PLASTICS ENGINEERED PRODUCT DESIGN pdf

1: RT Plastics â€“ Engineering Design Analysis and Process

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Practically all RTPs with short glass fibers are injection molded at very fast cycles, producing high performance products in highly automated environments. RPs can be characterized by their ability to be molded into either extremely small to extremely large structurally loaded shapes well beyond the basic capabilities of other materials or processes at little or no pressure. In addition to shape and size, RPs possess other characteristics that make them very desirable in design engineering. The other - 1 Overview 17 characteristics include cost reduction, ease of fabrication, simplified installation, weight reduction, aesthetic appeal, and the potential to be combined with many other usehl qualities. Their products have gone worldwide into the deep ocean waters, on land, and into the air including landing on the moon and in spacecraft. The form the RP takes, as with non-reinforced plastics, is determined by the product requirements. It has no inherent form of its own; it must be shaped. This provides an opportunity to select the most efficient forms for the application. Shape can help to overcome limitations that may exist in using a lower-cost material with low stiffness. As an example underground he1 tanks can include ribs to provide added strength and stiffness to the RP orientation in order to meet required stresses at the lowest production cost. The formability of these products usually leads to one-piece consolidation of construction products to eliminate joints, fasteners, seals, and other potential joining problems. As an example, formed building fascia panels eliminate many fastenings and seals. Examples of design characteristics gained by using RP materials are presented as follows: Thermal Expansions Nonreinforced plastics generally have much higher coefficients of linear thermal expansion CLTE than conventional metal, wood, concrete, and other materials. CLTEs also vary significantly with temperature changes. There are RPs that do not have these characteristics. With certain types and forms of fillers, such as graphite, RPs can eliminate CLTE or actually shrink when the temperature increases. Ductilities Substantial yielding can occur in response to loading beyond the limit of approximate proportionality of stress to strain. This action is referred to as ductility. Most RPs do not exhibit such behavior. However, the absence of ductility does not necessarily result in brittleness or lack of flexibility. For example, glass fiber-TS polycster Ws do not exhibit ductility in their stress-strain behavior, yet they are not brittle, have good flexibility, and do not shatter upon impact. TS plastic matrix is brittle when unreinforced. However, with the addition of glass or other fibers in any orientation except parallel, unidirectional, the fibers arrest 18 Plastics Engineered Product Design crack propagation. This RP construction results in toughness and the ability to absorb a high amount of energy. Because of the generally high ratio of strength to stiffness of RPs, energy absorption is accomplished by high elastic deflection prior to failure. Thus ductility has been a major factor promoting the use of RPs in many different applications. Toughness The generally low-specific gravity and high strength of reinforcement fibers such as glass, aramid, carbon, and graphite can provide additional benefits of toughness. For example, the toughness of these fibers allows them to be molded into very thin constructions. Each fiber has special characteristics. For instance, compared to other fiber reinforcements, aramid fibers can increase wear resistance with exceptionally high strength or modulus to weight. For injection molded products they can be held to extremely close tolerances of less than a thousandth of an inch 0. RPs can sigmficantly reduce or even eliminate this dimensional change afier molding. Working with crystalline RTPs can be yet more complicated if the fabricator does not understand their behavior. Crystalline plastics generally have different rates of shrinkage in the longitudinal, melt flow direction, and transverse directions. In turn, these directional shrinkages can vary significantly due to changes in processes such as during injection molding IM. Tolerance and shrinkage behaviors are influenced by factors such as injection pressure, melt heat, mold heat, and part thickness and shape. The amorphous type materials can be easier to balance. Compounds Commercial RP compounds are available in several forms: There are RTP - 1 Overview 19 elastomeric materials that provide special engineered products such as conveyor belts, mechanical belts, high temperature or chemical resistant suits, wire and cable insulation, and architectural designed shapes. Common categories of RP compounds are reviewed. PrepreBs Preimpregnated materials usually are a compound of a reinforcement and a hot melt or solvent system. Prepreg also includes wet systems without solvent using TS polyester. They are stored for use at a latter time either in-house or to ship to a fabricator. The plastic is partially cured, B-stage, ready-to-mold material in web form that may have a substrate of glass fiber mat, fabric, roving, paper, cotton cloth, and so forth. With proper temperature storage conditions, their shelf life can be controlled to last at least 6 months. It is usuaUy a glass fiber-reinforced TS polyester resin compound in sheet form. The sheet can be rolled into coils during its continuous fabricating process. A plastic film covering, usually polyethylene, separates the layers to enable coiling and to prevent contamination, sticking, and monomer evaporation. This film is removed before the SMC is charged into a mold, such as a matched-die or compression mold. They are used to enhance the performance or processing of the material. Glass fibers are usually chopped into lengths of 12 mm 0. The usual ratio is based on performance requirements, processability, and cost considerations. This mixture, with the consistency of modeling clay, can be produced in bulk form or extruded in rope-like form for easy handling. BMC is commercially available in different combinations of resins, predominantly TS polyesters, additives, and reinforcements. They meet a wide variety of end-use requirements in high-volume applications where fine finish, good dimensional stability, part complexity, and good overall mechanical properties are important. They can also be injection molded in much the same way as other RTS compounds using ram, ram-screw, and, for certain BMC mixes, conventional reciprocating screw. The term elastomer developed with the advent of rubber-like synthetic materials. At room temperature all elastomers basically stretch under low stress to at least twice in length and snaps back to approximately the original length on release of the stress, pull, within a specified time period. The term elastomer is often used interchangeably with the term plastic or rubber; however, certain industries use only one or the other terminology. Different properties identifjr them such as strength and stiffness, abrasion resistance, oil resistance, chemical resistance, shock and vibration control, electrical and thermal insulation, waterproofing, tear resistance, cost-to-performance, etc. Examples include transportation tires, with their relative heat build-up resistance, and certain types vibrators. However, both synthetic TSE and TPE have made major inroads in product markets previously held only by natural rubber. Worldwide, more synthetic types are used than natural. The basic processing types are conventional, vulcanizable, elastomer, reactive type, and thermoplastic elastomer. PIast ic behaviors A knowledge of the chemistry of plastics can be used to help with the understanding of the performance of designed products. Chemistry is the science that deals with the composition, structure, properties and transformations of substances. It provides the theory of organic chemistry, in particular our understanding of the mechanisms of reactions of carbon C compounds. The chemical composition of plastics is basically organic polymers. They have very large molecules composed of connecting chains of carbon C , generally connected to hydrogen atoms H and often also oxygen 0 ,nitrogen N , chlorine Cl , fluorine F , and sulhr S. Thus, while polymers form the structural backbone of plastics, they are rarely used in pure form. The chemical and physical characteristics of plastics are derived from the four factors of chemical structure, form, arrangement, and size of the polymer. As an example, the chemical structure influences density. Chemical structure refers to the types of atoms and the way they are joined to one another. The form of the molecules, their size and disposition within the material, influences mechanical behavior. It is possible to deliberately vary the crystal state in order to vary hardness or softness, toughness or brittleness, resistance to temperature, and so 22 Plastics Engineered Product Design on. The chemical structure and nature of plastics have a significant relationship both to properties and the ways they can bc processed, designed, or otherwise translated into a finished product. As a result of morphology differences among polymers, great differences exist in mechanical and other properties as well as processing plastics. Knowledge of molecular size and flexibility explains how individual molecules behave when completely isolated. However, such isolated molecules are encountered only in theoretical studies of dilute solutions. In practice, molecules always occur in a mass, and the behavior of each individual molecule is very greatly affected by its intermolecular relationships to adjacent molecules in the mass. Three basic molecular properties affect processing performances, such as flow conditions, that in turn affect product performances, such as strength or dimensional stability. Densities Absolute density d is the mass of any substance per unit volume of a material. Both d and s. Like density, specific gravity is used extensively in determining product cost vs. It is frequently used as a means of setting plastic specifications and monitoring product consistency. In crystalline plastics, density has a direct effect on properties such as stiffness and permeability to gases and liquids. Changes in density may also affcct other mechanical properties. The term apparent density of a material is sometimes used. It is the weight in air of a unit volume of material including voids usually inherent in the material. Also used is the term bulk density that is commonly used for compounds or materials such as molding powders, pellets, or flakes. Bulk density is the ratio of the weight of the compound to its volume of a solid material including voids. Atomic weight is the relative mass of an atom of any element based on a scale in which a specific carbon atom carbon is assigned a mass value of For polymers, it represents a measure of the molecular chain length. MW of plastics influences their properties. With increasing MW, polymer properties increase for abrasion resistance, brittleness, chemical resistance, elongation, hardness, melt viscosity, tensile strength, modulus, toughness, and yield strength. Decreases occur for adhesion, melt index, and solubility. Adequate MW is a fimdamental requirement to achieve desired properties of plastics. If the MW of incoming material varies, the fabricating and fabricated product performance can be altered.

2: Product Design - Melet Plastics Inc

This book, written by two very experienced plastics engineers, provides copious information on the materials, fabrication processes, design considerations and plastics performance, thus allowing informed decisions to be made by engineers.

This RP construction results in toughness and the ability to absorb a high amount of energy. Because of the generally high ratio of strength to stiffness of RPs, energy absorption is accomplished by high elastic deflection prior to failure. Thus ductility has been a major factor promoting the use of RPs in many different applications. The generally low-specific gravity and high strength of reinforcement fibers such as glass, aramid, carbon, and graphite can provide additional benefits of toughness. For example, the toughness of these fibers allows them to be molded into very thin constructions. Each fiber has special characteristics. For instance, compared to other fiber reinforcements, aramid fibers can increase wear resistance with exceptionally high strength or modulus to weight. For injection molded products they can be held to extremely close tolerances of less than a thousandth of an inch 0. RPs can significantly reduce or even eliminate this dimensional change after molding. 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Prepreg also includes wet systems without solvent using TS polyester. They are stored for use at a latter time either in-house or to ship to a fabricator. The plastic is partially cured, B-stage, ready-to-mold material in web form that may have a substrate of glass fiber mat, fabric, roving, paper, cotton cloth, and so forth. With proper temperature storage conditions, their shelf life can be controlled to last at least 6 months. A ready-to-mold material, SMC represent a special form of a prepreg. It is usually a glass fiber-reinforced TS polyester resin compound in sheet form. The sheet can be rolled into coils during its continuous fabricating process. A plastic film covering, usually polyethylene, separates the layers to enable coiling and to prevent contamination, sticking, and monomer evaporation. This film is removed before the SMC is charged into a mold, such as a matched-die or compression mold. Depending on product performance requirements, the SMC consists of additional ingredients such as low-profile additives, cure initiators, thickeners, and mold-release agents. They are used to enhance the performance or processing of the material. Glass fibers are usually chopped into lengths of 12 mm 0. The usual ratio is based on performance requirements, processability, and cost considerations. This mixture, with the consistency of modeling clay, can be produced in bulk form or extruded in rope-like form for easy handling. The extrudate type is called a "log" that is cut to specific lengths such as 0. BMC is commercially available in different combinations of resins, predominantly TS polyesters, additives, and reinforcements. They meet a wide variety of end-use requirements in high-volume applications where fine finish, good dimensional stability, part complexity, and good overall mechanical properties are important. The most popular method of molding BMCs is compression. They can also be injection molded in much the same way as other RTS compounds using ram, ram-screw, and, for certain BMC mixes, conventional reciprocating screw. In the past rubber meant a natural thermoset elastomeric TSE material obtained from a rubber tree, hevea braziliensis. The term elastomer developed with the advent of rubber-like synthetic materials. At room temperature all elastomers basically stretch under low stress to at least twice in length and snaps back to approximately the original length on release of the stress, pull, within a specified time period. The term elastomer is often used interchangeably with the term plastic or rubber; however, certain industries use only one or the other terminology. Different properties identify them such as strength and stiffness, abrasion resistance, oil resistance, chemical resistance, shock and vibration control, electrical and thermal insulation, waterproofing, tear resistance, cost-to-performance, etc. Examples include transportation fires, with their relative heat build-up resistance, and certain types vibrators. However, both synthetic TSE and TPE have made major inroads in product markets previously held only by natural rubber. Worldwide, more synthetic types are used than natural. The basic processing types are conventional, vulcanizable, elastomer, reactive type, and thermoplastic elastomer. A knowledge of the chemistry of plastics can be used to help with the understanding of the performance of designed products. Chemistry is the science that deals with the composition, structure, properties and transformations of substances. It provides the theory of organic chemistry, in particular our understanding of the mechanisms of reactions of carbon C compounds. The chemical composition of plastics is basically organic polymers. They have very large molecules composed of connecting chains of carbon C , generally connected to hydrogen atoms H and often also oxygen O , nitrogen N , chlorine C1 , fluorine F , and sulfur S. Thus, while polymers form the structural backbone of plastics, they are rarely used in pure form. The chemical and physical characteristics of plastics are derived from the four factors of chemical structure, form, arrangement, and size of the polymer. As an example, the chemical structure influences density. Chemical structure refers to the types of atoms and the way they are joined to one another. The form of the molecules, their size and disposition within the material, influences mechanical behavior. 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Also used is the term that is commonly used for compounds or materials such as molding powders, pellets, or flakes. Bulk density is the ratio of the weight of the compound to its volume of a solid material including voids. MW is the sum of the atomic weights of all the atoms in a molecule. Atomic weight is the relative mass of an atom of any element based on a scale in which a specific carbon atom carbon is assigned a mass value of For polymers, it represents a measure of the molecular chain length. MW of plastics influences their properties. With increasing MW, polymer properties increase for abrasion resistance, brittleness, chemical resistance, elongation, hardness, melt viscosity, tensile strength, modulus, toughness, and yield strength. Decreases occur for adhesion, melt index, and solubility. Adequate MW is a fundamental properties of plastics. If the MW fabricating and fabricated product greater the differences, the more during processing. The changes that occur MWD is basically the amounts of component polymers that make up a polymer Fig. Component polymers, in contrast, are a convenient term that recognizes the fact that all polymeric materials comprise a mixture of different polymers of differing molecular weights. The ratio of the weight average molecular weight to the number average molecular weight gives an indication of the MWD. One method of comparing the processability with product performances of plastics is to use their MWD. A narrow MWD enhances the performance of plastic products. Wide MWD permits easier processing. Melt flow rates are dependent on the MWD. With MWD differences of incoming material the fabricated performances can be altered requiring resetting process controls. The more the difference, the more dramatic changes that can occur in the products. Viscosity is a measure of resistance to plastic melt flow. It is the internal friction in a melt resulting when one layer of fluid is caused to move in relationship to another layer. Thus viscosity is the property of the resistance of flow exhibited within a body of material. It is the constant ratio of shearing stress to the rate of shear. Shearing is the motion of a fluid, layer by layer, like playing cards in a deck. When plastics flow through straight tubes or channels they are sheared: High MI implies low viscosity and low MI means high viscosity. Plastics are shear thinning, which means that their resistance to flow decreases as the shear rate increases. This is due to molecular alignments in the direction of flow and disentanglements.

3: Plastics Engineered Product Design - | SlugBooks

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Deflection relates to pipe stiffness El , pipe radius, external loads that will be imposed on the pipe, both the dead load of the dirt overburden as well as the live loads such as wheel and rail traffic, modulus of soil reaction, differential soil stress, bedding shape, and type of backfill. It has to be determined if the wall structure selected is of sufficient stiffness to resist the buckling pressures of burial or superimposed longitudinal loads. The ASME Standard of a four-to-one safety factor on critical buckling is used based on many years of field experience. To calculate the stiffness or wall thickness capable of meeting that design criterion one must know what anticipated external loads will occur Fig. As reviewed the strength of KTR pipe in its longitudinal and hoop directions are not equal. Before a final wall structure can be selected, it is necessary to conduct a combined strain analysis in both the longitudinal and hoop directions of the RTR pipe. These values are determinable through standard ASTM tests such as hydrostatic testing, parallel plate loading, coupon test, and accelerated aging tests. Stress-strain S-S analysis of the materials provides important information. The tensile S-S curve for steel-pipe material identifies its yield point that is used as the basis in their design. Beyond this static loaded yield point Chapter 2 the steel will enter into the range of plastic deformation that would lead to a total collapse of the pipe. The allowable design strain used is about two thirds of the yield point. Either the ASTM hydrostatic or coupon test determines it. The weep point is the point at which the RTR matrix plastic becomes excessively strained so that minute fractures beg in to a ppear in the structural wall. At this point it is probable that in time even a more elastic liner on the inner wall will be damaged and allow water or other liquid to weep through the wall. Even with this situation, as is the case with the yield point of steel pipe, reaching the weep point is not catastrophic. It will continue to withstand additional load before it reaches the point of ultimate strain and failure. By using a more substantial, stronger liner the weep point will be extended on the S-S curve. The filament-wound pipe weep point is less than 0. The design is at a strain of 0. For transient design conditions a strain of 0. Stress or strain analysis in the longitudinal and hoop directions is conducted with strain usually used, since it is easily and accurately measured using strain gauges, whereas stresses have to be calculated. From a practical standpoint both the longitudinal and the hoop analysis determine the minimum structural wall thickness of the pipe. However, since the longitudinal strength of RTR pipe is less than it is in the hoop direction, the longitudinal analysis is first conducted that considers the effects of internal pressure, expected temperature gradients, and ability of the pipe to bridge voids in the bedding. Analyzing these factors requires that several equations be superimposed, one on another. All these longitudinal design conditions can be solved simultaneously, the usual approach is to examine each individually. This effect occurs when an open-ended cylindcr is subjected to internal pressure. As the diameter of the cylinder expands, it also shortens longitudinally. Since in a buried pipe movement is resisted by the surrounding soil, a tensile load is produced within the pipe. The internal longitudinal pressure load in the pipe is independent of the length of the pipe. Equation provides a solution for a straight run of pipe in terms of strain. However, where there is a change in direction by pipe bends and thrust blocks are eliminated through the use of harness-welded joints, a Plastics Engineered Product Design different analysis is necessary. Longitudinal load imposed on either side of an elbow is high. Because of this increased load, the pipe joint and elbow thickness may have to be increased to avoid overstraining. The extent of the tensile forces imposed on the pipe because of cooling is to be determined. Temperature gradient produces the longitudinal tensile load. With an open-ended cylinder cooling, it attempts to shorten longitudinally. The resistance of the surrounding soil then imposes a tensile load. Any temperature change in the surrounding soil or medium that the pipe may be carrying also can produce a tensile load. Engineering-wise the effects of temperature gradient on a pipe can be determined in terms of strain. Design of the pipe includes making it strong enough to support the weight of its contents, itself, and its overburden while spanning a void of two pipe diameters. When a pipe provides a support the normal practice is to solve all equations simultaneously, then determine the minimum wall thickness that has strains equal to or less than the allowable design strain. The result is obtaining the minimum structural wall thickness. This approach provides the designer with a minimum wall thickness on which to base the ultimate choice of pipe configuration. In deciding which wall thickness, or what pipe configuration straight wall or ribbed wall is to be used, economic considerations are involved. Required is to determine if the combined loads of internal pressure and diametrical bending deflection will excccd the allowable design strain. There was a tendency in the past to overlook designing of joints. The performance of the whole piping system is directly related to the performance of the joints rather than just as an internal pressure-seal pipe. Examples of joints are bell-and-spigot joints with an elastomeric seal or weld overlay joints designed with the required stiffness and longitudinal strength. The bell type permits rapid assembly of a piping system offering an installation cost advantage. It should be able to rotate at least two degrees without a loss of flexibility. The weld type is used to eliminate the need for costly thrust blocks. With metals shape options are the usual torsion bar, helical coil, and flat-shaped leaf spring. The TPs and TSs can be fabricated into a variety of shapes to meet different product requirements. An example is TP spring actions with a dual action shape Fig. This stapler illustrates a spring design with the body and curved spring section molded in a single part. When the stapler is depressed, the outer curved shape is in tension and the ribbed center section is put into compression. When the pressure is released, the tension and compression forces are in turn released and the stapler returns to its original position. Other thermoplastics are used to fabricate springs. Acetal plastic has been used as a direct replacement for conventional metal springs as well providing the capability to use different spring designs such as in zigzag springs, un-coil springs, cord locks with molded-in springs, snap fits, etc. The plastic spring hand-operating pump as well as other plastic spring designs did not contaminate the blood. RP leaf springs have the potential in the replacements for steel springs. These unidirectional fiber Ws have been used in trucks and automotive suspension applications. Their use in aircraft landing systems dates back to the early s taking advantage of weight savings and cigurib: The design advantages of these springs is to fabricate spring leaves having continuously variable widths and thicknesses along their length. These leaf springs serve multiple functions, thereby providing a consolidation of parts and simplification of suspension systems. One distinction between steel and plastic is that complete knowledge of shear stresses is not important in a steel part undergoing flexure, whereas with RP design shear stresses, rather than normal stress components, usually control the design. They provide the equations for evaluating design parameters that are derived from geometric and material considerations. However, none of this currently available literature is directly relevant to the problem of design and design evaluation rcgarding RP structures. The design of any RP product is unique because the stress conditions within a given structure depend on its manufacturing methods, not just its shape. Programs have therefore been developed on the basis of the strain balance within the spring to enable suitable design criteria to be met. Stress levels were then calculated, after which the design and manufacture of RP springs became feasible. Such design features can lead to new suspension arrangements in which the composite leaf spring will serve multiple functions thereby providing part consolidation and simplification of the suspension system. The spring configuration and material of construction should be selected so as to maximize the strain energy storage capacity per unit mass without exceeding stress levels consistent with reliable, long life operation. Elastic strain energy must be computed relative to a 4 - Product design particular stress state. For simplicity, two materials are compared, steel and unidirectional glass fibers in an epoxy matrix having a volume fraction of 0. On a volume basis the RP is about twice as efficient as steel in storing energy; on a weight basis it is about eight times as efficient. Under a different loading condition such as torsion the results would be reversed unless the RP were redesigned for that condition. The above results are applicable to the leaf spring being reviewed because the principal stress component in the spring will be a normal stress along the length of the spring that is the natural direction for fiber orientation. In addition to the influence of material type on elastic energy storage, it is also important to consider spring configuration. The most efficient configuration although not very practical as a spring is the uniform bar in uniaxial tension because the stresses are completely homogeneous. The low efficiency of this latter configuration is due to stress gradients through the thickness zero at the mid-surface and maximum at the

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Plastics Engineered Product Design upper and lower surfaces as well as along the length maximum at mid-span and zero at the tips. Recognition of this latter contribution to inefficiency led to development of so-called constant strength beams which for a cantilever of constant thickness dictates a geometry of uiangular plan-form. However, a spring leaf molded of the RP can have both thickness and width variations along its length. This approaches the efficiency of a tapered multi-leaf configuration and is accomplished with a material whose inherent energy storage efficiency is eight times better than steel. In this design, the dimensions of the spring are chosen in such a way that the maximum bending stresses due to vertical loads are uniform along the central portion of the spring. This method of selection of the spring dimensions allows the unidirectional long fiber reinforced plastic material to be used most effectively. Consequently, the amount of material needed for the construction of the spring is reduced and the maximum bending stresses are evenly distributed along the length of the spring. Thus, the maximum design stress in the spring can be reduced without paying a penalty for an increase in the weight of the spring. Two design equations are given in the following using the concepts described above. To develop design formulas for RP springs, we model a spring as a Figure RP spring model 4 - Product design - circular arc or as a parabolic arc carrying a concentrated load 2FV at mid-length Fig. Using the coordinate system shown in Fig, 4. Once the maximum allowable design stress in the spring is chosen, equation will be used to determine the load carrying capability of the spring. It should be noted that equation is only an approximate representation of the deformation of the spring. Although a nonlinear relation can be used in place of equation , it would be difficult to derive simple equations for design purposes. For this particular design, the thicknesses of the spring decreases front the center to the two ends of the spring. Hence, the cross-sectional area of the spring varies along its length. The value of a, is a design parameter that is used to control the thickness and the load carrying capability of the spring. The factor I - v2 is introduced to account for the fact that b could be several times larger than h. If b and h are of the same order of magnitude, a zero value of v is suggested to be used with equation 4- Plastics Engineered Product Design

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12 Plastics Engineered Product Design influences the dimensional tolerances that can be met d e r accounting for the heating/cooling process and the design of molds or dies. Crystalline plastics require tighter process control during fabrication.

8: Plastics Product Design, Engineering, Tooling & Analysis

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