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METHOD FOR DETECTING FLAWS, CRACKS AND NONHOMOGENEITY IN MATERIALS USING COMBINED PENETRANT AND MAGNETIC PARTICLE SYSTEMS

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ABSTRACT OF THE DISCLOSURE

A method for detecting and locating flaws in members is disclosed which combines the use of penetrant and magnetic particle systems. A penetrant is applied to the surface of the member and is absorbed by flaws. A developer is then applied to the member along with a strippable liquid plastic magnetic particle solution. The combined penetrant and magnetic particle record may then be removed and examined. In one embodiment the developer may be contained in the strippable liquid plastic magnetic particle solution.

This invention relates to method and composition for detecting flaws, cracks, and nonhomogeneity in materials, particularly for detecting flaws which are not revealed by other methods of detection, and has for an object the provision of improvements in this art.

The invention is especially useful in that it provides means for obtaining records of cracks and other flaws detectable by penetrant and magnetic particle methods of inspection.

Several methods exist for detecting and recording penetrant and magnetic particle patterns or flaws. The penetrant solutions are applied to the surface and time is allowed for the penetrant to seep into the surface flaws. This dwell time varies with the type of penetrant. The excess penetrant is wiped off the surface, often with the aid of a solvent. A developer comprising a dry penetrant-absorbing powder or powders in a volatile liquid vehicle, such as water or alcohol, is applied to the surface. The developer usually dries white and absorbs the penetrant, which is often red, to permit easy visual detection of the flaw as indicated by the seeped-out penetrant. Records of these patterns are obtained by photography and more recently by direct application of an adhesive tape onto the developer-coated surface and then stripping the tape off the surface with the penetrant pattern fixed thereon. This method is disclosed in U.S. Patent 2,667,070, issued to L. W. Sockman et al. on Jan. 26, 1954.

The practice of applying pressure-sensitive tape, such as "Scotch" tape, directly to a seeped-out penetrant has been used without the aid of a developer. However, these tape methods have limitations such as distortion of the patterns and difficulties in handling large areas.

Both the photographic and tape methods have also been used to obtain records of magnetic particle patterns. In this use the particles are applied dry or in water, kerosene, or a light oil vehicle, to the surface of the magnetized part. Records of the dry magnetic powders are directly lifted with tape. The patterns obtained by the wet method are recorded by permitting the water to dry out or by washing away the oil with a volatile solvent and then directly lifting the dry particles with tape. The tape is applied to a sheet of paper and stored for future reference.

Considerable study has been given to improving the sensitivity of penetrant insepection procedures. Both water and oil-soluble penetrants have been formulated. The developer material and liquid vehicles used are varied according to specific applications. The use of colored and fluorescent penetrant and magnetic particle materials stems from the search for more sensitive testing and better methods for recording inspection information. The use of radioactive magnetic particles has also been proposed.

My U.S. Patent No. 3,040,164, granted June 19, 1962, discloses the concept of liquid plastic magnetic particle solutions for improved operator sensitivity and improved methods for obtaining permanent records of magnetic particle patterns. It provides that after the magnetic particles collect on the surface around spot welds or along surface or subsurface flaws the solution sets up as a strippable plastic film with the magnetic particle patterns "frozen" in. The record is stripped off the surface when permanent records are desired.

The method is applicable to automatic and remote inspection methods which are disclosed in the aforementioned patent. Additional methods for obtaining permanent records of magnetic particle patterns are disclosed in my French Patent No. 1,240,359, granted in 1959. One such method comprises the application of the liquid plastic magnetic particle solution to the surface of a magnetized part, allowing the particles to migrate to regions of varying magnetic permeability and permitting the solution to set up as a strippable plastic film. This plastic magnetic particle record is subsequently strengthened by applying one or more coatings of the same or other resins which adhere or bond to the plastic film, and stripping the entire record off the surface of the part.

It is apparent from the variety of penetrant and magnetic particle formulations being introduced that there is a definite desire for improved methods and compositions.

It is one of the specific objects of the present invention to simplify flaw detection by providing a combination penetrant and magnetic particle system which is strippable and easily automated.

It is another object of the invention to reduce the number of steps required for obtaining permanent records of penetrant patterns by incorporating an absorbent filler material into a strippable plastic developer.

It is another object of the invention to strengthen a liquid plastic magnetic particle solution with the aid of a filler material added to the solution.

It is another object of the invention to reduce the run-off of liquid developer solutions and liquid plastic magnetic particle solutions from vertical surfaces by adding a thixotropic filler and absorbent material.

It is another object of the invention to provide a means for preserving the location of penetrant and magnetic particle indications relative to complex curved surfaces by using a thermosetting resin as the liquid plastic solution.

The present invention utilizes liquid plastic solutions such as described in my U.S. Patent 3,040,164. One of these solutions consists of:

Solvent, ethyl alcohol (50% by vol.) ---------cc--	150
Solute—	
Polyvinyl alcohol (resin) ----------cc--	90
Total dispersant ----------cc--	240
Dispersoid, iron oxide (Fe_3O_4) powder (300 mesh) ----------gm--	4

A wetting agent and rust inhibitor are added. A yellow dye is added to the solution to enhance the visual contrast between the magnetic particle patterns and reflective steel surfaces. A flash point control additive is used when higher flash points are required. Another method for raising the flash point is by replacing the alcohol in the solution with water.

One example of the present invention utilizes a solution comprised of polyvinyl alcohol resin, an ethyl alcohol-water solvent, magnetic particles, and glycerine as a wetting agent. This solution is used in step (6) of the

following procedure which detects the presence and nature of a crack formed at a spot weld in a fatigue tested type 301 stainless steel specimen. The steel is in a partially cold-rolled condition and has a metallurgical structure of austenite with a percentage of martensite transformed during the cold-rolling process.

The procedure hereby provided to inspect this part is as follows:

(1) Clean the specimen surface with industrial solvent;
(2) Spray on a red penetrant and allow it to soak in until the penetrant enters the cracks;
(3) Clean off excess penetrant with solvent;
(4) Apply wet developer and let dry until white. Penetrant seeps out of crack into developer;
(5) Apply magnetic field to the specimen;
(6) Spray on the liquid plastic magnetic particle solution described above;
(7) Permit the solution to dry for about 30 minutes at normal room conditions. The drying time may be hastened with heat;
(8) Apply pressure sensitive tape to the strippable plastic film;
(9) Strip the record off the surface of the part.

The part may be examined visually after step (4) and after step (7). The stripped record is examined directly and by transmitted light when placed on a viewer such as used in X-ray inspection.

Information not obtainable by the dye penetrant alone and magnetic particles alone is obtained with this method. The dye penetrant shows the cracks which are open to the surface. The magnetic particles show the cracks which progress slightly subsurface beyond the open portion and the presence of deformed (nonhomogeneous) metal beyond the crack. The deformation is attributed to the stress field applied and the geometry of the test specimen which produce a triaxial deformation resulting in the transformation of additional austenite to martensite. Martensite, being a magnetic phase, attracts additional magnetic particles during the inspection described above.

The above inspection method may be simplified by adding a suspendable colloidal silica to the magnetic particle solution; the colloidal silica being absorbent to the penetrant solution used. Better results are obtained by replacing the alcohol portion of the solvent with water. The thixotropic properties of this solution are optimum when the colloidal silica comprises about 3 to 5% of the solution by weight.

This new solution is used in step 3 in the following inspection procedure:

(1) Apply red dye penetrant;
(2) Remove excess penetrant;
(3) Spray on the above-described colloidal-silica-filled liquid plastic magnetic particle solution while exposing the part to a magnetic field. The magnetic particles immediately align themselves along the flaw and the penetrant is absorbed into the colloidal silica as the solution dries. In effect, the liquid plastic functions as a strippable magnetic particle penetrant developer;
(4) Strip the record off the surface with the aid of pressure sensitive tape;
(5) Wash the solution of step (3) off with water or alcohol when records are not required.

The present method is not limited to paramagnetic and ferromagnetic materials but is applicable to nonmagnetic and nonmetallic materials. In this case, magnetic particles may not be desirable and may be left out of the solution.

Care must be taken in formulating the liquid plastic penetrant developer to adjust the amount of filler material and the solution viscosity when Aerosol spray type equipment is used. A wetting agent is used to assure wetting of the penetrant in the cracks. The resin may be soluble or insoluble with the penetrant.

The above are merely limited examples of the formulations covered by the invention. Also covered by the invention are (1) formulations comprising other strippable resins and non-flammable fast drying solvents, (2) water insoluble resins such as polyvinyl chloride with a solvent such as methyl ethyl ketone, and (3) other compositions containing penetrant absorbent filler materials.

The filler materials may be suspendable colloidal silicas, as described, or other suspendable filler materials. It may also be desirable to use filler materials that are soluble in the liquid plastic solutions. Such a formulation may improve the absorbing power of the developer to the penetrant.

The use of postemulsification cleaners has recently been introduced in penetrant inspection when certain penetrants and developers resist washing with water. This practice may no longer be necessary with the new liquid plastic developer which leaves the surface very clean after being stripped off the surface of the part.

These new formulations may also be adapted for use with fluorescent magnetic particles and penetrants.

My U.S. Patent 3,040,164 discloses automating magnetic particle inspection utilizing strippable magnetic particle solutions. This inspection concept is also applicable to strippable penetrant developer and magnetic particle combined with penetrant developer combined strippable solutions. Additional stations will be needed along the inspection line to allow for exposure to penetrants and the removal of excess penetrant.

While the above discussion has been directed mainly to preferred examples of compositions and processes for flaw inspection, it is to be understood that these are but illustrative of the principles and applications of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

I claim:

1. The method for the detection and location of flaws, cracks, and nonhomogeneity at and near the surface of ferromagnetic and paramagnetic parts, which comprises, initially applying a penetrant solution to the surface of the part, allowing the penetrant solution to enter into surface flaws, wiping off the excess, applying a developer, allowing the developer solution to dry and absorb the penetrant from the surface cracks, subsequently applying a strippable liquid plastic magnetic particle solution over the developer while magnetizing the part, and visually examining the coating thus formed for the flaws present on the part.

2. The method as set forth in claim **1**, which further comprises, drying the coating to form a dry plastic film, applying an adherent reinforcing backing material over the dry plastic film, and stripping the combined penetrant and magnetic particle record coating film off the surface to provide a permanent record of the flaw.

3. The method as set forth in claim **2**, which further comprises, photometrically analyzing the strippable record coating film.

4. The method for the detection and location of flaws, cracks, and non-homogeneity at and near the surface of a ferromagnetic or paramagnetic part, which comprises, initially applying a penetrant solution to the surface of the part, allowing the penetrant solution to enter into surface flaws, wiping off the excess, applying a strippable liquid plastic magnetic particle containing developer solution over the surface while exposing the part to a magnetic field, and allowing the developer solution to absorb the penetrant from the surface flaws and the magnetic particles to migrate to set up as a strippable plastic film which can be visually examined for the presence of flaws.

5. The method as set forth in claim **4**, which further comprises, applying an adherent reinforcing backing, comprising one of a pressure sensitive tape and a sprayed-

on resin backing, and stripping the entire record film and backing off the part for inspection.

6. The method as set forth in claim 5, which further comprises, photometrically analyzing the stripped record film.

7. The method for the detection and location of flaws, cracks, and nonhomogeneity at and near the surface of magnetic or nonmagnetic materials, which comprises, initially cleaning the surface, applying a penetrant solution to the surface, allowing the penetrant to enter any cracks and pores, wiping off the excess, and applying a strippable liquid plastic solution containing a thixotropic penetrant absorbent filler material, and letting the penetrant patterns develop.

8. The method as set forth in claim 7, which further comprises, applying an adherent reinforcing backing material to the dry strippable plastic, and stripping the entire record coating film off the part and examining the record coating film for penetrant indications.

9. The method as set forth in claim 8, which further comprises, photometrically analyzing the stripped record coating film.

10. The method of obtaining a permanent record of a magnetic particle pattern formed on the surface of a workpiece during the course of magnetic particle inspection of the workpiece, which comprises, applying an adherent magnetic particle coating to the workpiece, causing the magnetic particles to form an adherent surface pattern of magnetic nonhomogeneity, applying a liquid plastic solution to the magnetic particle coating after the particles have formed a pattern on the workpiece, allowing the plastic coating to encompass the patterned particles without affecting their pattern orientation, drying the plastic coating containing the patterned particles, and stripping the dried plastic coating carrying the patterned particles off the surface of the workpiece.

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