文章编号:1004 - 7204(2001)06 - 0012 - 12

FACTORS OF WEATHERING AND CLIMATE

气候及老化之因素

Matt McGreer

(美国 ATLAS 气候服务集团凤凰城试验场)

摘要: 尽管大部分试验都与研究和开发有关,但人们从事试验的主要原因仍是为了满足客户对材料的要求。在试验期间或评估结果时可做出若干结论或决定。引起老化的三大主要因素是:光(日光辐射)、水(湿度)和温度。但这不仅是每种因素需要多少量才能最终导致材料降解的问题,因为辐射波长不同、潮湿程度不同、以及实际温度的冷热循环,均会对曝露的材料造成很大(甚至主要)的影响。这些因素(及其变化)的共同作用导致降解。辐射能量分为直射分量和漫射分量,按波段不同又分为紫外部分、可见部分和红外部分。文中给出了各种辐射量的大小、定义和等式。气候在降解过程中起着关键作用。不同气候以不同方式对材料产生作用。气候老化研究的两种典型气候为亚热带和沙漠气候。

关键词: 自然老化; 气候因素

中图分类号: V1 **文献标识码**: A

Abstract:

While nearly all testing is done in one way or another for research and development purposes, the main reason why people test is to meet specifications required by those who buy their material. There are several answers or decisions that may be made during a test or in evaluating results. The three main factors of weathering are light (solar radiation), water (moisture) and temperature. But it is not just "how much" of each of these factors that ultimately cause degradation to materials, because different wavelengths of radiation, different phases of moisture, and actual temperature cycling have a significant, if not greater, effect on materials on exposure. These factors (and secondary effects) work in synergy to cause degradation. Radiant energy can be broken into direct and diffuse components, and different wavelength bands have been categorized into the UV, Visible, and IR regions. Radiometric quantities, definitions, and equations are presented. Climate plays a key role in degradation processes. Different climates will affect materials in varying ways. The two benchmarks for weathering studies include subtropical and desert climates.

"你为什么试验?"

该问题曾在几年前的一次市场调查中提出,旨在了解人们为什么将试样送到独

收稿日期: 2001 - 07 - 31

作者简介: Matt McGreer,男,美国 ATLAS 气候服务集团凤凰城试验场教授。

"Why Do You Test?"

This paraphrased question was asked in a marketing survey several years ago to determine why companies sent specimens to independent testing laboratories and/or purchased artificial weathering equipment. The results were not surprising. Nearly two-thirds of those surveyed indicated that they test simply "because we have to." This means that, in order

立实验室和/或购买人工老化设备进行试验。调查结果并不出人意料。几乎有三分之二被调查者表示,他们试验只是"因为不得不做"。这意味着,为了销售某种产品,他们必须按客户要求证明其材料在户外条件下的性能。大部分试验是严格按公司、行业或政府规范执行的。如果没有资料支持其性能,客户是不会同意购买新的配方和工艺的。这显示了试验标准和规范的重要性,同时也突出了理解如何正确试验的重要性。

调查的其它答案中,还包括"需要与竞争对手的材料进行对比,以帮助公司开展各种营销活动。"几乎所有试验都或多或少与研究和开发有关,而其中约有 10 %是完全用于研发目的,而另有 10 %是为了确保其材料能达到质量保证或其它要求。

期望从老化试验中得出的结论

理解气候老化试验的应用和评估技术后,人们可以准确地按性能将材料分级。换言之,在耐用性和成本等方面,"新配方/工艺是否优于老配方/工艺?"。这种分级方法,通常是将新配方与"已知"或受控材料加以比较。这些材料经过反复测试和研究,其性能被广泛接收,并记录在各种文件中。这可以是由某个行业开发出来的标准参考材料,如聚碳酸酯参考片或蓝羊毛,也可以是由某个组织内部开发出来的某种特定材料的老配方。

在研究工作中,试验能够使人们理解并确定由气候导致的各种失效机理的发生过程。对这些过程的理解,有助于材料科学家开发出能遏制这些机理发生的新型配方和工艺。尽管气候老化试验的主要对象是新的配方,但试验期间也可以对新的表面处理方法或节能工艺进行评估。对于所有加速试验,人们首要关心的是试验是否

to sell their material, they were required by their buyer to prove the performance of their material to outdoor conditions. Most of this testing is done to exacting corporate, industry, or government specifications. Without data to support the performance of a new formulation or process, the buyer simply would not agree to purchase their material. This demonstrates the importance of test standards and specifications, and also underlines the importance of understanding how to properly conduct these tests.

Other responses to this survey included the need to compare materials to the competitor, which may allow for sales and marketing campaigns for a company. While almost all testing is in some way related to research and development, about 10 % of the testing done was strictly for these purposes, while another 10 % tested to ensure that their material would meet the warranty claims, or other requirements.

Answers Expected From Weathering Tests

Understanding weathering test applications and evaluation techniques, one should be able to accurately rank materials by performance. In other words, "Is this new formulation/process better than the old one?" in terms of durability, cost, etc. This ranking technique is commonly performed comparing a new formulation to a "known" or control material. These are materials that have been tested and characterized in a way that its performance is well known and documented. This can include standard reference materials developed by an industry, such as polycarbonate reference chips or blue wool materials, or maybe an old formulation of a specific material developed internally by an organization.

In research work, testing may allow one to understand and identify the likely failure mechanisms that occur as a result of weathering. Understanding these processes may lead material scientists to develop new formulations and processes that inhibit these mechanisms. While new formulations may be the primary factor in testing, new surface preparation methods or cost saving processes may also be evaluated during a weathering test. For all accelerated testing, a primary concern is how well the test compares to what happens in the actual end use environment of a material. This is often called a correlation factor.

与材料最终使用环境中实际发生的情况相符,并称之为相关系数。该系数与材料使用寿命的评估密切相关,这正是所有老化试验的最终目的。不幸的是,任何材料都没有公认的相关系数,大部分专家认为,相关(或加速)系数只能通过试验取得。

导致材料降解的三大气候因素为:日光辐射、水(湿度)和温度。但必须明白的是,这不仅是需要“多少”辐射、“多少”湿度、和“多少”温度才能破坏一种材料的问题。事实上,光的质量(或光源)是设计和评估老化试验中一个极其重要的因素。与水的接触也分为不同的形式或阶段,这些不同将导致不同的降解过程。温度的冷热循环会产生机械应力,特别是对于复合材料,与长期高温作用相比,会产生更多类型的降解。温度、湿度和辐射的共同作用,使气候老化试验的研究和预测变得极端困难。

日光辐射

地球上的日光通常分为三个主要波段。根据 CIE 出版物 85 的定义,名义日光是由 295 nm 至 3000 nm(1×10^{-9} m)波长的辐射组成。295 nm 至 385 nm 的波长为日光光谱的紫外(UV)部分,占据了总能量的 4 % - 7 %。光谱 UV 部分一般又分为 UV - A(315 nm - 385 nm)和 UV - B(280 nm - 315 nm)。大气平流层的臭氧吸收作用基本上已将所有低于 295 nm 的辐射能量排除。可见辐射(肉眼能看见的辐射)在 385 nm - 780 nm 之间,约占整个日光光谱的 45 %。几乎太阳辐射的一半包含在日光光谱 780 nm 以上的近红外(N - IR)部分。

进入地球日光的波长及各波段的比例随纬度、高度和大气状况的不同而变化。

This factor relates very closely with predicting service life, which is the ultimate goal of any weathering test. Unfortunately, no "universal" correlation factor exists for all materials, and most experts agree that correlation (or acceleration) factors can only be determined empirically.

The three main factors of weather that cause degradation to materials are solar radiation, water (moisture), and temperature. However, it must be understood that is not just a matter of "how much" radiation, "how much" moisture, and "how much" temperature is required to break down a material. In fact, the quality of the light (or light source) is an extremely important factor in the design and evaluation of weathering tests. Water contact may be in several forms or phases, and these different phases can contribute to different degradation processes. While the temperature of a material can significantly influence the rate of degradation, temperature cycling can cause mechanical stress, particularly in composite systems, which may cause more types of degradation than just the long durations of high temperatures. The synergistic effects of temperature with moisture and radiation make the study and predictability of weathering tests extremely difficult.

Solar Radiation

Terrestrial daylight is commonly separated into three main wavelength bands. According to CIE (Commission Internationale l'Eclairage) Publication 85, daylight nominally consists of wavelengths of radiation between 295 and 3000 nanometers (1×10^{-9} meters). Wavelengths between 295 and 385 nm are considered the ultraviolet (UV) portion of the solar spectrum, making up between 4 % - 7 % of the total energy. It is common practice to separate the UV portion of the spectrum into the UV - A (between 315 - 385 nm), and the UV - B (between 280 - 315 nm). Ozone absorption in the stratosphere essentially eliminates all radiant energy below 295 nm. Visible radiation (the radiation the human eye can detect) is between 385 and 780 nm, making up approximately 45 % of the solar spectrum. Nearly half of the radiation from the sun is contained in the near - infrared (N - IR) portion of the solar spectrum beyond 780 nm.

而且光谱的紫外和可见光部分的划分也视信息来源不同而有所不同。有些地方将 295 nm - 400 nm 视为紫外部分。尽管看起来有些琐碎,但必须明白,在计算户外或人工条件下的辐射曝露量时,295 nm - 385 nm 范围与 295 nm - 400 nm 之差可能超过 10 %,而这一差别对于材料使用寿命的准确评估可能极其重要。

光能随着太阳辐射波长的减小而增加。波长越短,所含能量越高,越有可能破坏油漆或涂料聚合结构中的化学键。随着化学结构的变化,材料的外观和物理性质也会发生变化,最后导致物理或化学降解。这就解释了为什么探讨材料降解最重要的部分是光谱中含较高能量的紫外部分。光化学是一门复杂的学科,但有两条重要原理必须牢记:

1、只有能够被某种材料吸收的波长才能对该材料产生影响;

2、只有当被吸收之能量足以破坏(或改变)化学键时才能发生光化反应。

这些原理是理解材料老化时发生的光化过程、并采取相应保护措施的基础。

直射和漫射

直射是指抵达地球而又未被任何大气成份所散射的辐射能。为了方便辐射量的测定,它被定义为在正对太阳 6°视野范围内的辐射能。漫射是指被大气散射后的辐射能,因此 180°平面内从各个角度(非直射角)抵达曝露表面。从而可以假设,对于一个曝露水平表面,既接收日光直射,又接收漫射。人们有时称之为日光总辐射。正如我们稍后将会探讨的,在自然条件下,一般

The cut - on wavelength of terrestrial sunlight and the percentages of each wavelength band reported will vary slightly depending on latitude, altitude, and atmospheric conditions. Also, the defined break between the UV and visible portions of the spectrum may be different depending on the source of the information. Some consider the UV portion of the spectrum to be between 295 - 400 nm. While this may be considered a trivial point, it must be understood when calculating radiant dosages for exposure, whether in outdoor or artificial conditions. The variance between the 295 - 385 range and 295 - 400 may be more than 10 %, which could be extremely important when attempting to predict service life estimations for a material.

Photon energy increases with decreasing wavelengths of solar radiation. These shorter wavelengths may contain enough energy to break chemical bonds in the polymeric structure of a paint or coating. As the chemical structures change, the appearance and physical properties of a material will change, resulting in physical or chemical degradation. This explains why the higher energies contained in the UV portion of the spectrum are the most important for discussion of material degradation. While photochemistry is a complex subject, there are two important laws that must be remembered:

1) A material may only be affected by the wavelengths of radiation it will absorb, and

2) Photochemical changes can only occur if the radiant energy absorbed is great enough to break (or alter) chemical bonds.

These concepts serve as the foundation for understanding the photochemical processes that occur as a material is being weathered, and more importantly, how to protect materials from these processes.

Direct And Diffuse Radiation

Direct radiation is radiant energy that reaches the earth's surface without being scattered by any component of the atmosphere. For radiometry measurements, this is defined as radiant energy within a 6° field of view of the sun itself. Diffuse radiant energy is radiation that has been scattered by the atmosphere, and therefore reaches exposed surfaces at all angles (that are not defined as direct) above a 180° plane. It can therefore be assumed that for an ex -

会将曝露试样倾斜放置,以增加所接收的日光辐射量,或更好地仿真最终使用条件。在这些条件下,试样表面仍然接收先前提到的直射和漫射能量。另外,还有一部分地球表面反射的入射能(有时称之为反射能)也会抵达试样表面。地球表面反射能的多少取决于地面覆盖物。山岩、沙滩或石粒所反射的辐射能比草地要多得多。水面或雪地反射的辐射能更多。

抵达地表的直射和漫射能,受大气状况影响的程度非常大。水汽(湿度)和污染会增加漫射分量所含的辐射能。沙漠地带(如亚利桑那中部)的辐射能中直射分量的比例要高得多。这是因为沙漠地带的湿度比亚热带地区如佛罗里达南部要小得多。通过对比发现,污染越高的地区其直射能量越低。日光总辐射量(包括日光光谱的所有部分)与仅仅是紫外部分的直射分量也有所不同。波长越短,越容易被散射。因此,直射分量中的紫外部分永远少于总日光辐射量中的紫外部分。

直射和漫射能量的探讨在对于确定某一特定气候下的曝露角度非常重要。由于亚热带气候(如南佛罗里达)较高的湿度,在晴天约有 50 %的紫外辐射是漫射。佛罗里达的很多日子并非晴天,这会导致辐射中漫射分量所占比例的进一步增加。结果为了增加日光辐射量,在亚热带气候,如南佛罗里达,曝露试样应以接近水平的角度(如 5°)放置。相反,在沙漠气候如亚利桑那中部,直射分量中紫外辐射能量的比例较大(多达 75 %),这意味着一年中大部分辐射能量会抵达曝露场中以接近纬度角度放置的试样。

posed horizontal surface, both direct and diffuse solar radiation is received. This is sometimes referred to as total, or global, solar radiation. As we will discuss later, it is common to expose specimens in natural conditions with some kind of tilt, that will increase solar radiation received, or better simulate end - use conditions. Under these conditions, the surface of a specimen still receives the direct and diffuse radiation as discussed previously. In addition, there is percentatage of incident radiation that reflects off the earth's surface (sometimes referred to as albedo radiation) that also reaches the surface of a specimen. The amount of radiation reflected off the earth's surface is dependent upon the ground covering. Bare rocks, sand or gravel will reflect much more radiant energy than a grass - covered surface. Water or snow will reflect an even greater amount of radiant energy.

The ratio between direct and diffuse energy reaching the earth's surface is strongly influenced by atmospheric conditions. Water vapor (humidity) and pollution will increase the amount of radiant energy found in the diffuse component. A desert location (such as centralArizona) has a much higher percentage of radiant energy in the direct component. This occurs because there is much less humidity in the desert than in a subtropical environment such as south Florida. By contrast, a site with higher levels of pollution dramatically drops the amount of direct radiant energy. There is also a difference in direct component between total solar radiation (including all regions of the solar spectrum) and the UV only. Shorter wavelengths of radiation are more likely to be scattered. Therefore, the percentage of UV in the direct component will always be less than total solar radiation.

The discussion of direct and diffuse radiant energy is important when considering exposure angles in a specific climate. Because of the high humidity in a subtropical climate such as south Florida, about 50 % of the UV radiation is diffuse on clear days. Many days in Florida are not clear, which will result in even a greater percentage of radiation in the diffuse component. As a result, to maximize solar radiation, specimens in a subtropical climate such as south Florida should be exposed at an angle close to horizontal, such as 5°. Conversely, a desert climate such as central Arizona would have a greater percentage of

人们通常使用两种辐射仪测量日光辐射。测量总日光辐射量(紫外、可见和红外)的称作总日射表。它们以 180°视野范围测量辐射量。另外一种辐射仪称为 TUVR - 总紫外辐射仪。由于直射和漫射分量的存在,不同曝露角度接收到不同的辐射能量。因此我们一般以与正常曝露角度相应的角度测量辐射量。

既然讨论到辐射能的测量,就有必要对测量和计算曝露试样所接收到的辐射能的一些术语加以定义。上文所提到的辐射仪用于测量所接收辐射量的瞬间等级,称为辐照度。辐照度可以定义为单位表面积上所穿过的辐照通量,通常表示为 W/ m^2。对于这一参数,有必要指出测量或计算时的光谱范围,如 295 nm - 3000 nm(总日光)或 295 nm - 385 nm(总紫外)。如果将注意力转向较窄的光谱范围,那么得到的是光谱辐照度,测量单位为 W/ m^2/ nm。对于老化试验,作为(光谱)辐照度时间积分量的辐射曝露量(单位为 J/ m^2)的概念可能更为重要。大部分辐射曝露量都以 KJ/ m^2 或 MJ/ m^2 为单位加以测量。有时也使用另外一个测量单位 - 兰勒,但它只适用于总日光辐射,不适用于人造光源。1 兰勒等于每平方厘米 1 克卡。1 兰勒等于 0.04184MJ/ m^2 (295 nm - 3000 nm)。在定义上,1“紫外兰勒”不存在。

温度

曝露在日光辐射下的材料温度对辐射作用有显著影响。尽管并非每种材料都是如此(或在测量物理或外观变化时观察不

UV radiant energy in the direct component (as much as 75 %). This would mean that the most radiant energy over the course of one calendar year would be on specimens that were near the latitude angle of the exposure site.

There are two types of radiometers commonly used to measure solar radiation. Those that measure total solar radiation (UV, Visible, and IR) are called pyranometers. They measure radiation in a 180° field of view. The other type of radiometer shown is a TUVR, which stands for Total UltraViolet Radiometer. Because of the direct and diffuse components, different exposure angles will receive varying amounts of radiant energy. Therefore, we commonly measure radiation at angles that correspond to common angles of exposure.

During our discussion of the measurement of radiant energy, it is necessary to define some terms used in measuring and calculating radiant energy dosages received by specimens on exposure The radiometers mentioned above are used to measure instantaneous levels of radiation received, called irradiance. Irradiance can be defined as the amount of radiant flux striking a defined surface area, commonly expressed in W/ m^2. For this parameter, it is necessary to indicate the spectral range in which the measurements were taken or for which the values were calculated, such as 295 - 3000 nm (total solar) or 295 - 385nm (total UV). If we turn our attention to narrow wavelength intervals, then we obtain the spectral irradiance, measured in W/ m^2/ nm. For weathering tests, the concept of radiant exposure, which is the time integral of (spectral) irradiance, may be more important, stated in J/ m^2. Most radiant exposure dosages are measured in either kJ/ m^2 or MJ/ m^2. Another unit of measurement, the langley, is sometimes used, however it can only be applied to total solar radiation and not artificial light sources. A langley is equal to one gram - calorie per square centimeter. One langley is equal to 0.04184 MJ/ m^2 (295 - 3000nm). By definition, a "langley of UV" does not exist.

Temperature

The temperature of materials exposed to solar radiation has a significant influence on the effect of the radiation. The destructive effects of light are usually accelerated at elevated temperatures as a result of the

到) ,但二次反应速度增加的结果 ,是导致日光的破坏作用在温度升高下被加速 ,每升温 10 摄氏度 ,反应速度就会翻倍。在较高温度下 ,分子的活性较大。在高温下发生的反应 ,在较低温度时速度很慢 ,或根本不发生。

在日光照射下 ,物体表面温度一般比周围空气温度高得多。日光的吸收率与颜色的关系密切 ,从白色材料的 20 %到黑色材料的 90 %;因此不同颜色的材料会达到不同的曝露温度。由于塑料基片的导热性和热容量一般较低 ,因此油漆或涂层表面可以达到比材料本身高得多的温度。因此 ,曝露材料的表面温度很大程度上受取决于材料颜色的红外辐射吸收量的影响 ,而环境空气温度及其变化在材料降解过程中起着一定作用。

昼夜和季节温度变化是自然气候老化中不可或缺的因素。温度周期可以导致机械应力 ,特别是对于由不同温度膨胀系数材料组成的合成系统。温度及其冷热周期与水的各种形式密切相关。降温引起水分在材料表面凝聚为露珠 ,升温产生蒸发 ,突然降雨导致热应力。最后 ,热量和所吸收日光辐射量的共同作用造成聚合物的组成元素(如增塑剂)从系统中挥发出去。以仪表板系统的曝露为例。覆盖在仪表板表面的乙烯树脂面膜必须含有使聚合物柔软的增塑剂 ,以使其弯曲 ,并适应仪表板的板形。曝露的结果 ,会使该添加剂从聚合物中渗透出去 ,并沉积在曝露箱的盖板玻璃上。随着时间的推移 ,这一挥发过程会导致乙烯树脂面膜变脆。极端的冷热循环会导致材料的物理性降解 ,比如断裂。

increased rate of secondary reactions, with reaction rates approximately doubling with each 10 (C rise, although this may not be true of all materials (or be seen when measuring physical or appearance changes). At high temperatures molecules have greater mobility. Reactions may take place at higher temperatures that occur at a very low rate or not at all at lower temperatures.

In the presence of sunlight the surface temperature of an object is usually considerably higher than the temperature of the air. Solar absorptivity is closely related to color, varying from about 20 % for white materials to over 90 % for black materials; thus samples of different colors will reach different on - exposure temperatures. Because the thermal conductivity and heat capacity of plastic substrates are generally low, much higher temperatures can be obtained on the painted or coated surface than in the bulk of the material. Therefore, the surface temperatures of the exposed materials is affected largely by infrared radiation absorption which varies by material color, and the ambient air temperature and its fluctuations during exposure play a role in material degradation rates.

Diurnal and seasonal temperature variations are inherent to natural weathering conditions. Temperature cycling can cause mechanical stress, particularly in composite systems consisting of materials with widely differing temperature coefficients of expansion. Temperature and its cycles are also closely linked with water in all of its forms. Drops in temperature can cause water to condense on the material as dew, a rise in temperature causes evaporation, and sudden rainfall can cause thermal stress. Finally, the combination of heat and absorbed solar radiation may cause constituents in a polymer (such as a plasticizer) to volatilize out of the system. One example of this relates to the exposure of instrument panel systems. The vinyl skin covering an instrument panel must contain plasticizers that make the polymer pliable and bendable around the shape of the panel. As a result of exposure, this additive may exude out from the polymer and be deposited on the cover glass of the exposure box. In time, this volatilization process causes the vinyl skin to become brittle. Extreme temperature cycling may result in physical degradation such as cracking.

水(湿度)

水份能以不同程度的形式沉淀或融入曝露的油漆或涂层中。随着环境温度的变化,水份以不同的形式存在,如湿、露、雨、雪、霜或雹等。水份还能够对材料产生物理或化学作用。

合成材料及涂层受潮的过程是一个受扩散作用控制的吸收水份的过程。这一吸水过程会导致表面体积膨胀,从而在内部较干的层面上产生机械应力。随后的干燥过程开始逐渐脱水,使材料表面产生体积收缩,而内部较湿的层面会抵抗收缩,从而使材料表面出现应力裂纹。吸水和脱水状态的交替出现会使材料产生应力碎裂。由于其内部扩散率的原故,有机材料可能需要几周甚至几个月时间才能达到水份平衡状态。

另外一种物理作用是结冰 - 解冻过程。因为水在结冰时膨胀,所以材料中,特别是受潮后镀膜硬质板系统中的水份会产生膨胀和应力,从而导致涂膜的撕开、断裂或剥落。降雨会周期性地冲洗材料表面的尘埃和污秽,同时由于降雨频率的不同,也可能产生长期的老化作用。当雨水冲击曝露表面时,蒸发作用使试样表面迅速降温,这会导致材料的进一步物理降解。冰雨或冰雹在降落时携带强大动能,也会导致涂层或油漆的物理降解。

从各种角度来看,以 H^+ 和 OH^- 形式存在的湿度,在气候老化试验过程中起非常重要作用。在二氧化钛加色涂层和聚合物的粉化过程中,就可以观察到湿度的化学作用。尽管无论有无氢或氢离子的化学参与,聚合物表面都会发生光化反应,但通过化学反应吸入的水份的循环作用会加强(甚至导

Water (Moisture)

Moisture can become deposited or incorporated in a paint or coating on exposure in different phases. Moisture can take the form of humidity, dew, rain, snow, frost or hail, depending on the ambient temperature. Moisture can have both physical and/or chemical effects on materials as well.

Water absorption by synthetic materials and coatings from humidity and direct wetness is a diffusion controlled process. This hydration of the surface layers produces a volume expansion that places mechanical stress on the dry subsurface layers. A following drying out period signifies a desorption of water. Drying out of the surface layers will lead to a volume contraction; the hydrated inner layers resist this contraction, leading to surface stress cracking. This oscillation between hydrated and dehydrated states may result in stress fractures. Because of diffusion rates in organic materials, it may take weeks or months to reach moisture equilibrium.

The freeze - thaw cycle is another physical effect. Because water expands when it freezes, absorbed moisture in a material, especially in coated hardboard systems, causes expansion and stresses that cause peeling, cracking, and flaking in the coating. Rain, which periodically washes dirt and pollutants from the surface, has an effect upon the long - term rate of deterioration that is determined by its frequency. When rain strikes an exposed surface, the evaporative processes cool the surface of a specimen down rapidly, which may cause further physical degradation to a material. Frozen rain, or hail, may also cause physical degradation to coatings or paint because of the strong kinetic energy associated with its impact.

Moisture, as H^+ and OH^-, is important in weathering from several points of view. The chemical effects of moisture can be viewed in the chalking of titanium dioxide (TiO_2) pigmented coatings and polymers. The structure of a polymer is changed photochemically, either with or without chemical participation of hydrogen or hydroxide ions, but the actual physical release of material on the surface is enhanced, if not caused, by the cyclic action of chemically absorbed moisture. Moisture may also act as a pH adjuster, especially when considering the effects of acid rain, which may cause an etching of many paints and coatings.

致) 表面材料的实际物理释放过程。湿度有时也会作为 pH 调节剂,特别是在考虑酸雨作用时,酸雨对多种油漆和涂层有侵蚀作用。

在探讨光照、湿度和温度如何对曝露试样产生作用时,必须明白一个重要的事实,那就是材料降解是这些因素共同作用的结果。例如,只在某一种因素中曝露的材料,其降解结果很难与在户外条件下、由三种因素共同作用的曝露材料的降解结果看上去有任何相似之处。

气候或大气中二级因素的降解作用也不可低估。大气中的气体和污染物,特别是在酸雨形式下,会引发完全不同的新的反应。在高度工业化地区,由于酸性气体尘埃无法大面积转移,酸雨已成为很多材料老化的首要因素。尘埃粒子本身也会对老化过程产生非交互式影响。这些影响包括,有紫外吸收作用的气体尘埃或油粒等会将紫外部分从对材料的辐射中过滤掉,以及令人讨厌的、半永久性“漆粒”被光聚合在曝露材料表面等。霉菌等微生物和植物媒介也可能对材料降解发挥重要作用,特别是在热带和亚热带气候,但大部分时候人们在讨论气候老化时都会将之忽略。一般自然现象不会直接导致老化过程的发生,但是厄尔尼诺、拉尼娜现象以及火山活动等重大自然现象可以通过改变气候条件来改变降解速度。

气候

看看世界气象图就会发现,随着纬度、气候模式、地形和地理特征的不同,存在各种各样的气候。世界气象组织(WMO) 在世界范围内划分了七种主要气候。对老化试验来说,两种最重要的气候(或典型气候) 为亚热带气候,如南佛罗里达,以及沙漠气候,如墨西哥北部和亚利桑那中部。有时也在其它气候中进行特殊应用的曝露

The important fact to understand when considering the roles that light, moisture, and temperature play on an exposed specimen is that these factors work together to degrade materials. For example, if a material is exposed only to one of these factors, it is very unlikely that the degradation incurred will look anything like that of a material exposed to outdoor conditions, where all three of these factors play a role in the degradation processes.

One must not underestimate the secondary effects of weather or the atmosphere that may cause degradation. Gases and pollutants in the atmosphere, especially in the form of acid rain, may cause entirely new reactions to be initiated. In highly industrialized areas, where long range transport of airborne acidic particles is not a consideration, acid rain is the primary element driving the weathering process affecting a wide range of materials. Dirt and dust may have non - interactive effects on the weathering process itself. These include the screening of ultraviolet radiation from the materials by ultraviolet - absorbing dirt, airborne grease, etc., and undesirable, semi - permanent "varnishes" that may be photo - polymerized on the surface of exposed materials. Mold, mildew and other microbiological and botanical agents may play a significant role in material degradation, particularly in tropical and subtropical climates, although they may not be generally thought of as weathering factors. Acts of Nature may not directly cause weathering processes to occur. However, Acts of Nature such as El Ni ? o, La Ni ? a, and volcanism may affect climatic conditions, which in turn result in different degradation rates.

Climate

In viewing a climatological map of the world, it is obvious that depending on latitude, weather patterns, topographical and geographical features, etc. that a wide range of climates exist. The World Meteorological Organization (WMO) has identified seven major climates around the world. The two most important climates (or benchmarks) for weathering tests, are the subtropical environment, such as south Florida, and the desert environment, such as northern Mexico and the central Arizona. Other climates, such as polar, tropical rain forests, humid meso thermal, humid micro thermal, and undifferentiated highlands, are sometimes used as weathering test sites for specific applications. In most cases, the subtropical and desert environments

老化试验,如极地气候、热带雨林气候、温带气候、寒带气候和高地气候。大部分情况下,亚热带和沙漠气候是世界公认的、材料最终使用环境中最严酷的户外曝露气候。

“为何要在典型气候中进行试验?”

最初在南佛罗里达潮湿的亚热带气候进行曝露试验是早在 19 世纪 20 和 30 年代。当时,油漆行业越来越关心他们产品的抗气候老化能力,使得这一地区成为历史上重要的户外试验区。最大的独立试验站位于当地内陆区域,因此不受海岸腐蚀性气候的影响。在亚利桑那中部的沙漠环境中,可以观察到较高的极端气温。对于汽车内饰材料来说,这是世界上最具破坏性的气候。所有曝露试验站均远离大城市,以降低工业或城市污染的影响。

无论亚热带或沙漠气候,均存在季节性的季节变化。变化的大小取决于曝露的角度和气候,尤其是大气状况,不同的大气状况会导致直射与漫射辐射量比例的不同。由于在沙漠环境如亚利桑那中部,直接辐射量的比例很高,因此在当地成 5°角曝露的季节性变化最大。而在南佛罗里达进行的 5°角曝露则相对稳定,这是因为 UV 部分被水蒸汽散射的缘故。以纬度角度(南佛罗里达 26°度,亚利桑那中部 34°)进行曝露的结果的季节变化最小,因为全年太阳光都几乎与试样表面成直角。对于亚利桑那中部,最佳的曝露角度是 45°角,因为直射分量及总辐射量较高;而由于辐射量的漫射,在 45°角时,南佛罗里达的 UV 能量又较少。

表 2(见下文)显示了在佛罗里达和亚利桑那的常用曝露角所接收到的平均辐射能量。尽管中部亚利桑那的曝露接收到较高的 UV 辐射能量,但也不能因此假设该

are recognized around the world as the most severe climates for materials exposed outdoors in their expected end - use application.

"Why Test In These Benchmark Climates ?"

Exposures in the moist, subtropical climate of south Florida were first conducted in the 1920s and 1930s as the paint industry became more and more concerned about the weathering resistance of their products, making this area an important historical outdoor testing region. The largest independent test sites are located in areas that are considered an inland location, and therefore do not see any adverse corrosive coastal effects. In the desert environment of central Arizona higher extreme temperatures are seen, which is known to cause high stresses to automotive interior materials than any other climate of the world. Independent test sites are also located in areas outside of major metropolitan areas to minimize industrial or urban pollution.

Seasonal variability exists in both subtropical and desert environments. The amount of variation will depend on the exposure angle and climate, especially the atmospheric conditions that cause different ratios of direct and diffuse radiation. Because of the high percentage of direct radiant energy in a desert environment such as central Arizona, there is a high seasonal variation for 5° exposures at that location. Exposures conducted at 5° in south Florida are relatively constant in UV due to the scattering by water vapor. Exposures conducted at the latitude angles (which are 26° in south Florida and 34° in central Arizona) result in minimized seasonal variations, because the sun is closer to the perpendicular of these surfaces over the entire year. A 45° exposure is optimal for central Arizona due to the high direct beam component, and overall, south Florida has less UV at 45° due to the diffusing of radiant energy.

Table 1 (see below) shows the average annual radiant energy received at common exposure angles in Florida and Arizona. Although higher amounts of UV radiant energy are received by exposures in central Arizona, one should not assume that this is a harsher climate to expose materials, because of the dramatic increase in moisture received in south Florida. This addition of moisture has shown to be very effective in the degradation of paints and coatings and, in general,

气候对曝露材料来说更为恶劣,因为在南佛罗里达曝露的湿度大得多。湿度的增加对油漆和涂层的降解影响极大,一般来说,在南佛罗里达对油漆和涂层进行的试验比在亚利桑那中部沙漠多得多。但是,亚利桑那中部的干燥气候,再加上剧烈的昼夜冷热循环,已证明对汽车内饰材料和其它聚合物更为有效。但很普遍的是,许多公司既在亚热带,又在热带(和其它气候)进行材料曝露试验,因为这些极端气候会产生不同类型的降解过程。

气候老化试验基地要求监控和记录所有气候学主要资料。WMO 规定了用于放置环境温度和相对湿度仪器的试验间的要求。试验间必须要有双重屋顶,换言之,必须要用两张木板盖住试验间屋顶,木板之间留一较小气隙。这是为了防止直接辐射能量冲击试验间的屋顶。试验间必须自然通风,使气流能够穿过。另外,试验间必须离地一定高度,以防阳光反射影响间内温度或相对湿度。风速计、风向计、温湿度传感器、雨量计、潮湿时间传感器,以及专用的辐射仪器均与中央资料收集系统相联,以实现主要气候参数的持续监控。

人们已广泛接收采用黑板温度装置控制人工气候老化仪内部温度的方法。为了研究与户外曝露温度的相关性,也经常要测量黑板(和白板)温度。由于黑色油漆对日光的高吸收性,这些装置被用作温度参考物,它们的温度被认为是曝露试样能达到的最高温度。这些黑板一般为薄金属板(不锈钢或经过防腐处理的铝板),并涂有一层高质量黑色底漆。标准组织正在起草界定黑漆特性的规范,并正在开发监控和安装黑板上测温组件的方法。

more paints and coatings are tested to this environment than the desert of Arizona. However, the dry climate of central Arizona, in conjunction with the dramatic diurnal temperature cycling, has proven to be very effective in the degradation of interior automotive materials and many other polymers. It is common that many companies will test their materials in both the subtropical and desert climates (and others, for that matter) because the effects of these extremes will result in different types of degradation processes.

Weathering test fields are required to monitor and store all major climatological data. The enclosure used to house the ambient temperature and relative humidity devices is specified by WMO. The enclosure must have a double roof; in other words, there is essentially two pieces of wood over the top of the enclosure, with a small air space between. This is to inhibit any direct radiant energy from striking the roof of the enclosure. The enclosure must also be naturally aspirated to allow wind to flow through the housing. Also, the enclosure must be mounted a specific height above the ground so the reflected solar radiation does not affect either the ambient temperature or relative humidity. Wind speed and wind direction sensors, relative humidity sensors, rain gauges, wet time sensors, and special radiometric devices are all connected to a data acquisition system for continuous monitoring of the major weather parameters.

It is widely accepted that black panel temperature devices are used to control temperatures inside artificial weathering instruments. In order to study some kind of correlation to temperatures reached in outdoor exposures, black panel (and white panel) temperatures are also commonly measured. Because of the high solar absorptance of the black paint, these devices are used as a reference temperature, that may be thought of as the highest temperature that specimens on exposure may reach. These panels are usually thin metal (stainless steel or anodized aluminum) and are coated with a primer and a quality black paint. Standards organizations are in the process of writing a specification to define the properties of the paint, as well as developing methods to monitor and attach temperature - measuring devices to the panel.

表 1　沙漠与亚热带气候老化因素的比较

参　　数	亚利桑那中部沙漠气候	南佛罗里达亚热带气候
以试验站纬度角度曝露的平均总 UV 辐射量(295 nm - 385 nm) ,MJ/ m^2	350	280
平均年相对湿度	30 %	74 %
平均降雨量	25 cm	188 cm
平均年潮湿时间	525 h	4500 h
平均最高夏季(5 - 9 月)气温	39 ℃	34 ℃

表 2　平均年辐射能量　MJ/ m^2

测量角度	佛罗里达(北纬 26°)	亚利桑那(北纬 34°)
南 5°	310	360
纬度角(南)	280	350
南 45°	290	330
南 90°	180	200

注:以上参数是在 ATLAS 气候老化服务集团基地测得的 5 年(1994 - 1998) 平均值。

参考文献:

[1]　George Wypych. 材料气候老化手册,第二版,1995. [Z].

[2]　Larry Bond,等. 气候老化技术手册,1995. [Z].

[3]　Allen Zielnik. 气候及加速试验简介 [Z].

Table 1 Weathering Parameter Comparison - Desert vs. Subtropical Climates

Parameter[1]	Desert Climate of central Arizona	Subtropical Climate of South Florida
Average Total UV Radiant Energy (295 - 385 nm) at site latitude	350 MJ/ m^2	280 MJ/ m^2
Average annual % R. H.	30 %	74 %
Average rainfall	10" (25 cm)	74" (188 cm)
Average annual wet time	525 Hours	4500 Hours
Average summer (May - Sept.) maximum ambient temperature	39 ℃ (102 ℉)	34 ℃ (93 ℉)

Table 2 Average Annual Radiant Energy

Angle of Measure	Florida (26 °N Latitude)	Arizona (34 °N Latitude)
5 ° South	310 MJ/ m^2	360 MJ/ m^2
Site latitude (South)	280 MJ/ m^2	350 MJ/ m^2
45 ° South	290 MJ/ m^2	330 MJ/ m^2
90 ° South	180 MJ/ m^2	200 MJ/ m^2

[1] Five - year averages between 1994 - 1998 measured at Atlas Weathering Services Group sitesBibliography

[1]　Dr. George Wypych, author of Handbook of Material Weathering, 2nd Edition, ChemTec Publishing, Toronto - Scarborough, Ontario, Canada, 1995. [Z].

[2]　Larry Bond, Gene Zerlaut, Jack Martin, Kelly Hardcastle, and other associates of the Atlas Weathering Services Group, authors of The Weathering Technology I Manual, 1995 edition. [Z].

[3]　Allen Zielnik, General Manager, Polymer Evaluation Products, Atlas Electric Devices Co. for his manuscript Introduction to Weathering and Accelerated Testing. [Z].