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(54) COMPOSITE PART AND METHOD FOR THE PRODUCTION THEREOF

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(57) ABSTRACT

Process for producing a composite structural element from a metal structural element (4) and a plastics structure (1), in which the metal structural element, which has at least one surface with at least one punched rim or punched collar (7), and the plastics structure are pressed together with the aid of one or more joining tools (11, 13, 26, 29, 32, 37), the punched rim/collar penetrating into or through the plastics structure in a positively and nonpositively locking manner.

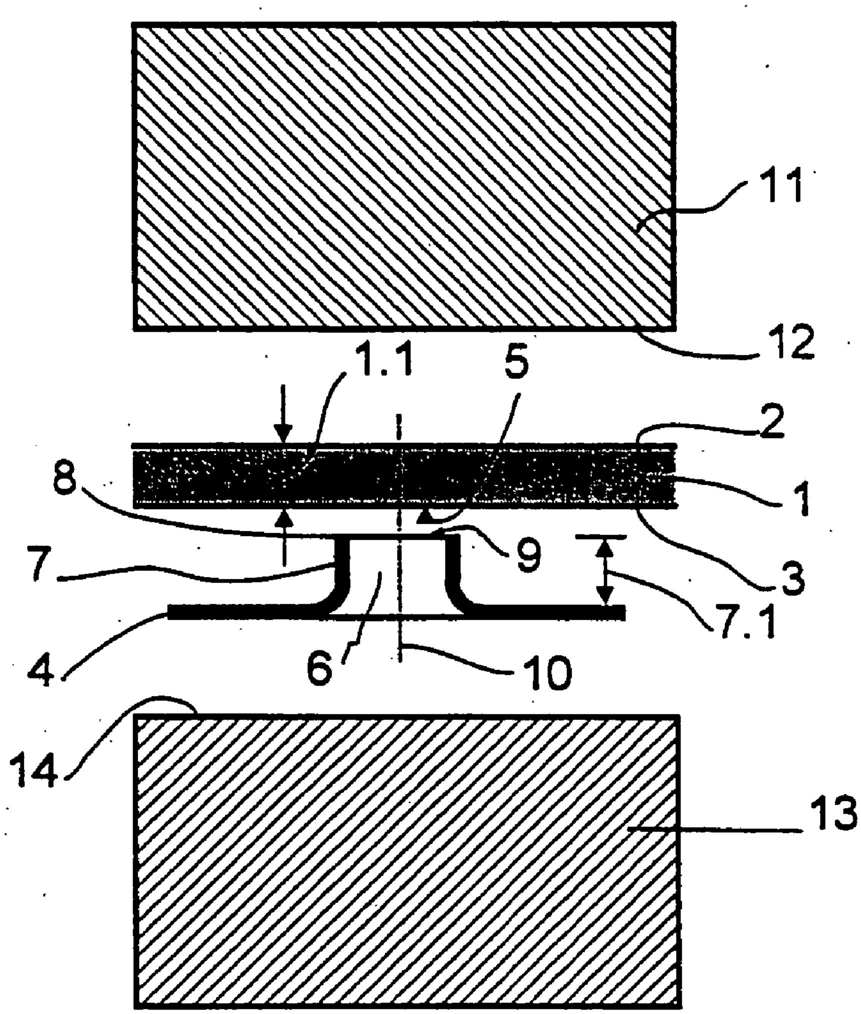


FIG.1

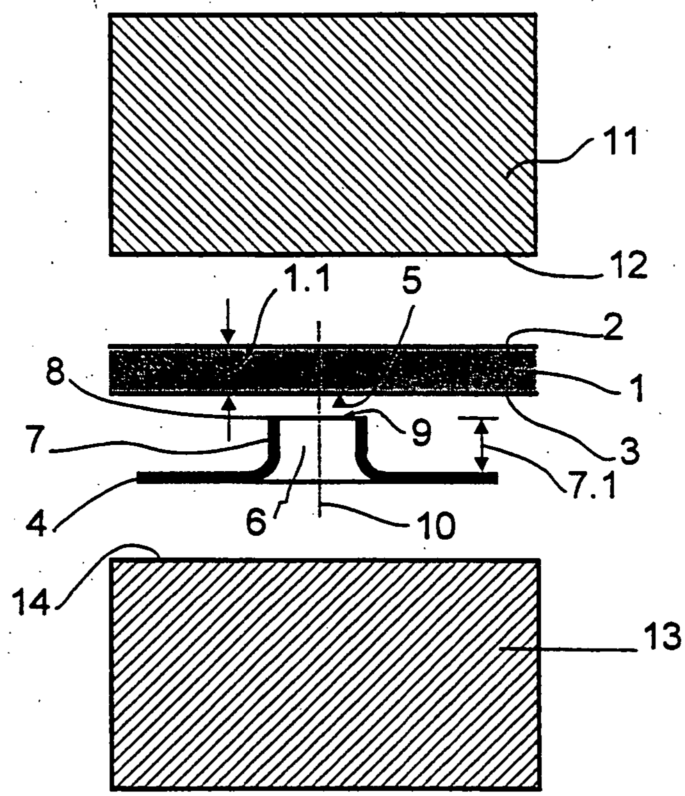


FIG.2

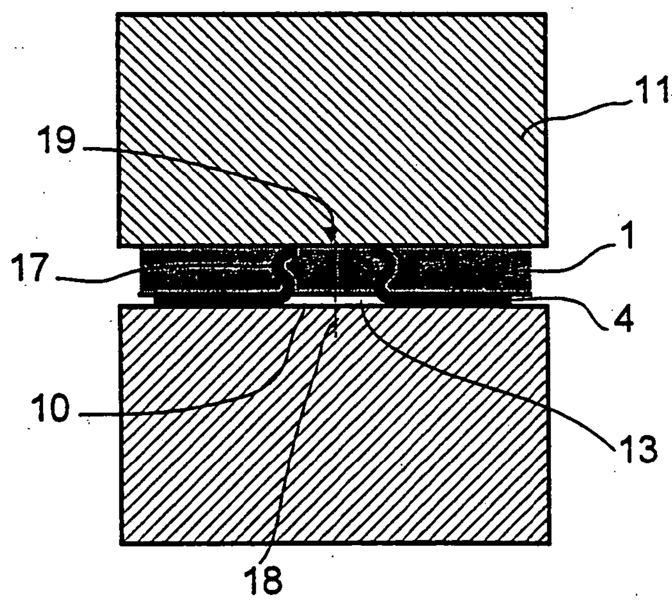


FIG.3

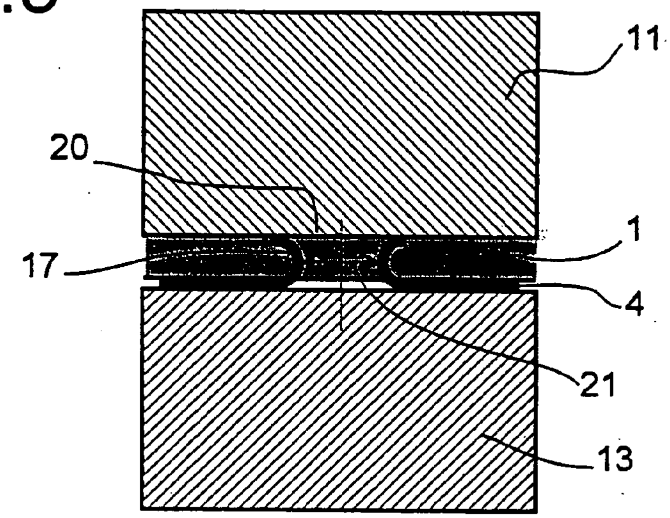


FIG.4

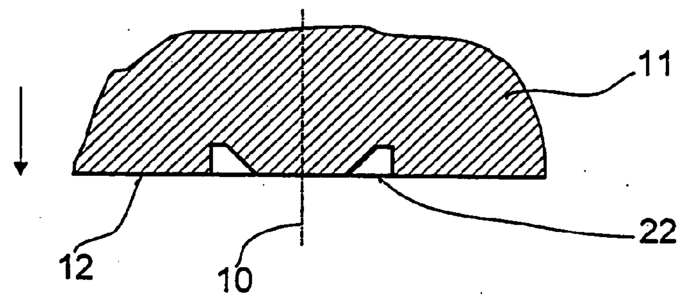


FIG.5

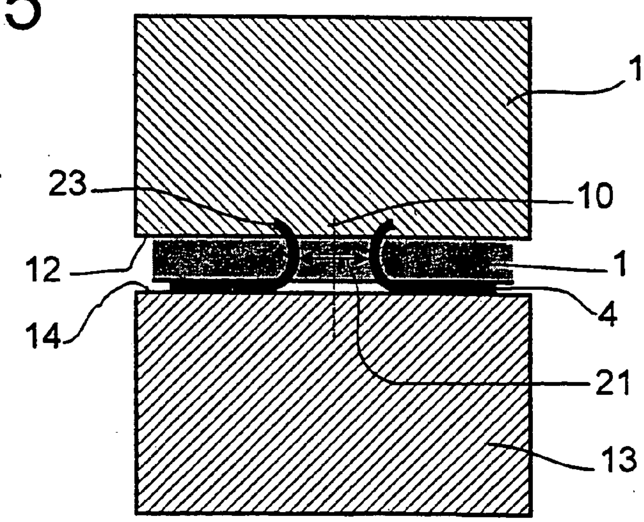


Fig. 6

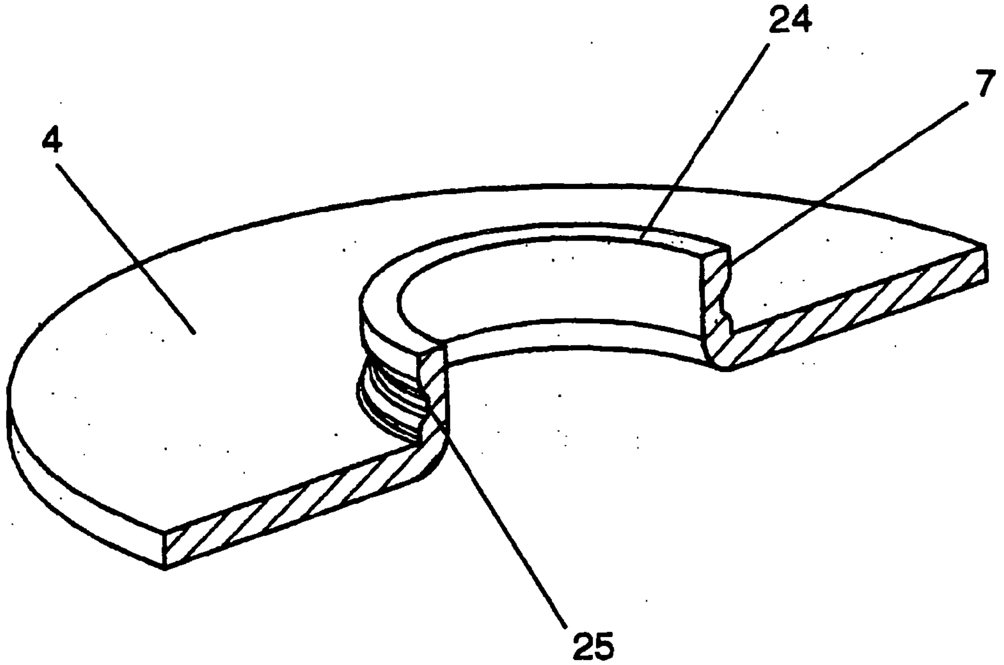


Fig. 7

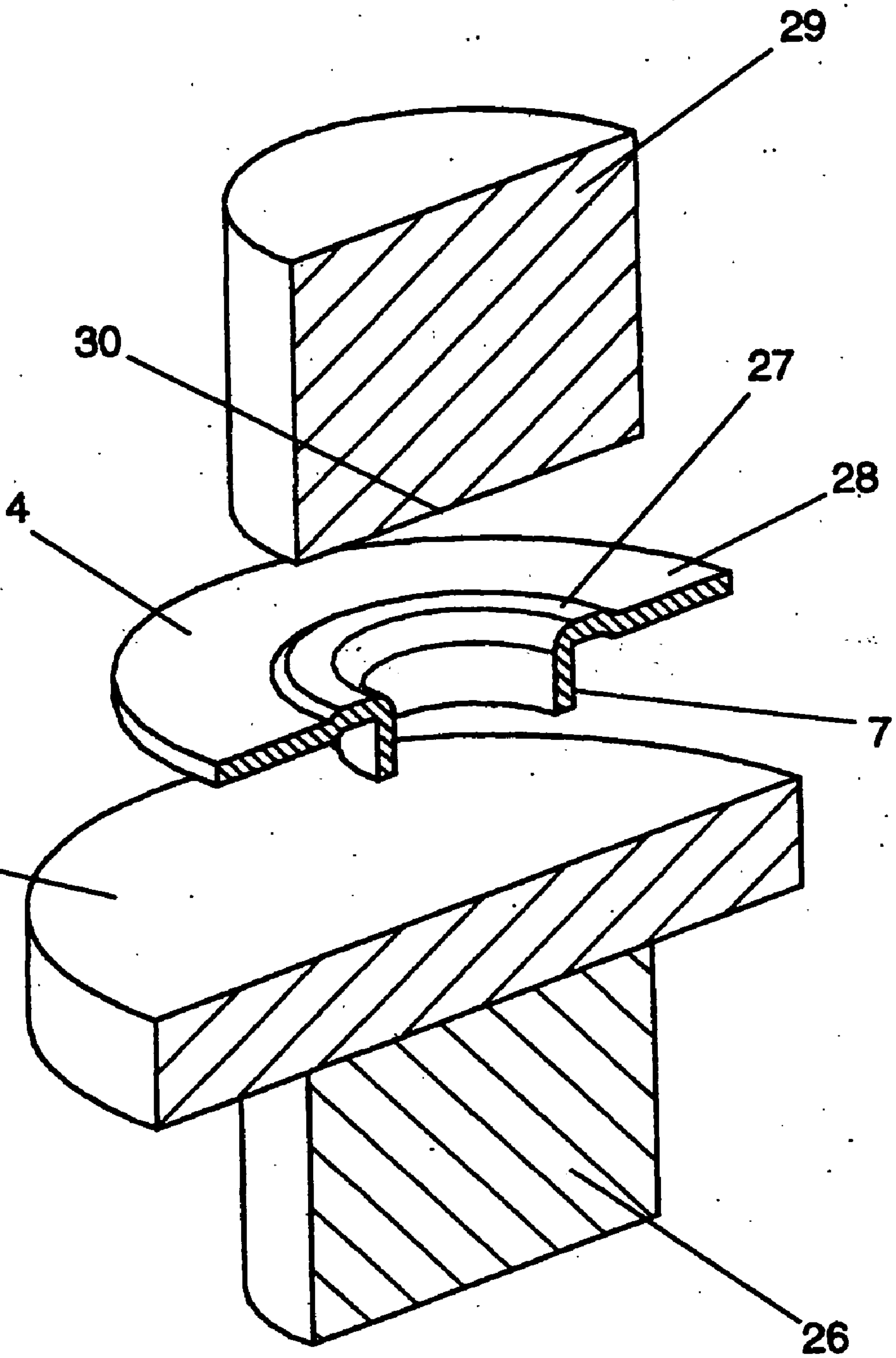


Fig.8

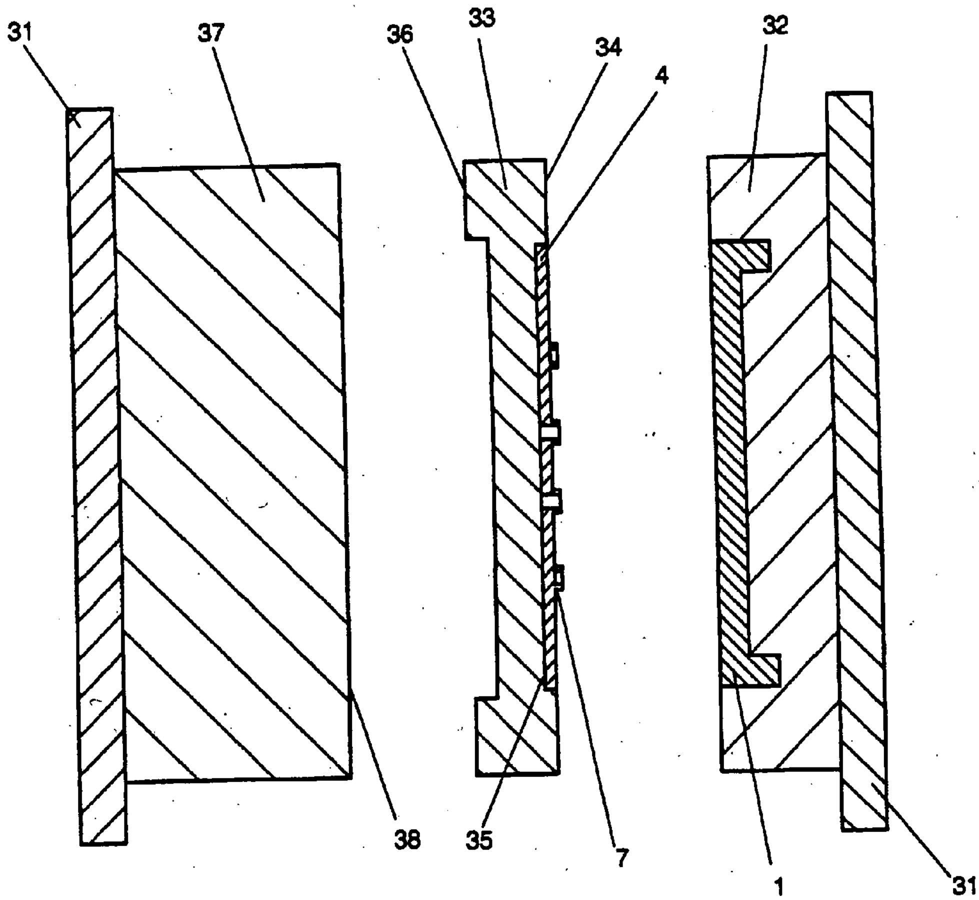
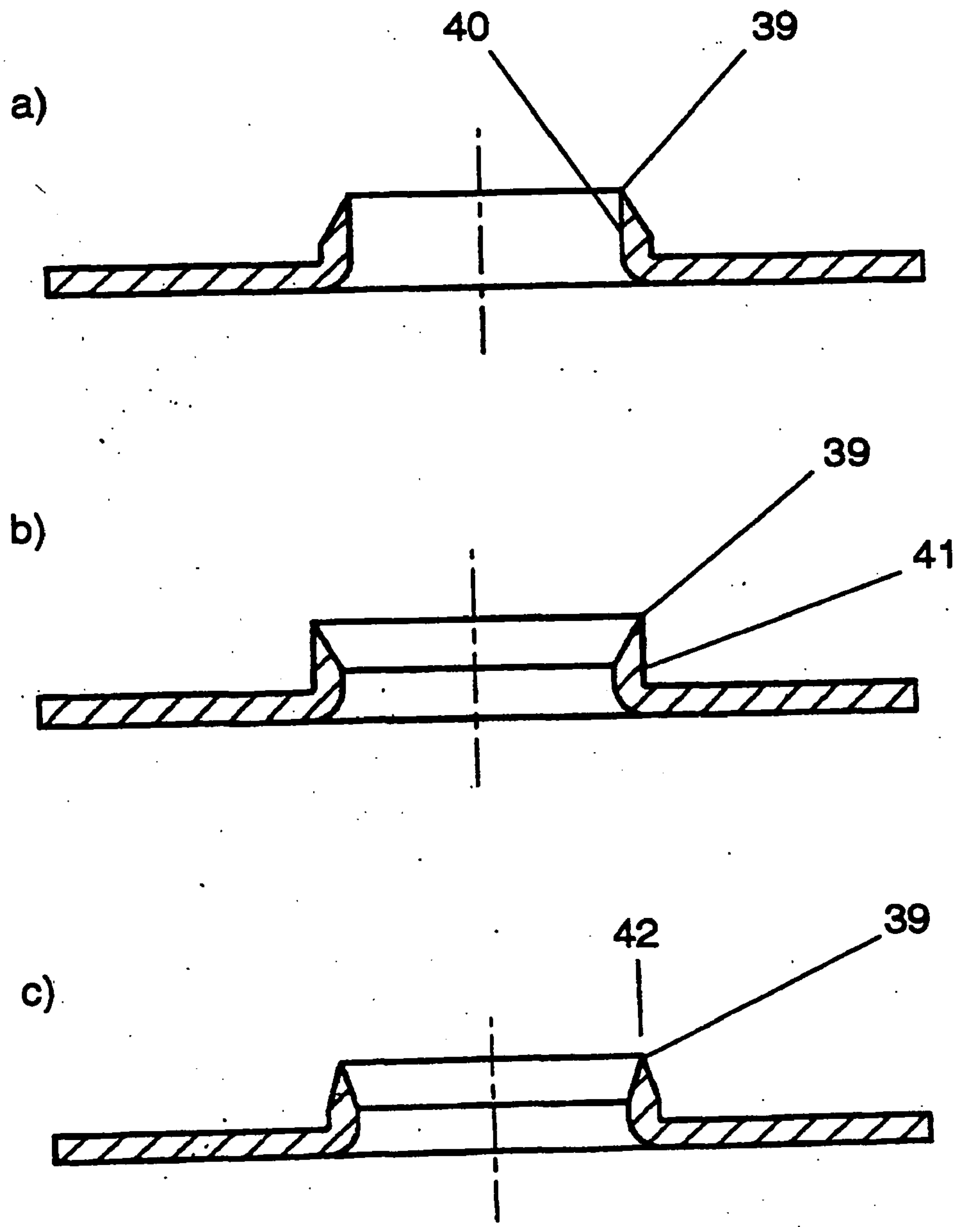


Fig. 9



COMPOSITE PART AND METHOD FOR THE PRODUCTION THEREOF

[0001] The invention relates to a composite structural element, in particular to a plastic/metal connection having a positively and nonpositively locking engagement, a process for producing it and to the use of these composite structural elements as structural elements or structural element components in automotive engineering, aircraft construction or shipbuilding or in the production of domestic or electric appliances. Furthermore, the invention relates to front-end modules, front-end supports, seat pans, seat structures, side doors, instrument panel supports, functional supports for doors, functional modules for doors, tailgates, washing machines, refrigerators or dishwashers containing the composite structural element according to the invention.

[0002] EP-A 0 370 342 relates to a lightweight structural element. This has a shell-shaped basic body, the interior space of which has reinforcing ribs, which are firmly connected to the basic body. The reinforcing ribs consist of molded-on plastic, the connection to the basic body taking place at discrete connecting locations via apertures in the basic body, through which the plastic passes and over the surfaces of which it extends. This process for molding the plastics molding compounds onto the metal plate placed into the injection mold is very complex and sensitive to tolerances. It requires high expenditure in terms of mold technology. A high level of scrap often cannot be avoided.

[0003] Furthermore, a new, usually complicated, injection mold is required for each new model variant or modification, which further increases the cost of the process. Series production therefore often entails incalculable risks. Further metal/plastic connecting techniques are described in European Patent Application EP-A 1 084 816. These are said to lead to a reduced level of product scrap. By way of example, the document discloses adhesive bonding of metal and plastic over part or all of the surface in the contact areas, followed by the formation of plastic rivets by melting in the apertures of the metal plate, joining by screws or snap-action lugs and by flanging over tabs on the metal sheet in the region of the rims or apertures of the plastics structure. However, these joining techniques require either the use of further materials, for example adhesives or screws, or additional process steps.

[0004] Finally, a further process, which is described in the as yet unpublished German patent application with the application number 100 14 332.6, can be used to produce a composite structural element which comprises a hollow-profile basic body. The hollow-profile basic body has a hollow-profile cross section which can be produced by the internal high-pressure forming process. At least one plastics element is firmly connected to the hollow-profile basic body. The plastics element is molded onto the hollow-profile basic body and its connection to the hollow-profile basic body takes place at discrete connecting locations by partial or complete sheathing of the hollow-profile basic body.

[0005] Plastic-metal composite structural elements produced according to the process outlined above, which are also referred to as hybrids or hybrid structural elements, are used in a corresponding configuration in motor vehicles. The hybrid structural elements generally have a shell-shaped basic body or a hollow profile made of metal and a plastics structure firmly connected to it. The metallic basic body gives the composite structural element the fundamental rigidity and strength. The plastics structure serves on the one hand for further increasing the rigidity and strength, on the other hand for the functional integration in the sense of forming a system and module, in addition to a weight reduction. Especially suitable applications for hybrid structural elements are in automotive engineering, for example the front-end supports or front-end modules, instrument panel modules or instrument panel supports, functional supports for doors, functional modules for doors and similar structural elements for tailgates or rear doors.

[0006] In view of the prior art solutions presented, it is an object of the present invention to provide a hybrid structural element by using a commercially available joining process, the hybrid structural element being distinguished by increased rigidity and strength, given a comparable weight, and being readily suitable for series production.

[0007] We have found that this object is achieved by a process for producing a composite structural element from a metal structural element and a plastics structure, the metal structural element, which has at least one surface with at least one punched rim or punched collar, and the plastics structure being pressed together with the aid of one or more joining tools, the punched rim/collar penetrating into or through the plastics structure in a positively and nonpositively locking manner.

[0008] A permanent positively and nonpositively locking connection can be achieved at the joining location by pressing together the plastics structure and metal structural element.

[0009] Customary presses or punching and/or deep-drawing machines that are suitable for sheet metal working or forming, or similar joining machines working hydraulically or on the basis of some other operating principle, may be used for the joining, i.e. pressing together, of the metal structural element and plastics structure. These machines are generally equipped with one or more tools, which are adapted as far as possible to the contour of the composite structural element or elements, at least from the side of the plastics structure and in particular in the region of the joining points. When joining, to avoid ruptures or cracks, it usually has to be ensured that the metal component and the opposite plastics structure bear with their respective rear sides at the connecting/joining location or locations or in their respective direct vicinity against the tool directly and in planar contact, or the respective tools have correspondingly shaped bearing or pressure points in these regions.

[0010] For producing higher numbers of items, the joining machines may be equipped with one or more tools which are adapted as exactly as possible to the contours of the components respectively to be joined of the hybrid structural elements, i.e. the composite structural elements, at least from the side of the plastics structure and in particular in the region of the joining points, the joining force being introduced in an optimum way such that the metallic body bears against the mold on the one tool side and the opposite plastics body bears against the tool on the other tool side, at least at the connecting locations or in their direct vicinity.

[0011] If there are a plurality of punched rims/collars on a metal structural element, these can be pressed into the plastics structure simultaneously and, in particular in the case of large-format composite structural elements, e.g. front-end modules, sequentially. The same also applies to composite structural elements in which the joining points do not lie in one plane but on a curved surface or line. For the case of sequential pressing-in, it is preferred to revert to tools of a contour which itself is not planar, but has a continuous or stepped convexity. In the case of sequential pressing-in or joining, punched collars, which are located for example in the edge region of the joining tool surface, are possibly only partially pressed in. This only partially joined punched collar can be completely pressed into the plastics structure in one go or bit by bit during subsequent joining operations, the joining tool being regularly repositioned in each case. For the sequential joining of punched collars, it is recommendable for example to use a joining tool similar to tongs, which can also be used under robot control.

[0012] In a further embodiment of the invention, the joining operation is not performed by a separate joining machine but in the injection-molding machine in which the plastics structure of the composite structural element has previously been injection-molded. For this purpose, after the injection-molding of the plastics structure, the injection mold is opened, the plastics structure remaining in the mold. The metal structural element to be joined, which has at least one surface with a punched rim, is introduced into the opened injection mold, i.e. between the two mold halves of the injection mold, and brought into the desired joining position in relation to the plastics structure. The punched rim or rims are located on the side facing the plastics structure. The punched rim or rims is or are pressed into the plastics structure, and form a positively and nonpositively locking connection, by the mold halves of the injection-molding machine being moved together again. The composite structural element according to the invention can then already be removed from the injection-molding machine when it is opened again.

[0013] It has proven to be advantageous to introduce a deformation-resistant or stable female die between the metal structural element and the rear injection mold half before the closing or joining operation of the injection molding machine and to position it, the front side of which female die advantageously receives the contour of the metal structural element, in particular in the region of the joining points, and which is supported on the rear side on the rear injection mold half, if appropriate also on the platen of this injection mold half. In this case, the metal structural element does not bear directly against the rear mold half of the injection mold, but instead the rear shape of the metal structural element is received by the front surface of the female die. During the pressing operation, this female die is in indirect or direct contact with the rear mold half of the injection mold. The pressure of the rear injection mold half can be transferred, for example via special resting male dies, to the female die and/or the rear mold half, which can also be subsequently inserted, after the injection-molding of the plastics structure, or via the mold frame to the female die. Furthermore, the rear side of the female die may also receive the surface contour of the rear mold half. In one embodiment, the metal structural element and the female die can already be placed one on top of the other, in such a way that they fit, before introduction into the injection mold, and subsequently be introduced into the opened injection mold and brought into the desired joining position and possibly arrested.

[0014] Joining in the injection-molding machine has the advantage that the joining operation can be readily carried out even when the plastics structure is at an elevated temperature. The punched rim regularly penetrates more easily into the still warm plastics material, thereby avoiding damage to the metal structural element and/or plastics structure and also avoiding scrap. Furthermore, the joining operation can be carried out in a simple way at an identical temperature of the plastics structure with every new composite structural element to be joined, for example with the aid of suitable temperature sensors, whereby a high degree of reproducibility is ensured. It goes without saying that it is also of advantage that it is possible to dispense entirely with a separate joining machine.

[0015] Joining of the punched collar, also known as joining of the punched rim, in the injection-molding machine is recommendable in particular whenever the height of the punched collar is less than the thickness of the plastics structure at the location to be joined, that is to say the punched rim only penetrates into the plastics structure, but does not penetrate through it.

[0016] The joining allows an elevation made in the form of a punched collar or punched rim in the metallic basic body to be braced or clasped in the wall of the plastics structural element, so that a positively and nonpositively locking connection is produced. The joining operation allows the punched rim or punched collar to be deformed already as it penetrates into the body of plastic. The shape of the projection deformed by the joining operation can be influenced on the one hand by the setting angle, the height and cross-sectional profile of the undeformed projection on the metallic structural element, and on the other hand by the shaping of the joining tool.

[0017] With the process proposed according to the invention, both conventional plastics structures, which are for example at ambient temperature, and freshly molded parts made with the mold being used for actual production, which are still at an elevated temperature and are therefore still relatively soft, and also subsequently heat-treated plastics structures, i.e. those which have been brought to an elevated temperature only just before joining, can be joined together with a metal structural element to form a connection which can withstand loading.

[0018] Hybrid structural elements obtained in such a way have advantages over corresponding known constructions of the same weight with regard to their rigidity and strength.

[0019] The metal structural element has at least one surface which has a punched rim/collar. This punched rim or punched collar may already be taken into account directly during the production of the metal structural element or be subsequently attached. This is in this case an attachment, projection or elevation which is suitable for penetrating into the plastics structure when pressure is applied. The end of the punched rim is preferably of an angular form, that is to say can be worked for example such that it is rectangular, triangular or trapezoidal in cross section.

[0020] Suitable punched rims can be obtained by being subsequently attached onto the metal surface by means of known processs such as soldering or welding. Furthermore, such punched rims can be already taken into account during the production of the metal structure. It is preferred for these punched rims to be obtained by making apertures into the surface of the metal structural element by means of punching or deep-drawing processes. Depending on the choice of punching tool, a wide variety of forms of aperture are possible, which are distinguished by the fact that they have a substantially perpendicular punched rim which delimits the aperture with respect to the metal surface. A substantially perpendicular position of the punched rim, irrespective of whether it is formed as an aperture or produced separately or in one piece, is intended to mean for the purposes of the present invention that the punched rim assumes a setting angle of 60 to 120°, in particular of 80 to 100°, with respect to the metal surface of the metal structural element.

[0021] When the metal surface is seen in plan view, the punched rim may reproduce the shape of a straight or wavy or angular line or take the shape of a rectangle, square, triangle, oval, circle or some other desired geometrical figure. In addition, any other conceivable shape is possible, provided that it allows the metal structural element and plastics structure to be joined together by means of pressing them together. Two or more punched rims with the same or different shapes may also be provided on a metal surface.

[0022] The thickness of the punched rim can be freely selected in large ranges, as long as the plastics structure is not destroyed during the pressing operation and a composite structural element is created. The thickness of the punched rim generally lies in the range from 0.2 to 4 mm, with thicknesses in the range from 0.2 to 2 mm, in particular from 0.4 to 1.2 mm, being preferred.

[0023] The height of the punched rim, measured from the metal surface, is generally already adequate if it corresponds to the thickness of the plastics structure at the location to be connected. However, a permanent connection can also already be brought about with lower heights, for example with a height in the range of half the thickness of the plastics structure at the location to be joined.

[0024] The metal structural element, also known as a metallic body or metal body, may be produced from any metal or any alloy. Under the joining conditions it must have a strength which is adequate to allow it to enter into a permanent and positively locking connection with the plastics structure via the punched rims, if they are made of the same material. It goes without saying that the height of a punched rim may also vary in itself.

[0025] In a preferred way, the wall thickness of the plastics structure is at least 1 mm, preferably at least 2 mm. If plastics structures in this wall thickness are joined with metal bodies by the process proposed according to the invention, the elevations of the metal body in the form of punched collars penetrate into the plastics structure, so that a permanent, positively and nonpositively locking connection is obtained.

[0026] The apertures in the metallic bodies are preferably formed such that they are round. They may, for example, also be made to be oval or as a rectangle with rounded corners. In an advantageous way, the apertures can be formed at the regions at the rim with elevations configured in the form of punched collars, which are driven out of the metal plates and bent upward. Collar-shaped elevations with a peripheral edge are preferred. This edge is formed in particular as a sharp edge, to achieve improved entry into the plastic. In the metallic basic body, the apertures can be achieved for example by punching out, with the regions at the rim of the apertures automatically being deformed during the punching. In addition to punching out, the deformations can be formed in the metallic basic body by deep-drawing of the metallic body. Sharply edged ends of the punched rims or punched collars are also preferred in particular, since the plastics structure is not convexly curved, or only slightly, at the rear in the region of the joining location when a punched collar of such a form penetrates into the plastics structure and does not penetrate through it. An end of a punched collar is typically referred to as sharply edged if the collar wall tapers to a point or virtually to a point, it being possible for its cross-sectional shape to be symmetrical and unsymmetrical.

[0027] In the case of the process proposed according to the invention, the height of the elevations on the metal body or the height of the punched collar may exceed the wall thickness of the plastics structure at the location to be joined; the punched rim or punched collar in this case penetrates through the plastics structure if it is aligned perpendicularly or virtually perpendicularly in relation to the metal surface. If apertures are desired, it is preferred in these cases to revert to punched rims of heights which exceed the thickness of the plastics structure at the connecting location by 2 to 40, preferably by 5 to 25 and particularly preferably by 10 to 20%. Since, during the joining operation, pressure is built up and maintained both from the rear side of the metal structural element and from the rear side of the plastics structure through generally deformation-resistant mold walls, for example made of metal, the projecting punched rims are deformed after penetration through the plastics structure on the opposite pressing plate, whereby a still positively and nonpositively locking connection with the plastics structure is produced.

[0028] In addition to the formation of the punched collar-like elevations on the metal body in a height exceeding the wall thickness of the plastics structure, the punched-collar-shaped elevations can also be made in a height which lies below or at the same level as the wall thickness of the plastics structure which is to be joined to a metal body. A positively and nonpositively locking connection is also brought about in this case by the pressing together process.

[0029] According to a further configurational variant of the idea on which the invention is based, the deformations may be provided in the metallic body at a setting angle deviating from 90°, so that they project virtually perpendicularly in relation to the plane of the metallic body. The choice of the setting angle of the projections with respect to the plane of the metallic workpiece in which the apertures and consequently the deformations are produced allows the shape of the connecting location that is produced during the joining operation to be significantly influenced. Depending on the setting angle of the deformation on the metal structural element, the deformation contour of the punched-collar-like elevation can, for example, be widened or narrowed in the middle or at the upper region. In addition, the resultant deformation contour between the metallic structural element and the plastics structure in the region of the joining location of the two structural element components can be influenced by the configuration of the contact surface of the corresponding joining tool on the plastic side that acts on the joining location, if the punched rim is higher than the thickness of the plastics structure at the joining location.

[0030] In a preferred configuration of the process according to the invention, the diameter range of the apertures produced in the metallic structural element lies in the range from 2 to 50, in particular from 2 to 12 mm.

[0031] During the production of the apertures, it is preferred for the edge or peripheral edge of the punched collars or punched rims bounding the apertures to be formed such that they are edged, in particular sharply edged, to permit the edge or peripheral edge to enter the plastics structure when the part-components which are to be joined and which form a composite structural element meet each other.

[0032] In a further embodiment, two or more plastics structures attached one on top of the other are joined in the way described above to a metal structural element, which has at least one punched rim, in one operation by pressing them together. For this purpose, the plastics structures lie with no play over each other at the joining location, so that a positively and nonpositively locking connection is possible. The height of the punched rim is to be set such that the end of the punched rim penetrates through the plastics structure or structures bearing against the metal structural element and penetrates at least into the outer plastics structure bearing against the wall of the joining tool, or else penetrates through it, preferably thereby deforming the punched rim.

[0033] In a preferred embodiment, the punched collar or punched rim has on at least one of its side faces one or more constrictions, indentations or depressions. These constrictions, indentations or depressions may be present over certain portions or in a distributed arrangement over the side face(s) of the punched collar. In the case of peripheral punched collars, for example circular, rectangular or triangular shapes of punched collars, the indentation, constriction or depression is preferably present in a peripheral form, for example in the form of a peripheral channel or groove on the punched collar side face or faces.

[0034] Composite structural elements according to the invention, in which the connection is brought about with the aid of punched collars having the aforementioned constrictions, indentations or depressions, exhibit a particularly strong connecting strength.

[0035] The constriction, depression or indentation in the region of the punched collar side faces can be produced in various ways, for example by pressing an object into the punched collar side face supported at the rear. Furthermore, these indentations can also be produced already on the not yet punched metal plate, for example by pressing or stamping deformation-resistant objects, for example rings or ring segments, into the metal surface. Furthermore, the metal plate can be placed onto an underlying surface, for example the lower half of the tool used for punching, which has at the suitable or desired locations elevations which are pressed into the metal plate when pressure is applied at the rear. Subsequently, the punched collar can be, produced at the intended position, by driving a male die through the metal plate at the location referred to above, after which the described indentations are present in the outer wall of the punched collar.

[0036] In a preferred embodiment, the constriction is produced directly during the production of the punched collar along with it in one operation. This occurs for example whenever the force of the male die required for producing the collar is so high that, when the male die pushes through the metal surface, a cross-sectional constriction caused by the loading occurs in the region of the collar base that is forming. The constrictions can also be produced particularly advantageously directly during the production process if the male die used has sharply edged cross-sectional transitions. These constrictions likewise occur with particular preference if the metal structural element already has at the position to be punched an opening or aperture of a size or diameter which is relatively small in comparison with the size or diameter of the aperture produced during the production of the actual collar, and is preferably no more than half the size/half the diameter of the aperture of the punched collar. It goes without saying that the aforementioned preferred embodiments for producing constrictions, indentations or depressions in the punched rim can also be combined in any way desired.

[0037] In a further preferred embodiment, the surface of the metal plate is deflected in the region around the punched collar with respect to the surface defined by the surrounding metal plate in the direction of the punched collar base. The height of the punched rim or punched collar of this embodiment, determined in relation to the non-deflected surface formed by the surrounding metal plate, is consequently less than the actual height of the punched rim. The joining tool preferably does not reproduce this deflection of the surface around the punched rim in its surface contour. In this way, composite structural elements in which the metal structural element and plastics structure bear closely against each other are obtained, so that foreign bodies or liquids cannot penetrate into or be incorporated in the composite structure. The formation of a gap between these structural elements is effectively prevented in this way.

[0038] In a further preferred embodiment, in addition to the punched-collar joining or punched-rim joining, the bonding strength of the composite structural elements according to the invention can be further increased by the metal structural element to be connected and/or the plastics structure to be connected being partially or completely provided with an adhesive before the pressing in of the punched collars/rims. Suitable adhesives for bonding metal and plastic are known to a person skilled in the art and are commercially available.

[0039] In a further embodiment, the joined punched rim is subsequently, i.e. after the joining operation, closed or sealed off with an adhesive or a sealing compound in the region of the joining location. If the punched collar penetrates through the plastics structure, it is recommendable to seal off the region of the punched collar on the upper side and underside. If the punched collar only penetrates into the plastics structure, without penetrating through it, it is adequate to provide only the region of the punched collar on the metal side with an adhesive or sealing compound. The aforementioned procedure is preferred in particular whenever the metal structural element has been subjected to a coating process before the joining operation and damage to or impairment of the anticorrosive coating layer at the punched rim/collar cannot be ruled out because of the joining process.

[0040] The invention is explained in more detail below on the basis of drawings, in which:

[0041] **FIG. 1** shows a metal basic body and the plastics structure in the region of the connecting location before joining,

[0042] **FIG. 2** shows a metal basic body and the plastics structure in the region of the connecting location after joining, with a positively and nonpositively locking connection provided by widening the elevation configured in a manner of a punched collar in its middle and constricting it at the upper end,

[0043] **FIG. 3** shows a metal basic body and the plastics structure in the region of the connecting location after joining with a positively and nonpositively locking connection provided by constricting the punched collar in the middle and widening it at the upper end,

[0044] **FIG. 4** shows a detail of the upper half of the joining tool with a specially peripheral annular groove in an enlarged representation,

[0045] **FIG. 5** shows a metal basic body and the plastics structure in the region of the connecting location after joining with a positively and nonpositively locking connection provided by widening the punched-collar-like elevation, protruding out of the plastics structure, at its upper end,

[0046] **FIG. 6** shows in cross section a punched rim having a constriction,

[0047] **FIG. 7** shows a plastics structure and a metal structural element before the joining operation in cross section, the surface of the metal structural element having been deflected in the region of the punched collar with respect to the surrounding surface of the metal structural element in the direction of the punched collar base,

[0048] **FIG. 8** shows an opened injection mold in cross section, with a plastics structure remaining in the injection mold and a metal structural element present on a female die, containing punched rims, and

[0049] **FIG. 9** shows three embodiments of a metal structural element with a sharply edged, peripheral punched collar.

[0050] The representation according to **FIG. 1** reveals a metal basic body and the plastics structure in the region of the connecting location before the joining operation.

[0051] In the representation according to **FIG. 1**, the pressing tools of a mold performing the joining operation are shown in the state in which they have been moved apart. The two joining tools lying opposite each other, the upper joining tool **11** and the lower joining tool **13**, have mutually facing meeting faces **12** and **14**, respectively. Between the moved-apart meeting faces **12** and **14** of the upper joining tool **11** and of the lower joining tool **13** are the two parts of the composite structural element which are to be joined to each other, that is the plastics structure **1** and the metallic structural element **4**.

[0052] The metal body or the metal plate **4** may be provided in the course of punching or deep-drawing with apertures **6**, configured for example in a circular manner. The apertures **6** configured in a circular manner are preferably formed in the metal structural element **4** in the diameter range from 2 to 12 mm, it being possible to use the method mentioned for producing them. During the punching or deep-drawing operation, elevations **7** similar to punched collars are producing laterally at the apertures **6**, running out at the upper end of the aperture in a sharp peripheral edge **8**. The aperture **6** is produced substantially symmetrically in relation to its line of symmetry **10**. The peripheral edge **8** produced at the upper end **9** of the deformed region **7**, configured in the manner of a punched collar, is preferably formed as a sharp edge, in order to permit the deformation **7** to penetrate in on the underside **3** of the plastics structure **1**.

[0053] Presses or punching and/or deep-drawing machines suitable for sheet-metal working or sheet-metal forming or similar hydraulically operating joining machines may be used for the pressing together of the metal-plate basic body **4** and plastics structure **1**. These are generally equipped with one or more tools **11** and **13**, which are adapted exactly to the contour of the structural elements **1** and **4** to be connected to each other. For the optimum introduction of the joining force when said structural elements are joined together, it is important that both the metallic basic body **4** on one side and the plastics structure **1** arranged opposite it on the other side bear with an exact fit against the corresponding mold meeting face **12** and **14**, respectively, at the connecting locations, i.e. the joining locations or in their respective direct vicinity.

[0054] Any metal or any metal alloy can generally be used for the metal structural element, provided that it is hard enough in the solid state to allow it to be pressed into the plastics structure. A metal structural element of ungalvanized or galvanized steel, aluminum or magnesium is usually used. The metal structural element may also be coated with a commercially available coating for reasons of corrosion protection or for visual reasons. Anticorrosive or color coatings of this type and their application are known to a person skilled in the art.

[0055] Injection-molded, extruded or thermoformed parts, including films and semifinished products (panels, tubes, sheets, bars etc.) come into consideration as plastics structures. The plastics structures are usually constructed from thermoplastic semicrystalline or amorphous polymers, but may also be formed from thermosetting materials or mixtures of these polymer classes.

[0056] All thermoplastics known to a person skilled in the art come into consideration as thermoplastic polymers. Suitable thermoplastic polymers are described, for example, in the Kunststoff-Taschenbuch [plastics pocketbook], published by Saechtling, 25th edition, Hanser-Verlag, Munich, 1992, in particular section 4 and references cited therein, and in the Kunststoff-Taschenbuch, published by G. Becker and D. Braun, volumes 1-11, Hanser-Verlag, 1966-1996.

[0057] Examples of suitable thermoplastics which may be mentioned are polyoxyalkylenes such as polyoxymethylene, for example Ultraform® (BASF AG), polycarbonates (PC), polyesters such as polybutylene terephthalate (PBT), for example Ultradur® (BASF AG) or polyethylene terephthalate (PET), polyolefins such as polyethylene (PE) or polypropylene (PP), poly(meth)acrylates, for example PMMA, polyamides such as nylon-6 or nylon-66 (for example Ultramid®; BASF AG), vinylaromatic (co)polymers such as polystyrene, syndiotactic polystyrene, impactmodified polystyrene, for example HIPS, or ASA polymers (for example Luran® S; BASF AG), ABS polymers (for example Terluran®; BASF AG), SAN polymers (for example Luran®; BASF AG) or AES polymers, polyarylene ethers such as polyphenylene ethers (PPE), polyphenylene sulfides, polysulfones, polyether sulfones, polyurethanes, polylactides, halogen-containing polymers, polymers containing imide groups, cellulose esters, silicone polymers and thermoplastic elastomers. It is also possible to use mixtures of various thermoplastics as materials for the plastics structures. These mixtures may be single- or multi-phase polymer blends.

[**0058**] The plastics structures may additionally contain customary additives and processing aids.

[**0059**] Examples of suitable additives and processing aids are lubricants, mold-release agents, rubbers, antioxidants, stabilizers to protect against exposure to light, antistatic agents, flame retardants or fibrous and pulverulent fillers or reinforcing agents and also other additives or mixtures of them.

[**0060**] Examples of fibrous or pulverulent fillers and reinforcing agents which may be mentioned are carbon or glass fibers in the form of glass fabrics, mats or rovings, chopped glass and glass beads. Particularly preferred are glass fibers. The glass fibers used may be of E, A or C glass and are preferably provided with a size, for example based on epoxy resin, silane, aminosilane or polyurethane and an adhesion promoter based on functionalized silanes. The glass fibers may be incorporated both in the form of chopped strands and in the form of continuous strands (rovings).

[**0061**] Suitable as particulate fillers are, for example, carbon black, graphite, amorphous silica, whiskers, aluminum oxide fibers, magnesium carbonate (chalk), powdered quartz, mica, bentonite, talc, feldspar or in particular calcium silicates such as wollastonite and kaolin.

[**0062**] Furthermore, the plastics structures may also contain colorants or pigments.

[**0063**] The aforementioned-additives, processing aids and/or colorants are preferably mixed in an extruder or other mixing device at temperatures of 100 to 320° C., thereby melting the thermoplastic polymer, and discharged. The use of an extruder is particularly preferred, in particular a co-rotating, closely meshing twin-screw extruder. Processes for preparing the plastics molding compounds are sufficiently known to a person skilled in the art.

[**0064**] The molding compounds obtained in this way can be used for producing plastics structures (including semi-finished products) of all kinds, for example by the injection-molding, extrusion or thermoforming process.

[**0065**] The representation according to **FIG. 1** also shows more precisely the wall thickness **1.1** of the plastics structure **1** between the upper side **2** and underside **3** and the height of the elevations **7** formed in the manner of punched collars on the metallic basic body **4**. Preferred values for the wall thickness **1.1** of the plastics body lie between 2 and 8 mm. The height denoted by **7.1** of the rims of the apertures **6**, deformed in the manner of punched collars, may exceed the thickness of the wall of plastic **1.1** in the initial state, i.e. in the undeformed state, preferably by approximately 10-30%. The percentage can vary according to the embodiment.

[**0066**] **FIG. 2** shows a metal basic body and the plastics structure in the region of the connecting location after joining with a positively and non-positively locking connection by widening the punched-collar-like elevation in its middle and constricting the punched-collar-like elevation at the upper end.

[**0067**] The elevation described above of the regions at the rim **7** of the aperture **6** in the metallic structural element **4** is achieved by the peripheral edge **8**, formed as a sharp edge, of the limitation of the apertures **6** on the underside **3** penetrating into the plastics structure **1** and undergoing toward the end of the phase of the penetration through the wall of plastic **1.1** the increased resistance of the oppositely arranged meeting face **12** of the upper joining tool and is deformed as a consequence. Depending on the setting angle or length of the elevation **7.1** with respect to the wall thickness **1.1**, a curvature **17** of the region at the rim **7** of the aperture **6** can be produced, with a widening **18** in the middle and a constriction in the upper region **19**. The deformed contour **17** has the effect that the punched-collar-like elevation **7** is braced or clasped in the wall of plastic **1**, whereby a permanent, positively and nonpositively locking connection is produced. The shape of the punched-collar-like elevation **7** deformed by the joining operation can be influenced on the one hand by the setting angle of the undeformed projection **7** and on the other hand by the configuration of the upper joining tool **11**. Depending on the setting angle of the projection **7** in its middle, it undergoes either a widening **18** or a constriction **21** (compare **FIG. 3**).

[**0068**] The representation according to **FIG. 3** shows a metal basic body and the plastics structure in the region of the connecting location after joining with a positively and nonpositively locking connection, the punched-collar-like elevation being constricted in its middle and widened at the upper end.

[**0069**] In this configuration, the punched-collar-like elevation **7** in the metal basic body **4** has been given a geometry opposite to that of the deformation contour **17** in **FIG. 2**. It is also the case in this example that the height **7.1** of the punched-collar-like elevation **7** protruding beyond the wall thickness **1.1** of the plastics structure **1** achieves the effect that, when the meeting face **12** of the upper joining tool **11** has made contact, a clasping or complete penetration, and consequently a positively locking connection between the plastics structure **1** and the metallic body **4** is achieved.

[**0070**] The extent of the widening or constriction of the punched-collar-like elevation **7** according to **FIGS. 2 and 3** is determined by the size of the difference between the height **7.1** of the punched-collar-like rims and the wall thickness **1.1** of the wall of plastic. This provides a further parameter for influencing the strength of the connection.

[**0071**] The representation according to **FIG. 4** shows more precisely a detail of the upper half of the joining tool with a specially configured meeting face **12**. According to this exemplary embodiment, in the meeting face **12** of the upper joining tool **11**, a recess symmetrical with respect to the center line **10**, in the form of an annular groove **22**, may be let into the meeting face **12** of the upper joining tool **11**. If a composite structural element is produced by means of an upper joining tool **11** configured as shown in **FIG. 4**, projections of the metallic punched collar **7** which rise above the upper side **2** of the plastics structure **1**, i.e. do not lie in it and are not changed in shape by the form of the annular groove **22**, are produced in the region of the upper side **2** of the plastics structural element **1** formed with wall thickness **1.1**.

[**0072**] The representation according to **FIG. 5** shows a joining tool **11** more precisely, the meeting face **12** of which is provided with an annular-groove-shaped recess **22** in a way corresponding to that represented in **FIG. 4**.

[**0073**] During the pressing together of the joining tools **11** and **13** arranged lying opposite each other, the elevation **7** configured in the manner of a punched collar in the metal body **4** or metal plate **4** penetrates through the plastics structural element **1** formed with wall thickness **1.1**, protruding portions of the punched-collar-like elevation **7** engaging in the annular groove **22**, represented in **FIG. 4**, in the meeting face **12** of the upper joining tool **11**. The representation according to **FIG. 5** shows that the elevations **7** of the metal plate, configured in the manner of punched collars, or of the metal body **4** have undergone a central constriction in the middle of the aperture **6**, while in the upper region the protruding portions **23** of the punched-collar-like elevation **7** are formed further apart, in a way corresponding to the geometry of the annular groove **22** in the meeting face **12** of the upper joining tool **11**. The accuracy of the joining operation according to **FIG. 5** is improved by the metal plate or the metal body **4** being supported on the corresponding meeting face **14** of the lower joining tool **13** with no play and with uniform support in the vicinity of the joining location. The same also applies to the arrangement of the plastics structural element **1**, arranged above the metal body or metal plate **4**, with respect to the meeting face **12** of the upper joining tool **11**.

[**0074**] **FIG. 6** shows in cross section a punched rim **(7)** with an edged punched rim end **(24)** on a surface of a metal structural element **(4)**, which is aligned perpendicularly or virtually perpendicularly with respect to the metal surface. The punched rim has a channel-like constriction/depression **(25)** peripherally on its outer side face. This constriction may be produced already during the production of the punched collar, along with it, or else be subsequently attached. In particular, warm plastics material of the plastics structure joined with the metal structural element penetrates into the constriction and often leads to a particularly stable connection.

[**0075**] **FIG. 7** shows a metal structural element **(4)** with a punched collar **(7)** and a plastics structure **(1)**, which rests on a lower joining tool half **(26)**, shortly before the actual joining operation. In the region of the punched collar **(7)**, the metal surface **(27)** is deflected with respect to the surface defined by the further outer-lying metal plate **(28)** in such a way that it has a greater distance from the surface defined by the plastics structure than the further outer-lying metal plate surface **(28)** immediately before the joining operation. This consequently constitutes a deflection of the surface in the region of the punched rim in the direction of the punched rim base. A joining or pressing tool **(29)**, which does not receive this deflection of the metal surface **(27)** in the region of the punched collar in its surface contour **(30)**, is preferably used for the joining operation on the rear side of the metal structural element. Consequently, unlike the metal structural element, this pressing tool has a uniform cross-sectional shape without deflections, at least in the region of the joining location.

[**0076**] **FIG. 8** schematically shows in cross section an opened injection mold **(31)**, in which the injection-molded plastics structure **(1)** has remained in the front mold half **(32)**. In the opened mold, the metal structural element **(4)** is located on a female die **(33)**, the punched rims **(7)** facing the plastics structure **(1)** and taking the form on the one hand of apertures driven through the metal (lying on the inside in **FIG. 8**) and the form of punched collar elevations attached on the metal surface. For the purposes of the present invention, a punched rim or punched collar is to be understood as meaning both an elevation attached or present on a metal surface, it also being possible for it to have been subsequently attached around an opening or a clearance in the metal, and an elevation, rim or collar obtained from a metal plate directly by means of piercing or punching out. The front side **(34)** of the female die **(33)** receives the rear shape **(35)** of the metal structural element **(4)**, the rear side of the female die **(33)** is supported during the joining operation by the rear injection mold half **(37)**. For this purpose, additional resting male dies **(36)** may also be provided, for example on the female die for bearing against the surface **(38)** of the rear injection mold half. When the injection mold halves **(32, 37)** are moved together, the closing rear mold half **(37)** moves the female die **(33)**, and consequently also the metal structure **(4)**, in the direction of the plastics structure **(1)**. The relative or opposing movement of the mold halves has the effect that the punched collar or collars **(7)** of the metal structural element **(4)** is pressed into the plastics structure **(1)** by the application of pressure. A positively and nonpositively locking composite structural element is obtained.

[**0077**] **FIG. 9** respectively shows in cross section schematically sharply edged embodiments of a peripheral punched collar **(7)**. In embodiment a), the sharp edge **(39)** is located on the inner rim **(40)**, in b) it is located on the outer rim **(41)** of the punched collar. It goes without saying that the end of the punched collar tapering to a sharp edge may also lie in any desired positions between the region specified by the embodiments a) and b), for example in a central position **(42)**, thereby forming a cross-sectionally symmetrically shaped edge tip **(39)** as in c). The described composite structural elements can be used in diverse ways, for example as structural elements or structural element components in automotive engineering, aircraft construction or shipbuilding or in the production of domestic or electrical appliances. Applications in automotive engineering are, for example, front-end modules, front-end supports, seat pans, seat structures, instrument panels, functional supports for doors, functional modules for doors, tailgates or side doors.

[**0078**] The composite structural elements presented have the advantage over the known hybrid structural elements, produced in a different way according to EP 0 370 342 B1, that the plastics structure can be shaped here largely without any restrictions, since the plastics structure according to the present invention can be produced in a separate production step. In contrast to this, the plastics structure according to EP 0 370 342 B1 is injection-molded onto the metallic, shell-shaped basic body, whereby the degrees of freedom with respect to the demolding of the injection-molded plastics structure are significantly reduced. As a consequence, the plastics structure according to the invention can be shaped more appropriately for loading than those from the prior art. This advantage is manifested in the composite structural element obtained by greater rigidity or strength, given a comparable weight of the structural element.

[0079] It is also of advantage that, since no additional processing steps, for example adhesive bonding steps, occur, short cycle times can be realized in series production. Furthermore, no additional structural elements or components are required for the joining of the plastics structure and metal structural element. Furthermore, the process according to the invention in all its embodiments is less sensitive overall to deviations in the positioning of the punched rim and plastics structure. In the case of the process according to EP 0 370 342 B1, a far higher positional accuracy has to be maintained in order to accomplish functionally capable composite structural elements. The joining process according to the invention also does not require any subsequent treatment. In addition, any desired plastics structures can be used, independently of the production process, fiber-reinforced plastics also being equivalently suitable. For example, in a shearing test on a composite structural element with a plastics structure of glass-fiber-reinforced (30% by weight) polyamide with circular punched rims of a diameter of 5 mm in the metal structural element, the rupturing forces for each connecting location are around 1300 N. It is also possible to perform the joining operation in the same injection mold in which the plastics structure to be joined is also injection-molded, thereby dispensing for example with a separate joining machine and additional working steps.

[0080] Finally, it is also of advantage that the joining technique according to the invention in all its embodiments can be combined in an easy and uncomplicated way with known joining techniques for producing hybrid structural elements, for example the molding-on variant described in EP-A 370 342. For example, a composite structural element initially obtained with the aid of the joining process described in EP-A 370 342 can be further processed in a following step using the process according to the invention, for example to form a sandwich structure (metal/plastic/metal). In the case of this combination of joining techniques, the operation of joining by punching is preferably also performed in the injection mold originally used for the molding of the plastic onto the metal plate, as already described above.

[0081] List of Designations

[0082] **1** plastics structure

[0083] **1.1** wall thickness

[0084] **2** upper side

[0085] **3** underside

[0086] **4** metal body/metal plate

[0087] **5** joining location

[0088] **6** aperture

[0089] **7** punched-collar-like elevation

[0090] **7.1** height of the projection

[0091] **8** peripheral edge

[0092] **9** end of collar

[0093] **10** center line

[0094] **11** upper joining tool

[0095] **12** meeting face

[0096] **13** lower joining tool

[0097] **14** meeting face

[0098] **15** deformed collar region

[0099] **16** reinforcing face

[0100] **17** curvature

[0101] **18** middle widening

[0102] **19** upper constriction

[0103] **20** upper widening

[0104] **21** middle constriction

[0105] **22** recess of upper joining tool **11**

[0106] **23** protruding portion

[0107] **24** edged punched rim end

[0108] **25** channel-like constriction/depression

[0109] **26** lower joining tool half

[0110] **27** metal surface deflected with respect to surrounding metal surface in the direction of the punched collar base

[0111] **28** metal surface of the metal structural element which surrounds the deflected metal surface

[0112] **29** pressing tool

[0113] **30** surface contour of the pressing tool

[0114] **31** injection mold

[0115] **32** front injection mold half

[0116] **33** female die

[0117] **34** front side of the female die

[0118] **35** rear shape of the metal structural element

[0119] **36** resting male die attached on rear side of the female die

[0120] **37** rear injection mold half

[0121] **38** surface of the rear mold half

[0122] **39** sharp-edged end of the punched collar/edge tip inner rim of the punched collar

[0123] **41** outer rim of the punched collar

[0124] **42** edge tip in central punched rim position

We claim:

1. A process for producing a composite structural element from a metal structural element **(4)** and a plastics structure **(1)**, wherein the metal structural element, which has at least one surface with at least one punched rim or punched collar **(7)**, and the plastics structure are pressed together with the aid of one or more joining tools **(11, 13, 26, 29, 32, 37)**, the punched rim/collar penetrating into or through the plastics structure in a positively and nonpositively locking manner.

2. A process for producing a composite structural element from a metal structural element **(4)** and a plastics structure **(1)**, wherein the plastics structure is injection-molded in an injection mold **(31)**, the injection mold is opened, a metal structural element **(4)** which has at least one surface with at least one punched rim **(7)** is introduced into the opened injection mold and positioned over or in front of the plastics structure remaining in the injection mold, and the injection mold halves **(32, 37)** are moved together, the punched rim or rims being pressed into the plastics structure in a positively and nonpositively locking manner.

3. A process as claimed in claim 2, wherein a female die **(33)**, which corresponds on the front side, at least in the region of the joining locations, substantially to the contour of the surface of the metal structural element, is introduced into the injection mold between the metal structural element **(4)** and the rear injection mold half **(37)** and is positioned.

4. A process as claimed in claim 3, wherein the rear side of the female die comes to bear against the rear injection mold half **(38)**, or against the platen of this mold half, when the mold halves **(32, 37)** are pressed together.

5. A process as claimed in claim 3 or **4**, wherein the female die **(33)** and metal structural element **(4)** are placed one on top of the other outside the injection mold and are introduced as a unit into the opened injection mold and positioned over or in front of the plastics structure.

6. A process as claimed in claims 1 to 5, wherein the punched rim is attached substantially perpendicularly on the metal surface.

7. A process as claimed in claims 1 to 6, wherein the end of the punched rim is edged, in particular sharply edged.

8. A process as claimed in claims 1 to 7, wherein the height of the punched rim exceeds the thickness of the plastics structure at the location to be connected by up to 40%.

9. A process as claimed in claims 1 to 7, wherein the height **(7.1)** of the elevation or of the punched rim **(7)** lies below the wall thickness **(1.1)** of the plastics structure **(1)** or is equal to the wall thickness **(1.1)** of the plastics structure.

10. A process as claimed in one of claims 1 to 9, wherein the punched rim represents a punched collar of an aperture through the metal surface of the metal structural element.

11. A process as claimed in claims 1 to 10, wherein the elevation or the punched rim **(7)** has a constriction, indentation or depression **(25)** on at least one punched collar side face.

12. A process as claimed in claims 1 to 11, wherein the surface **(27)** of the metal plate is deflected in the region around the punched rim/collar with respect to the surface defined by the surrounding metal plate **(28)** in the direction of the punched collar base, so that the height of the punched rim/collar determined with respect to the surface defined by the surrounding metal plate is less than the actual height determined by the punched rim/punched collar base.

13. A process as claimed in claims 1 to 12, wherein the surfaces to be connected of the metal structural element and the plastics structure are partially or completely provided with an adhesive before the joining operation.

14. A process as claimed in claims 1 to 13, wherein the joined locations are provided with an adhesive or a sealing compound in the region of the punched collar base and, if appropriate, in the region of the punched collar aperture.

15. A process as claimed in claims 1 to 14, wherein the plastics structure is in a warmed state during the joining operation or the composite structural element is heat-treated after the joining operation.

16. Composite structural elements which can be obtained by a process as claimed in claims 1 to 15.

17. The use of composite structural elements as claimed in claim 16 as structural elements or structural element components in automotive engineering or aircraft construction or shipbuilding or in the production of domestic or electrical appliances.

18. The use as claimed in claim 17, the structural element or the structural element components for automotive engineering taking the form of front-end modules, front-end supports, seat pans, seat structures, instrument panels, functional supports for doors, functional modules for doors, tailgates or side doors.

19. Front-end modules, front-end supports, seat pans, seat structures, side doors, instrument panel supports, functional supports for doors, functional modules for doors, tailgates, washing machines, refrigerators or dishwashers containing a composite structural element as claimed in claim 16.

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