil that, when amplified, produce a series of clicks in a loudspeaker. These jumps are interpreted as *discrete changes* in the size or rotation of ferromagnetic domains. Some microscopic clusters of similarly oriented magnetic atoms aligned with the external magnetizing field increase in size by a sudden aggregation of neighbouring atomic magnets; and, especially as the magnetizing field becomes relatively strong, other whole domains suddenly turn into the direction of the external field.

Reference: http://www.britannica.com