United States Patent

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[54] FATIGUE-RESISTANT ATTACHMENT FOR HIGHLY STRESSED MEMBERS SUCH AS PRINT HAMMERS

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[52] U.S. Cl. ..... **101/93 C**

[51] Int. Cl. **B41j 9/02**

[58] Field of Search ..... 101/93 C

[56] **References Cited**

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[57] **ABSTRACT**

Attachment of a relatively hard flexure member to a relatively elastic body member by a combination of mechanical anchoring and adhesive bonding is disclosed. An adhesive bond free of surface voids and affording intimate contact between an adhesive material and a thermoplastic elastic member is achieved by interfacing materials in the viscous state followed by cure to a resilient state; an attachment immune to repeated high-energy loading in tension and flexure and free of stress concentrations in the members results. Application of the attachment toward anchoring a metal spring within a plastic hammer and to a metal base member for a high-speed printer mechanism is disclosed.

11 Claims, 5 Drawing Figures

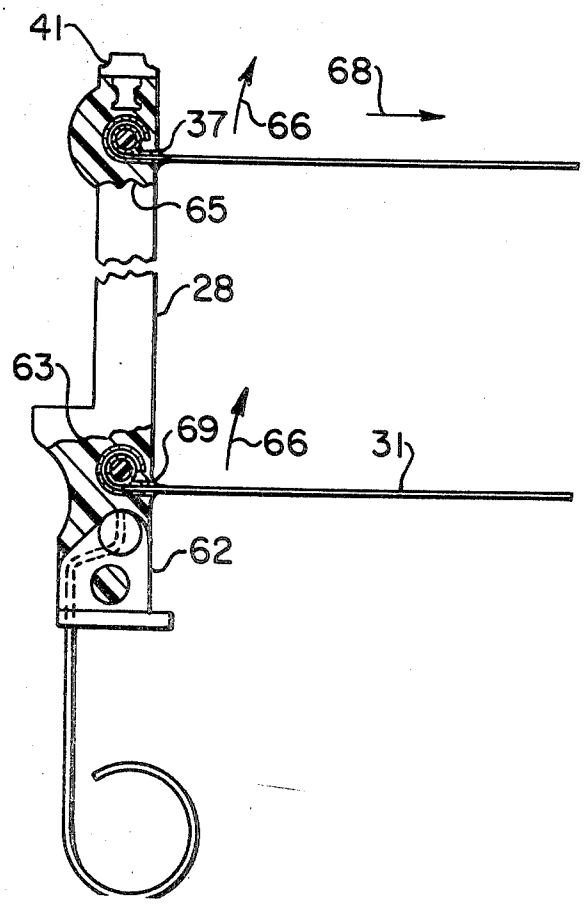


FIG. 1

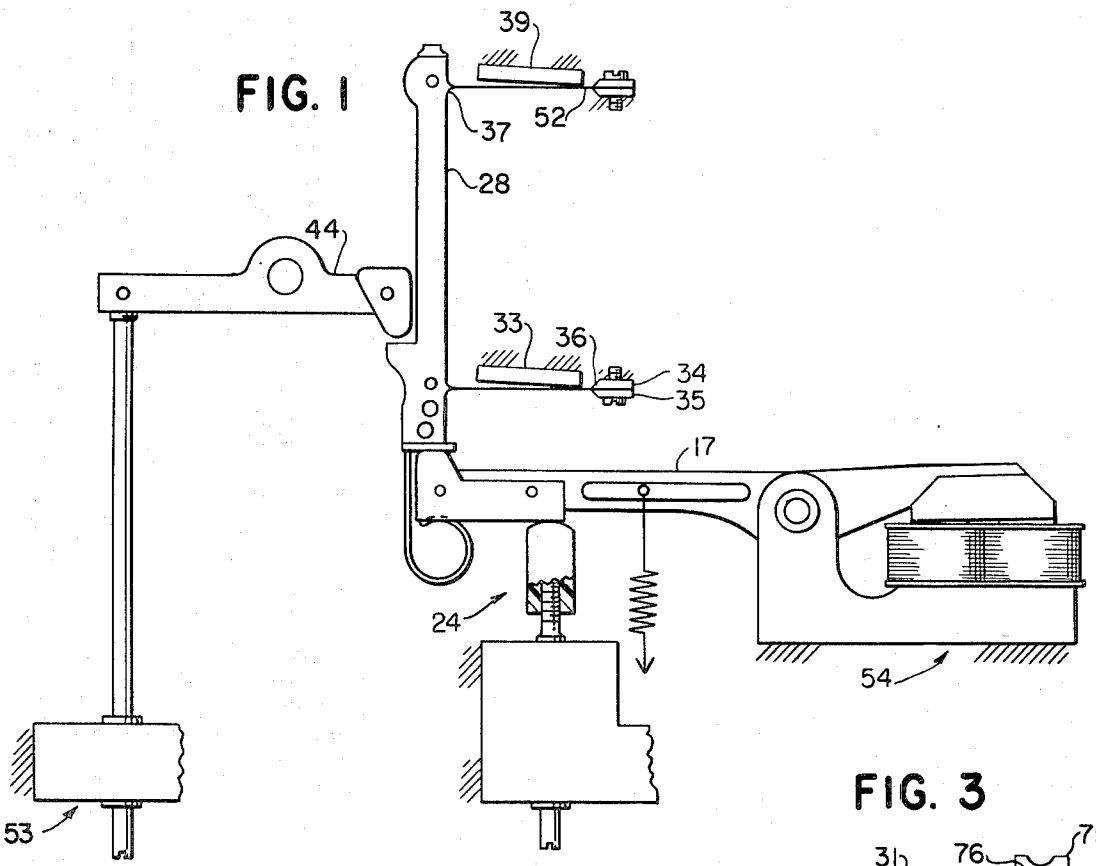


FIG. 2

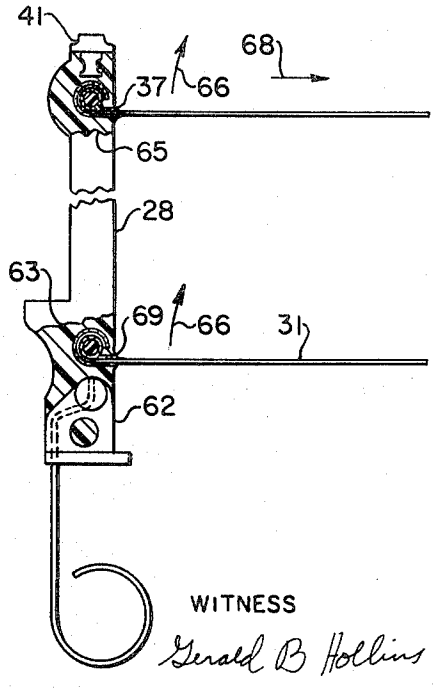


FIG. 3

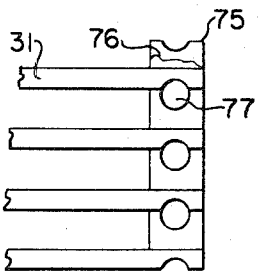
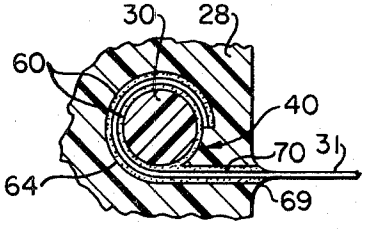


FIG. 2A



WITNESS

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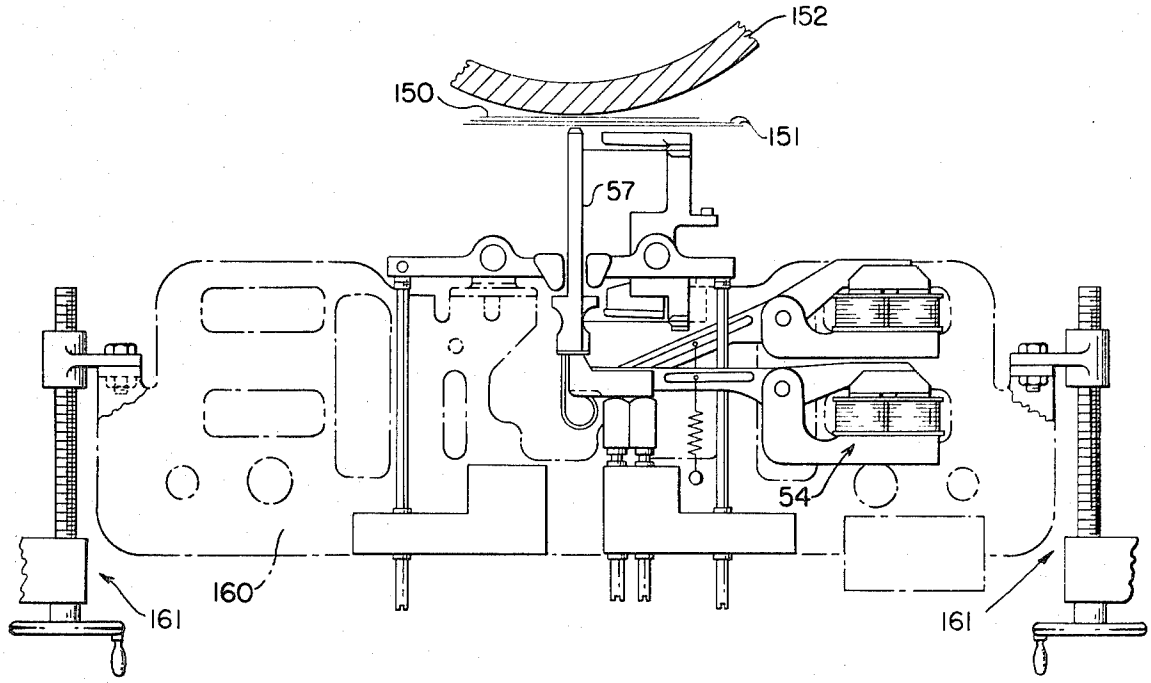
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FIG. 4



WITNESS

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FATIGUE-RESISTANT ATTACHMENT FOR HIGHLY STRESSED MEMBERS SUCH AS PRINT HAMMERS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention pertains to the art of joining two parts in a resilient manner to form a structure which is useful in a high-speed high-acceleration machine environment. The invention is disclosed by way of an embodiment involving an impact-excited member used as part of a business machine.

The specific embodiment into which the invention is placed in this disclosure is a high-speed printer comprising a portion of an Electronic Data-Processing System. In this embodiment, the present invention is used as a means for attaching supporting springs to a rapidly excited printing hammer.

The fatigue-resistant attachment disclosed herein may also be employed as a general means of fastening one member to another when one of the members is relatively hard and the other is relatively resilient and moldable.

2. Description of the Prior Art

In the prior art, one method for bonding thermoplastic resins to a variety of materials, including metals, is known. The present invention distinguishes over this prior art in that the prior art teaches a silicon bonding process wherein the organic bonding agent must have attached silyl groups. The present invention is also distinguished from this prior art in that it combines a bonding technique with mechanical anchoring of the metal part.

There is also disclosed in the prior art a technique for fastening a metal to a polyurethane plastic material. In addition to treating only the attachment of polyurethane materials, this prior art discloses only bonding attachment and does not combine bonding with mechanical anchoring.

The prior art also discloses the use of epoxy material to anchor a cantilever suspension spring into a hammer member where the hammer is a unitary metallic structure. The anchoring technique disclosed in the present invention is not restricted to the use of a metal hammer body or to being employed following complete fabrication of a hammer member.

In the prior art, it is also known to fasten the cantilever suspension springs for a ballistic print hammer within the hammer and within the base mounting by employing a soft metal anchor which adheres to the cantilever springs in combination with some resilient or elastomeric material which surrounds or joins to the metal anchor.

In the present invention, a simpler and more economical fabrication for the cantilever spring anchorage is shown. This fabrication, in addition to its simplicity, affords longer operating life, lower mass, and the capability of operating at higher speeds.

SUMMARY

The present invention is shown embodied into a reliable long-lived attachment of a metal cantilever supporting spring to a nonmetallic printing hammer having lower rigidity and less dimensional stability than the metal spring. The present invention provides an attachment which is effective where the hammer is composed of thermoplastic material having minimal bonding affinity for metal surfaces. The attachment is also applicable where hammer bodies made from thermosetting resins or other moldable nonmetallic materials are employed.

The disclosed invention provides for efficient utilization of mutually exposed surface areas, since intimately conforming and void-free interfaces are formed between plastic material and the bonding material and between the metal and the bonding material.

The attachment invention disclosed herein provides for anchoring of a cantilever support spring without employing welding, piercing, heating, or other stress concentrating and weakening operations on the spring member; the attachment also minimizes the effects of load-induced flexure on the spring; through minimal stress concentrations and minimal influence on the heat-treated or cold-worked status of the spring member; failure of the spring or of the hammer member near the region where the two members join, as is common in prior art attachments, is avoided.

The present specification discloses both an attachment structure and a method of forming the attachment. The attachment invention disclosed in this application is applicable to other arts in addition to that of high-speed printing mechanisms; the invention disclosed is useful as a general attachment between rigid and less rigid members where material for a larger less rigid member may be placed in a viscous state and molded surrounding a more rigid member.

DESCRIPTION OF THE DRAWINGS

FIG. 1 of the drawings is an overall view of a printer mechanism employing a printer hammer having cantilever support springs attached according to the present invention.

FIG. 2 of the drawings is a cutaway view of a printer hammer having cantilever support springs attached according to the present invention.

FIG. 2*a* of the drawings is an enlarged view of the cantilever spring attachment region shown in FIG. 2.

FIG. 3 of the drawings shows the mounting of a plurality of print hammer cantilever spring members at their lower extremity upon a header plate member.

FIG. 4 of the drawings shows a cantilever spring-supported hammer which is fabricated according to the present invention incorporated into a high-speed printer having its typefont mounted upon a rotating drum.

DESCRIPTION OF THE PREFERRED EMBODIMENT

A cantilever spring supported hammer for a high-speed printing mechanism is shown in FIG. 2 of the drawings. The cantilever supporting springs **31** are attached to the hammer body **28** by means of a fatigue-resistant resilient high-strength fastening which is made in accordance with the present invention. Details of this high-strength fastening are shown in FIG. 2A of the drawings, which is an enlargement of the fastening area shown in FIG. 2.

In FIG. 3 of the drawings, an assembly of the hammer-supporting springs **31** onto a header plate **75** is shown. This assembly also is made in accordance with the present invention.

In FIG. 1 of the drawings, a printing hammer having its supporting spring members attached in accordance with the present invention is shown in conjunction with the related active members of the printing mechanism. The relationship shown in FIG. 1 is helpful in understanding the loading and the stresses to which the hammer and its spring fastenings are subjected in use. In FIG. 1, the major component members of the printing mechanism are identified as a solenoid assembly **54**, the printing hammer **28**, a backstop assembly **24**, a penetration control member **44**, and spring stop members **33** and **39**.

In operating the mechanism shown in FIG. 1, the solenoid **54** is first energized to cause the solenoid arm **17** and the hammer **28** to be propelled upward in the figure; following the accelerating period, the solenoid arm **17** is decelerated to zero velocity at a point preceding contact of the hammer **28** with the penetration control **44**, so that the hammer travels by its own inertia in free flight toward the penetration control **44** and the paper to be printed upon, which is not shown but is located across the top of the drawing page. Following impact with the paper and the penetration control member **44**, the hammer and the solenoid armature arm relax back into contact with the stop assembly **24**.

In FIG. 4 of the drawings, the printing mechanism of FIG. 1 is shown mounted in conjunction with other similar mechanisms and in conjunction with one form of print carrier typeline **152**, the paper to be printed **151**, the printing ribbon **150**, a mounting frame **160**, and printer position adjustment apparatus **161**. In FIG. 4, the numeral **54** again identifies the excitation solenoid, and the numeral **28** identifies the printing hammer. The mounting frame **160** in FIG. 4 is a frame capable

of mounting up to eight printing mechanisms of the type shown in FIG. 1. The adjusting mechanism shown as 161 in FIG. 4 permits variable positioning of the printer frame and its printing mechanism before the typeline.

In prior art mechanism utilizing cantilever spring suspension of a printing hammer, a frequent failure area has involved the region where the cantilever springs attach to the movable printing hammer and where these same springs attach to a frame member of the printer—the area at 52 and the area near the fillet 37 in FIG. 1 of the drawings.

In these prior art high-speed printers, failure has commonly occurred because of designs which accentuate a failure tendency in the hammer or because of some operation performed upon the cantilever springs in manufacture causing a decrease in the spring's resistance to fatigue (by inducing high local stresses or changing the modulus of elasticity or some other property of the spring material, for instance) or because of some part in the structure having reduced cross-sectional area or residual stresses or induced microcracks. In particular, failure tendency in prior art designs has been so great as to effectively prevent the combination of a nonmetallic print hammer, especially one composed of thermoplastic resin material, and metal cantilever support springs. In these prior art hammers, when the relatively hard spring material, with its good dimensional stability, was bonded directly to the plastic hammer body, there was produced a fastening which was subject to one or more of the following:

1. internal stresses as a result of dimensional changes occurring in one of the two materials from temperature, humidity, or other environmental factors;

2. failure to achieve adequate bonding affinity with the plastic body, especially when the difficult-to-bond thermoplastic resins were employed;

3. materials failure such as cold working in the spring material and gaseous decomposition or fatigue in the plastic material; and

4. concentration stresses in the metal spring in a confined region near the entrance of the small spring into the larger body of the hammer or near the attachment of the spring to the printer frame.

The present invention relates to a novel attachment of one part to another. The attachment disclosed may be applied at the two critical end points of the cantilever springs of a printing mechanism hammer, as shown in FIG. 1. The disclosed attachment involves techniques which relate to manufacturing steps that are easily and cheaply performed and which are capable in the present embodiment of providing a printer hammer life measured in hundred million operations without failure.

FIG. 1 of the drawings shows a cantilever spring-mounted printing hammer and the related parts which make up a printing mechanism operating upon one column of type in a high-speed printer. In FIG. 1, in lieu of showing the elaborate frame member which is used to mount the various parts, only active functional parts are shown, and stationary mounted parts normally connected to a frame member are indicated by the symbol shown at 53.

FIG. 2 of the drawings depicts a cutaway view of the printing hammer shown in FIG. 1, with the cutaway portions so located as to reveal inner construction of the hammer in the region where external parts are attached. In FIG. 2, the line 63 represents a cutting line, below which a portion of the hammer body material is removed, so that the interior parts and construction of the hammer may be viewed; upwards of the line 63, the hammer is shown in normal view until the cutting line 65 is reached, whereupon the hammer material is again cut away, so that the interior parts may be viewed.

The operating environment of a cantilever supported printing hammer such as the one shown in FIGS. 1 and 2 is found to include several forces which are destructive to the hammer-to-spring fastening structure. Two of these forces are shown in FIG. 2, where the arrow 68 represents a force tending to extract the cantilever spring from the hammer body and the arrows 66 represent forces tending to flex the cantilever spring within its mountings in the hammer body.

In the present environment, it has been found that the force represented by the arrow 68, a force which results from frictional contact between a hammer insert member 41 and the moving paper-typefont complex shown in FIG. 4, may reach a magnitude of 6½ pounds in ordinary operation of the printer. The fatiguing effect of this force upon the spring fastening structure can be appreciated by realizing that this 6½-pound force is encountered with each operation of the hammer over the hundreds of million operations desired. In printer mechanisms which have the movable typefont mounted upon a laterally moving chain or a belt in lieu of the drum as shown in FIG. 4, the reaction of print font upon hammer member is not the direct tension force indicated by 68 in FIG. 2 but is instead a lateral force upon the hammer tending to rotate the hammer about an axis parallel with the mounting springs 31. Although this rotational force does not directly tend to extract the springs from the hammer, it nevertheless is sufficient to fatigue the fastening of spring to hammer.

The arrows 66 in FIG. 2 represent flexure forces to which the spring fastening structure and the spring material itself are subjected each time the hammer member 28 is displaced from its normal, quiescent, position. It may be appreciated that these flexure forces tend both to open a crevice parallel to the spring member 31 in the fastening structure and to work-harden or otherwise fatigue the spring material when they occur during each of the several hundred million life operations of the hammer mechanisms.

In many prior art designs for a spring to nonmetallic print hammer fastening where bonding of the type described in this specification was not employed, it was attempted to hold the spring within the hammer body by way of projections welded onto the spring or by way of holes pierced into the spring material. Other prior art techniques have attempted to roughen the surface of the spring by sand blasting or heavy chemical etching in order that a more secure bond might be achieved. It has been found by experience that all of these prior art attempts to better secure the cantilever spring result in weakening of the spring through impairing the elastic properties of its material or through locally concentrating stresses in the spring member; with any of these prior art designs, premature failure of the spring member has been found to occur in the region associated with the spring attachment.

In the present invention, it is desired to attach the cantilever springs to the nonrigid hammer without using any of these techniques which weaken the spring or reduce its endurance to repeated flexing. Since any form of heat-related attachment or severe mechanical deformation of the spring is believed conducive to premature failure, it is desirable to form an attachment by some technique which, instead of mechanical locking, utilizes a large surface area on the spring for fastening and which thereby achieves anchoring without dependence on heat or deformation. In forming the spring-to-hammer fastening in the printer shown in FIGS. 1 to 4 of the drawings, it has been found possible to employ a bond made of resilient organic polymeric strata material having the ability to achieve high-strength fastening between hammer and spring through wetting of the spring surface and bonding with the nonmetallic material of the hammer body. In considering the attachment, it is also found desirable to employ a polymeric strata material which is stable in the presence of the heat and pressure employed in a molding operation, since, if such a material is employed, the spring fastening structure can be fabricated in conjunction with forming the hammer body itself. Fabrication of the spring-fastening structure in conjunction with forming the hammer body offers the combination advantages of permitting fast low-cost assembly and permitting the imbedding of a complex spring shape within the hammer body while maintaining close intimate and wetted contact between all related portions of the spring and hammer structure.

In order that the forces 66 and 68 in FIG. 1, which were described earlier, may be effectively resisted by the fastening

structure of the present invention, it has been found desirable to increase the effectiveness of the hammer-to-spring bond by employing a circular shape formed into the end of the cantilever spring during an operation preliminary to spring bonding into the hammer body. This circular shape both increases the bonding area and assists mechanically in fastening the spring into the hammer.

In selecting a material to provide the desired polymeric strata and bond between cantilever spring and plastic hammer, there is a large group of potentially desirable materials from which to select; one material from this group which was successfully used but later replaced is a polyurethane.

A material which has been found especially useful for forming the polymeric strata is a modified epoxy adhesive similar to that used in the aircraft industry for fabricating helicopter rotor blades. The particular adhesive found suitable for this application has an acrylonitrile butadiene modifier and is produced by American Cyanamid Company under a nomenclature of WE 4030–D. Other modified epoxy adhesives such as a group manufactured by Minnesota Mining and Manufacturing Company might also be used in this application.

The American Cyanamid adhesive identified above has been found to have the desirable wetting ability for the cantilever spring when thinned with an appropriate solvent; the adhesive also has the elastomeric or resilient properties desirable for the prevention of high concentrations of stress in the hammer or the spring members. This adhesive also has the ability to bond well with the thermoplastic material employed in the hammer member's body portion and has the needed high-temperature stability to permit molding of the hammer body structure around a spring member which has been adhesive-coated. The selected adhesive material is also found to possess delayed curing properties which permit curing of the adhesive strata following molding and cooling of the hammer body structure.

Once the concept of fabricating both the hammer and the hammer-to-spring bond during the molding process is accepted, several alternatives are available as to the configuration of the hammer-to-spring fastening structure. One of these alternatives consist of attaching the spring to a face of the hammer body, so that the spring-to-hammer bond is external to the hammer body itself; another alternative is to locate the spring-to-hammer bond entirely within the hammer body, so that the elastomeric adhesive resilient coupling is located within the molded structure of the hammer. Location of an elastomeric adhesive member within a moldable part represents a departure from the conventional in molding operations but offers several advantages in strength of bonding and ease of fabrication.

A notable feature of the present invention is that reliable and long-lived attachment is accomplished between a metal member and a plastic material which is thermoplastic in nature; that is, the plastic material utilized for the hammer body is one which may be repeatedly cycled between the resilient and viscous states simply by applying heat and cooling. In the present embodiment of the attachment invention, the use of a thermoplastic material was a first consideration because of the desirable physical and manufacturing properties available in nylon, a polyamide, thermoplastic material.

In the printer hammer embodiment of the attachment invention, the nylon material employed in the hammer body affords desirable properties of resilience, density, and moldability along with relatively good dimensional stability and mold shrinkage properties. In the specific high-speed printer described, the properties of the nylon material are further modified by the addition of a stiffening filler material before the nylon is molded and by the addition of frontal and rearward insert members to the nylon hammer body.

In FIG. 2A of the drawings, a detailed view of a metal spring member attached to a nylon hammer body in accordance with the present resilient attachment invention is shown. In FIG. 2A, the numeral 60 is used to identify the modified epoxy adhesive which bonds the metal spring member 31 to the nylon hammer body member 28. The numeral 64 in FIG. 2A refers to the interface between the nylon body material and the adhesive material 60. As will be indicated below, the formation of this interface occurs while the nylon and the adhesive materials are in a viscous or semiviscous state, so that an interface which engages the maximum surface area of both the nylon body and the epoxy adhesive is formed. The numeral 70 in FIG. 2A refers to the interface between the metal spring member 31 and the adhesive material 60 in the fastening structure. As will be described below, this interface is fabricated while the adhesive material is in a viscous state resulting from dilution with a solvent. The diluted adhesive is caused to wet the spring surface, so that a close, intimate bond that is free of voids is realized between adhesive and metal materials.

In speaking of a bonded coupling or an adhesive joint, it is common practice to consider microscopic behavior of the two materials which make up the interface regions between members. A tutorial paper which defines some of the relationships found in an adhesive interface is the paper "The Mechanism of Bonding," by Dieter Kitscha, of the Illinois Institute of Technology Research Institute, Chicago, Ill., published by and delivered at the Industrial Adhesives Applications University Extension, University Extension, University of Wisconsin, Feb. 22, and 23, 1968. That paper also contains references to authoritative publications in the structural adhesives art.

From FIG. 2A, it is apparent that the curved end region of the spring member 31 serves two purposes in the hammer structure; the curved region permits a large surface area of the spring and the body material to be exposed to each other and thereby permits an adhesive bond having larger surface area to be formed; the curved region also provides mechanical locking or anchoring of the spring within the hammer body. Better shapes than the selected curve are readily available for mechanical locking of the spring within the hammer body; however, the selected circular curve offers the advantage of inducing minimum stress concentrations and minimum cold working of the spring material during shaping of the curve.

In FIG. 2A it will be noted that the adhesive material 60 continues its coating of the spring surface into the fillet region of the hammer body, so that no region of the spring is exposed directly to the nylon hammer body material without the intervening epoxy adhesive coating. It is found desirable to construct the spring fastening in this fashion in order that the fillets 69 and 37 may be formed of resilient material and attached to the spring. The fillets 69 and 37 are incorporated into the hammer structure to save the spring member 31 from exposure to a region of abrupt change in support; without the fillets and the gentle change of supporting structure for the spring that they provide, the spring would be subject to maximum flexure and stress concentration in the region adjacent to the hammer body and would thereby be subject to rapid failure. The fillets provide support for the spring members which decreases in rigidity as the distance from the hammer body increases.

The degree of flexure to which the cantilever spring body is exposed is limited in the printer mechanism by the stop members 29 and 33 shown in FIG. 1 of the drawings.

In constructing the resilient fastening for the spring member into the hammer body as shown in FIG. 2A, the spring member is made narrower in width than the body 28 of the hammer member. This relationship provides for the body material of the hammer to extend over the edges of the spring's anchored end, as indicated in FIG. 1 of the drawings. The greater width of the hammer body as compared to that of the spring also provides support and anchoring for the fillet members 69 and 37 at the edges of the spring material..

As indicated in FIG. 2A, the interior surface of the spring's curving end is engaged by way of an epoxy adhesive coupling also identified by the numeral 60. The member which is interior to the curving surface of the spring is identified with the numeral 30 in FIG. 2A. This member has the shape of a plug or a small cylinder. As will be described later, this plug is installed

into the hammer following fabrication of the hammer body member proper and fills a void remaining in the hammer following molding. The plug 30 is anchored to the body portion of the hammer by the combination of its ends being directly exposed to the hammer body material (because of the hammer body's being wider than the spring member) and by the plug's being exposed directly to the hammer body material in the region where the spring's curve does not close upon itself, the region identified as 40 in FIG. 2A. In one embodiment of the invention, the plug 30 is composed of nylon, and the adhesive used is the same as that employed on the spring members 31 within the hammer body. Alternate construction for this plug is possible; one such alternate which has been found useful is to fill the molding hole with a low-shrinkage epoxy material which is later cured to the resilient state. By adhering to both the spring member and the hammer member, this epoxy filling has been found to provide a high strength fastening for the spring. The epoxy filling technique has been found less costly to fabricate than is the nylon plug structure.

FIG. 3 of the drawings shows how the modified epoxy adhesive used for bonding the curved end of the cantilever spring may also be used in bonding the lower end of several cantilever springs to a header plate. In FIG. 3, the number 75 identifies a metallic header plate having holes 77 pierced through it at periodic intervals. The line 76 in FIG. 3 represents a cutaway portion of the adhesive coating, the header portion above the line 76 being uncoated, while the portion below the line 76 where contact with the springs occurs is coated. As shown in FIG. 1 of the drawings, the assembly comprising a header plate and several cantilever spring members is mounted with machine screws between two resilient members 34 and 35 onto the printer frame. The resilient members 34 and 35 each have cutaway nesting areas which receive the spring and header plate members. The resilient members 34 and 35 are also designed to incorporate fillets similar to those described for the hammer member itself. These fillets are designated 36 in FIG. 1, and they serve to prevent abrupt flexing of the cantilever spring members and failure which would otherwise occur near the spring-supporting structure.

As was the case for the hammer end of the cantilever spring members, the use of an epoxy adhesive for attaching the lower end of the cantilever spring members to the printer frame member alleviates need for welding or piercing or other attachment methods which had proven to be detrimental to the fatigue resistance of the spring. Although FIG. 3 shows each of the cantilever spring members to be partially removed in mating the springs with the mounting holes 77 in the header plate, the point at which the spring material is removed is located well into the immovable area of the spring in a region which is held rigid by the clamping pressure of the machine screws shown in FIG. 1. Partial removal of the cantilever spring material as shown in FIG. 3 is used as an aid in properly positioning the cantilever springs during manufacturing.

In fabricating the attachment structure of the present invention into the illustrated printer hammer embodiment, it has been found practical to employ a method in accordance with the following steps.

For the spring-to-hammer body attachment:

1. Cleaning the spring members 31 at their curved ends using a sequence of vapor degreasing, trichloroethylene bath, methyl ethyl Ketone bath, sodium dichromate solution bath at 150° F., and plural rinses in distilled or deionized water. The sodium dichromate solution may have the proportions of 450 grams of sodium dichromate to 408 milliliters of 1.8354 specific gravity sulfuric acid to 2,550 milliliters of distilled water. It has been found desirable to process the springs for several minutes in each of these baths and to dry the springs between each of these baths and following the final bath. It has also been found desirable to accomplish the next step of the process, that of applying adhesive, within 1 hour of completing the cleaning step.

2. Applying to the curved end of the spring 31 on its convex surface a coating of adhesive. When the American Cyanamid WE 4030–D adhesive is employed, it has been found practical to spray this coating of adhesive onto the springs. To provide desirable spraying properties and to assure wetting of the spring surface by the adhesive, it has been found desirable to dilute the adhesive as received from the manufacturer with methylene chloride in the proportion of 8 ounces by volume of adhesive to 600 milliliters of methylene chloride.

3. Drying the adhesive coating. To achieve drying, it has been found desirable to use a combination of room temperature drying for 1 hour followed by oven drying at 160° F. for 20 minutes, in order that complete removal of the adhesive solvent may occur and solvent entrapment not take place.

4. Mounting adhesive-coated spring members 31 on a holding and locating pin within a molding die.

5. Placing the frontal and rearward insert members of the hammer (62 and 41, respectively, in FIG. 2) in the molding die. Prior to die insertion, these members are cleaned with a standard vapor degreasing sequence.

6. Forcing molten hammer body material into the molding die. Hammer body material which is composed of 40 percent glass filler in nylon (called Nylafil G 10/40 by one manufacturer, a division of Rexall Drugs, located in Evansville, Ind., has been found desirable for the hammer member. In molding the springs 31 into the hammer composed of this material, it has been found desirable to maintain the die temperature at 160° F. and the nylon-injecting nozzle at a temperature of 570° F., and to inject with a pressure between 450 and 550 p.s.i. These parameters have been found satisfactory when a "Unimatic" molding press and a 10-cavity die are employed. Slight variations in these parameters may be desirable if different molding equipment is employed, as will be apparent to a person skilled in the art.

7. Plugging the hole left within the hammer by the spring mounting pins of the molding die. This plugging can be accomplished in desirable fashion by coating both the interior of the hole and the exterior of the plugging rod with a quantity of the WE 4030–D adhesive, then inserting the rod into the hole and trimming the rod ends to length. For use in plugging the die holes in the hammer, the WE 4030–D adhesive has been found satisfactory either as received from the manufacturer or when slightly diluted in the proportions of 8 ounces by volume of adhesive to 4 ounces by volume of methylene chloride.

8. Drying and curing the adhesive bonds (both the spring-to-hammer bonds and the nylon plugging rod bond). This drying and curing step has been found acceptable for the WE 4030–D adhesive when accomplished in the sequence of 1 hour of room temperature air drying followed by 40 minutes of oven baking at 340° F.

9. Smoothing the hammer surface around the plugged holes by clipping, scraping, and grinding the plug insert and adhesive runout.

10. Testing a sample quantity of hammers for pullout strength of the spring-to-hammer bond. The average pullout strength should be 42 pounds or more with a range of 25 pounds or less and a minimum no lower than 35 pounds when tested on a sample of 13 hammers (each having two springs) out of a batch of 140 hammers.

For the spring to header plate bonding (the member 31 to the member 75 in FIG. 3 of the drawings:

1. Clean the spring ends and header plates by the process described in step 1 above.

2. Coat the mountable surface of the springs with a coating of adhesive measuring between 2 and 5 thousandths of an inch in thickness. This coating may be of the same adhesive and performed in the same manner as in step 2 above.

3. Coat the mountable surface of the header plate with a coating of adhesive measuring between 2 and 5 thousandths of an inch in thickness. This coating may be of the same adhesive and performed in the same manner as in the previous step.

4. Dry the coated parts by a combination of 1 hour of drying in air at room temperature followed by 20 minutes of drying in an oven at 160° F.

5. Load the coated header plates and the hammers having coated spring ends into a holding and curing fixture which is capable of bringing the parts together in the proper relationship under force and while applying heat.

6. Curing the adhesive material. For the WE 4030–D adhesive, this curing can be accomplished by maintaining an adhesive temperature of 350 ° F. for 10 minutes.

7. Testing a sample quantity of hammers for failure strength of the spring-to-header-plate bond. All the tested bonds should fail above 30 pounds when loaded in shear.

Although the above steps for making the adhesive bonds and the earlier descriptions of the bonds in this specification indicate the use of an adhesive made by American Cyanamid Corporation and designated as WE 4030–D by the manufacturer, the scope of this invention is not limited to the use of this or any single material as an adhesive. Another adhesive which has proven to give satisfactory performance in the print hammer embodiment is one manufactured by Minnesota Mining and Manufacturing Company and designated as EC 2290. The EC 2290 adhesive is also applicable to the parts in a spray process, as is possible with the WE 4030–D adhesive.

In both the process for fabricating the print hammer and the structural description of the print hammer in this disclosure, the use of a nylon rod segment at 30 to plug the molding die hole is indicated. Although plugging the die hole with an adhesive-coated nylon rod gives satisfactory fastening anchorage of the metal spring, as mentioned above, it has been found that other techniques for filling the die hole are capable of providing satisfactory spring fastening at lower overall cost than does the nylon rod plugging technique. One of these other techniques for filling the die hole consists of employing an epoxy adhesive in viscous form to completely fill the hole and bond with both the hammer material and the spring material. If this technique is employed with an epoxy material and a curing technique which limits shrinkage along the diametrical axes of the die hole in favor of shrinking along the cylinder length axis of the hole, it has been found that a satisfactory and inexpensive plugging of the hole is produced.

In this specification, the fatigue-resistant attachment has been disclosed in the embodiment of a technique for fastening metal supporting springs within the molded body of a printing hammer. It will be apparent to a person skilled in the art that the disclosed attachment is directly applicable to other members in other types of high-speed mechanisms and that application outside the mechanisms art is also possible. Examples of other arts where the disclosed attachment is applicable is the attachment of metal hinges within the plastic frame members of eyeglass frames and the attachment of members to the framework of human prosthetic devices.

While examples of structure composition and methods of making have been described for purposes of illustration, the invention is not limited by these but includes variation and modification within the scope of the disclosure and claims as may be performed by a person skilled in the art.

We claim:

1. A steel flexure-spring supported ballistic print-hammer apparatus comprising:

a polymeric material hammer member having a holelike receptacle having substantially cylindrically shaped walls, the receptacle cylindrical axis being transverse to the length of said polymeric material hammer member;

at least one steel flexure-spring fixedly connected at one end thereof to said polymeric material hammer member for supporting and guiding said polymeric material hammer member;

a first layer of elastomeric structural adhesive material adherently disposed on said cylindrically shaped walls of said holelike receptacle of said polymeric material hammer member;

said one end of said steel flexure-spring having a substantially closed circular shape including external and internal curving surfaces, said external curving surface being adherently mated with said first layer of elastomeric structural adhesive material within said holelike receptacle;

a second layer of elastomeric structural adhesive material adherently disposed on said steel flexure-spring internal curving surface;

and a polymeric material pin member of substantially circular cross section, said polymeric material pin member being located within said substantially closed circular shape of said end portion of said steel flexure-spring and being adherently mated with said second layer of elastomeric structural adhesive material;

whereby said polymeric material pin member, said second layer of structural adhesive material, said one end of said steel flexure-spring, said first layer of structural adhesive material, and said cylindrical walls of said holelike receptacle are arranged in a nested coaxial relationship wherein said external and said internal curving surfaces of said one end of said steel flexure-spring having said substantially closed circular shape provides both mechanical anchoring for said steel flexure-spring and a large bonding surface therefor.

2. A steel flexure-spring supported ballistic print-hammer apparatus as in claim 1 wherein said first and second elastomeric structural adhesive layers are made of epoxy adhesive material containing an acrylonitrile butadiene modifier.

3. A steel flexure-spring supported ballistic print-hammer apparatus as in claim 1 wherein the apparatus also includes

a first metal plate member located at the end of said steel flexure-spring opposite said polymeric material hammer member, said first metal plate member being of width greater than the width of said steel flexure-spring;

a first layer of elastomeric structural adhesive material adherently disposed on said first metal plate member and one lateral surface of said end of said steel flexure-spring opposite said polymeric material hammer member;

a second metal plate member located at said end of said steel flexure-spring opposite said polymeric material hammer member, said second metal plate member being similar in size to said first metal plate member; and

a second layer of elastomeric structural adhesive material adherently disposed on said second metal plate member and the remaining lateral surface of said end of said steel flexure-spring opposite said polymeric material hammer member.

4. A steel flexure-spring supported ballistic print-hammer apparatus as in claim 3 wherein said first and second layers of elastomeric structural adhesive material adherently disposed on said first and second metal plate members are composed of epoxy adhesive material containing acrylonitrile butadiene as a modifier.

5. A steel flexure-spring supported ballistic print-hammer apparatus as in claim 1 wherein said polymeric material hammer member including said cylindrically shaped walls upon which said first layer of elastomeric structural adhesive material is disposed are composed of nylon material containing short randomly oriented particles of fiberglass.

6. Stress limiting attachment apparatus for securely joining a metal flexure support element to an internal portion of a polymeric material printing member in a long-life coupling tolerant or repeated bending in said flexure support element and impact acceleration of said polymeric material printing member, said attachment apparatus comprising the combination of:

a polymeric material body portion for said printing member, said body portion including cavity means located transverse of, and near an end of, said body portion for attaching said metal flexure support element to said body portion, said cavity means including a curving internal bonding surface portion and means for admitting said metal flexure support element thereto;

a shaped end portion of said metal flexure support element, said shaped end portion having a curving configuration with an internal surface and an external surface, the external surface being closely conformed to the shape of said body portion cavity means curving internal bonding surface portion;

an organic material cavity filling means member located within said curving configuration of said shaped end portion of said metal flexure support element and closely conformed in configuration with said shaped end portion interior surface for filling the unoccupied portion of said cavity means and for supporting said shaped end portion of said metal flexure support element in conformity with said cavity means curving internal bonding surface portion;

elastomeric structural adhesive bonding means located between said shaped end portion external surface of said metal flexure support element and said cavity means internal bonding surface portion of said polymeric material body portion and between said shaped end portion internal surface of said metal flexure support element and said organic material cavity filling means for bonding said shaped end portion of said metal flexure support element to said polymeric material body portion cavity means and to said organic material cavity filling means;

whereby said metal flexure support element is retained within said body portion by a combination of mechanical anchoring and structural adhesive bonding means, said structural adhesive bonding means also providing a stress limiting interface between the relatively hard and rigid metal of said flexure support element and the relatively soft and resilient polymeric material of said body portion during dimensional alteration thereof by the strain of high energy impact acceleration.

7. Stress limiting attachment apparatus as in claim 6 wherein said elastomeric structural adhesive bonding means includes an epoxy structural adhesive modified with acrylonitrile butadiene.

8. Stress limiting attachment apparatus as in claim 6 wherein said organic material cavity filling means member includes a pin member composed of epoxy structural adhesive material.

9. Stress limiting attachment apparatus as in claim 6 wherein said organic material cavity filling means member includes a pin member composed of nylon.

10. Stress limiting attachment apparatus as in claim 6 wherein said elastomeric structural adhesive bonding means includes adhesive bonding material extending along said metal flexure support element away from said shaped end portion and to the exterior of said polymeric material body portion whereby the stiffness of said metal flexure support element is graduated by said adhesive bonding material in the metal flexure support element region joining said shaped end portion.

11. Apparatus for supporting a nonmetallic printing member from a stationary structural portion of a printing mechanism; said apparatus comprising:

at last one metal flexure support element connected at a first end portion thereof with said nonmetallic printing member and at a second end portion thereof with said stationary structural portion of said printing mechanism;

attachment means for attaching said first end portion of said metal flexure support element to said nonmetallic printing member;

a first plate member rigid with respect to said metal flexure support element and located adjacent said second end portion thereof, and located between said second end portion and said stationary structural portion of said printing mechanism, said plate member being of at least twice the lateral width of said flexure support element;

a second plate member substantially similar in size to said first plate member and rigid with respect to said metal flexure support element and located facing said first plate member with said metal flexure support element second end portion being located between said first and second plate members;

elastomeric structural adhesive bonding means located between said metal flexure support element second end portion and said first plate member and between said flexure support element second end portion and said second plate member for bonding said flexure support element second end portion to said first and second plate members and for uniting said flexure support element and said plate members into a unitary assembly;

means for attaching said unitary assembly to said stationary structural portion of said printing mechanism;

whereby said plate members and said elastomeric structural adhesive bonding means retain said second end portion of said metal flexure support element in a sandwichlike structure providing large bonding surfaces and graduated rigidity for said flexure support element at said second end portion, and said plate members provide a manifold structure capable of uniting a plurality of flexure support elements and associated printing members into a unitary assembly for convenient insertion and removal from said printing mechanism.

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