Joining and fixing zinc alloy die castings

ZINC DEVELOPMENT ASSOCIATION, 34 BERKELEY SQUARE, LONDON W1X 6AJ

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Zinc die casting is probably unique in its ability to mass-produce complex parts to close dimensions, thereby minimising the number of joints required. Nevertheless zinc die castings have to be fixed to other assemblies and materials and sometimes it is necessary to produce a component as an assembly of zinc die castings. For these cases a wide variety of joining and fixing methods are available. Some methods – those involving deformation of the casting – are largely unique to zinc as they make use of the good ductility of zinc alloys. Such joints are integral and thus show significant economic advantages over joints made with separate fixings.

This booklet gives details of the following techniques:

Riveting, staking, crimping and spinning

Thread forming screws

Inserts; cast-in and driven-in

Spring clip fasteners

Adhesive bonding

Cast metal joining

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Further information on all aspects of zinc die casting may be obtained from
Zinc Development Association
Zinc Alloy Die Casters Association,
34 Berkeley Square, London W1X 6AJ. Tel: 01-499 6636 Telex: 261286.

A wide range of publications is available and those having particular relevance to joining and fixing methods are booklets: 'Die cast components: Aid to efficient design' and 'Machining and forming zinc die castings'

Riveting, staking, spinning and crimping

All these operations share the common purpose of fastening together permanently two or more die castings (or other mating parts of another material) by using the ductility of the zinc to form the attachment. Temperature should not be below 20°C and ductility is enhanced by operating up to 80°C.

Before riveting, or any similar operation is performed on a zinc die casting, experiments should be made to determine the best time after casting for it to be done. If the work cannot be done within three hours of casting, a delay of several weeks may be necessary. This is because there can be a decrease in ductility during the early part of the ageing process. Quenching the castings, which alters the microstructure compared to that produced by air cooling, may result in a different optimum delay before forming.

Riveting

Rivets or studs are formed as an integral feature of the zinc alloy die casting. They are usually cylindrical or conical and shouldered to provide a register face. The shoulder may also help prevent distortion and/or partial collapse of the stud, or of the component to be attached. The end of the stud may be countersunk to facilitate the operation and frequently a star type punch is employed to displace the metal in a controlled way.

Rivets need not be more than one diameter long and in no case should they be more than three diameters long. Rivets which are cast as extensions to pillars and buttresses may be up to four-and-a-half diameters long but only if this cannot be avoided.

Hollow or half-hollow rivets may also be used. The fully hollow (tubular) rivet is preferred if this can be tolerated from the point of view of appearance, particularly when the rivet must be more than two diameters long. There should always be a fillet at the base of the rivet, preferably one-quarter the rivet diameter with a minimum of 0.4mm; the fillet can be placed below the surface of the casting to make assembly easier.

Rivets may be clinched by staking or by spinning. Staking is quicker as a number of rivets may be fastened with a single blow. Staking also makes a joint more secure against vibrations, as the rivet shank is expanded in the hole as well as the top being spread. The staking tool should have a suitable shaped head and the top of the rivet may be counter-sunk to assist location of the staking tool.

Staking

Staking can be used to retain bushes, bearings, pins etc. A suitable punch is used to shear and flow the zinc to form a lip over the part to be fixed.

Crimping

Zinc alloy die castings can be fastened to each other or to other parts by means of lugs cast straight and then crimped over. The section to be crimped should be as thin as is consistent with the strength required in the joint, so that the smallest bending radius can be used. The section should be as dense as possible and the surface of the part to be bent should have a good finish, free from cold shuts or other cracks. Control of the deformation is facilitated by a bevel at the tip of the lug to be bent over.

Spinning

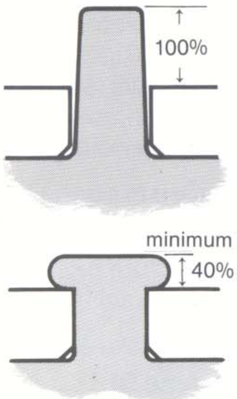
Spinning of rivets is often preferred to staking especially for hollow rivets because it proves a more controllable degree of fixing. Speeds for this process are not critical – about 1,500 rpm has been found suitable for diameters up to 6mm.

Spinning is especially useful for joining two circular components, eg a cover to a base.

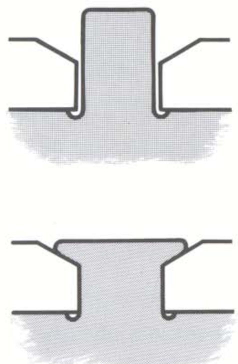
A permanent continuous joint may be made by spinning over a cast-in lip. The height of the lip should be 2-2½ times the height of the edge over which it is to be spun. The lip should be as thin as possible with a good surface finish.

Rivet types

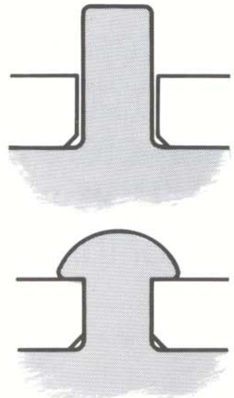
Solid flathead



Solid countersunk

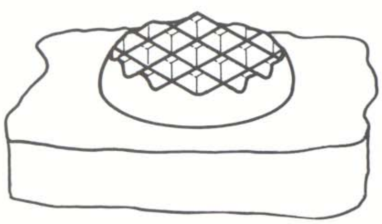


Solid dome head

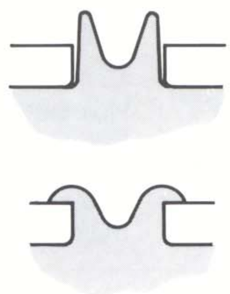


Crosshatched

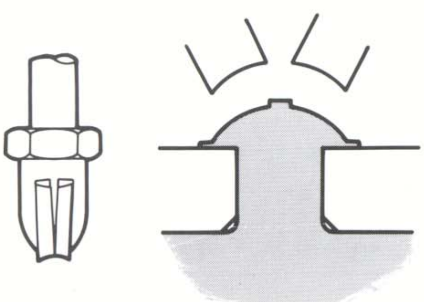
For controlled metal displacement of rivet heads



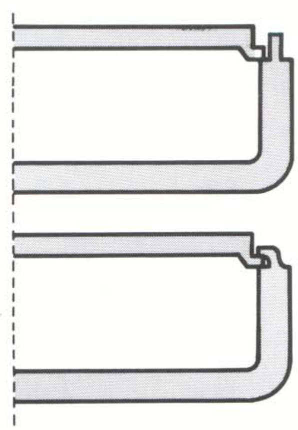
Hollow rivet



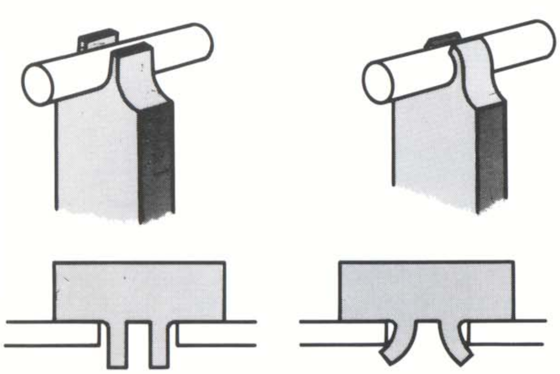
Spin riveting



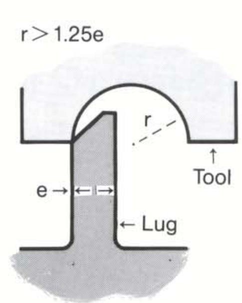
Spinning circular lips



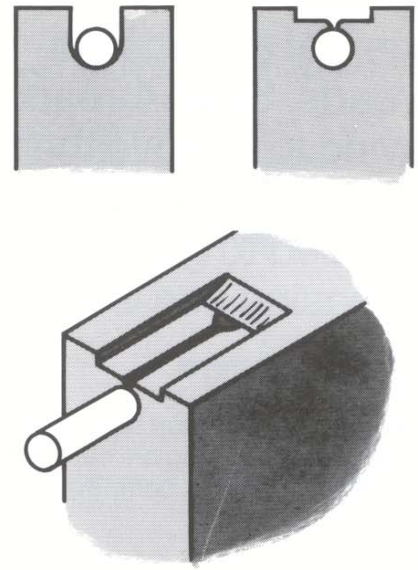
Crimping



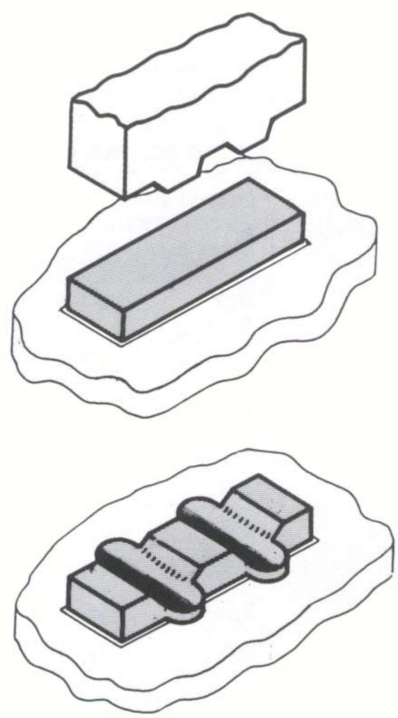
Recommended design of lug and tool for crimping



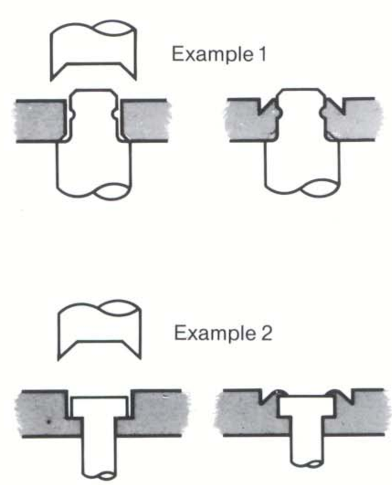
Wire staking



Double staking



Staking by ring punching



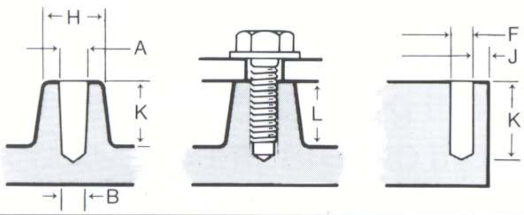
Threaded fasteners

External threads can be cast but it is rare to cast internal threads. Such threads may be tapped, usually without having to remove the taper from cored holes, provided they are not more than 2½ diameters deep. Cored holes are sized to give 70% of the full thread at the entrance. Increasing use is being made of thread forming screws.

Self tapping screws

Self tapping screws can be used very successfully for joining die castings to each other or to other components.

Dimension letter codes refer to those in table below.



The thread-forming variety (BS 4174, type B) are best suited for the ductile zinc alloy. A variety of head types are available, including hexagon, pan-head, countersunk (with raised or truncated features) and straight or cruciform slots).

Holes my be cast in or drilled. Recommended sizes and tapers, etc are shown in the table below, which is in agreement with information from the major screw suppliers.

Use of self tapping screws in zinc die castings (mm)

Screw size Dia x pitch	Hole diameter as cast including standard taper (+0.000−0.075) Top **A**	Bottom **B**	Drilled +.10−0 **F**	Minimum boss diameter **H**	Distance to edge minimum for no measurable distortion **J**	Hole depth as cast or drilled **K**	Length of thread engagement to develop strength of screw **L**
2.5 x 0.45	2.38	2.27	2.25	4.2	1.3	6	5
3 x 0.5	2.88	2.74	2.75	5.0	1.5	7	6
3.5 x 0.6	3.35	3.19	3.20	5.8	1.7	8	7
4 x 0.7	3.82	3.64	3.65	6.7	2.0	9	8
5 x 0.8	4.80	4.58	4.60	8.3	2.7	11	10
6 x 1	5.74	5.48	5.50	10.0	3.2	13	12
8 x 1.25	7.69	7.35	7.40	13.3	3.7	17	16
10 x 1.5	9.64	9.22	9.30	16.6	4.1	21	20

Standard taper on which the tabled dimensions are based is 1°11′ total

Spring clip fasteners

Spring clips can be used to give rigid permanent fixing onto round or square shafts from 2 to 25mm.

After components are assembled the spring clip is simply pushed on to the shaft either with a hand tool or using a press. The sharp "ears" of the clip bite into the shaft and can only be removed by breaking. Spring clips are available in many different shapes and many different materials. The most common are circular spring steel but may be in stainless steel, plastic coated, plated steel or copper based alloys. They may be designed to permit rotation (eg when holding on wheels) or to prevent rotation.

End caps are available to cover the clips where this is required. Features such as electrical (bullet) connectors may be incorporated. Zinc die cast alloy is very suitable for the shaft material since its inherent ductility will permit good engagement by the spring ears of the clips. The clips are listed in shaft sizes and are available in either metric or imperial dimensions. Shaft size is not critical so that normal draft may be specified on die castings.

Hammer-drive screws

Drive screws are a very simple way of fixing components to zinc alloy die castings. They will not withstand a tensile force as well as self tapping screws but are very good for light applications or where the major requirement is axial location giving a shear load.

Head shape is usually limited to round head.

Since insertion requires a heavy impact blow, die casting must be well supported and preferably have a flat face directly under the screw hole.

Hole sizes are given in the following table:

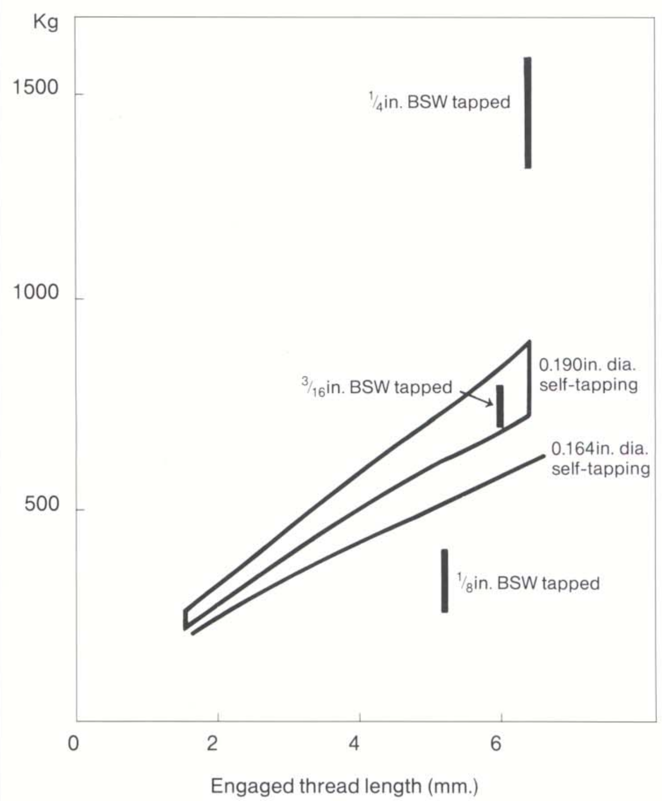
Screw size (No) and nominal diameter (in.)	Hole dia. required (in.)	Drill size (mm.)
00 (0.059)	0.051	1.30
0 (0.074)	0.065	1.65
2 (0.099)	0.087	2.20
4 (0.114)	0.100	2.55
6 (0.138)	0.122	3.10
8 (0.165)	0.146	3.70
10 (0.180)	0.161	4.10
12 (0.209)	0.189	4.80
14 (0.239)	0.217	5.50

Pull-out strength

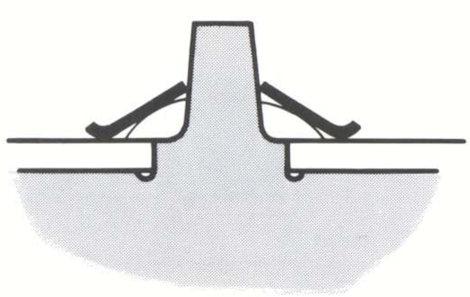
Measured values of the instantaneous load required to strip a thread made in zinc alloy are given in the graph. The results are not sufficient to indicate which type of thread (tapped, self cut or self formed) was strongest.

Where continuous heavy working loads are required, particularly at elevated temperatures, further advice should be sought.

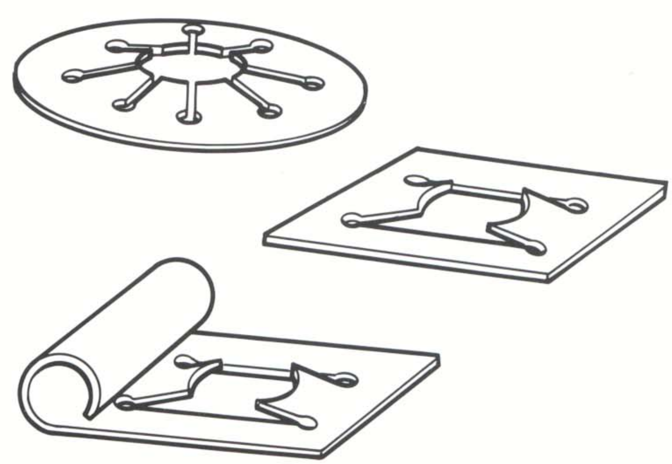
Tensile pull-out strength
(Data from Mullard, Mechanical Engineering, Oct 1943/Nov 1946 and Australian Die Casting Association)



Design of spring clip attachment



Types of spring clip attachment



Inserts

Inserts may be used in pressure die castings for a variety of reasons, for example as anchor points, as axles for wheels and pulleys, to produce fine accurate jets for such things as carburettors and to ensure absolute soundness in thick sections. Wherever possible the inserts should be driven into a cored (or drilled) hole during post-casting assembly. Cast-in inserts give higher strength but the operation of loading the inserts into the open die slows the cycle time of the machine and hence is more costly. The location must give adequate supporting material around the insert.

Driven inserts
The techniques shown may be applied depending on the requirements of the application.

Points to borne in mind are:

1. Hole draft angle
Use the minimum to produce uniform interference. Usually 0-¼° is acceptable.

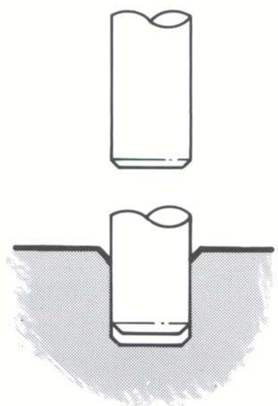
2. Chamfers
Both shaft and hole should be chamfered to prevent pick-up of the zinc during driving.

3. Depth of driving
At least equal to the diameter. Do not allow shaft to hit the bottom of the hole unless well supported.

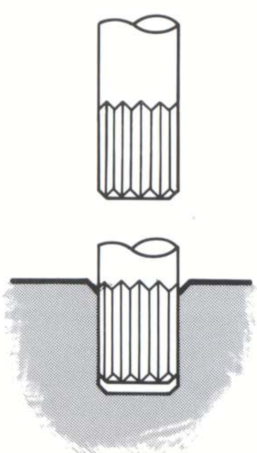
4. Interference
Trial and error may be needed as pull out load depends on surrounding casting shape as well as on the shaft fit. BS 1916 (hole H7, shaft S6 to P6) gives guidance. A typical interference would be 0.1mm.

5. Support
It is essential to support the die castings directly below or very close to the stud otherwise distortion will occur, particularly with the knurled and self-staking types.

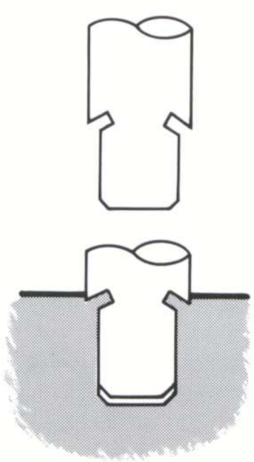
Straight shaft
This is the lowest cost type of insert. Chamfers should be incorporated where shown and, if possible, the shaft should be slightly tapered.



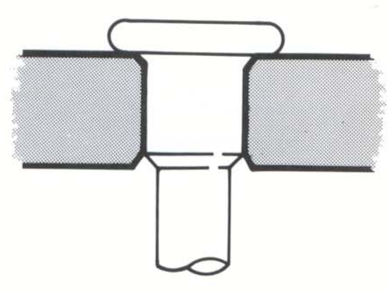
Straight knurl
Knurling the shaft produced a joint of higher torque strength than a plain shaft. Either stop the knurl short of the end or chamfer after knurling to reduce the chance of pick-up.



Self staking
Zinc alloy is forced into the machined groove during driving, giving a joint with a high pull-out strength.



Through driving
Preferred for applications where a thin deck is used or a high pull-out load is to be applied.

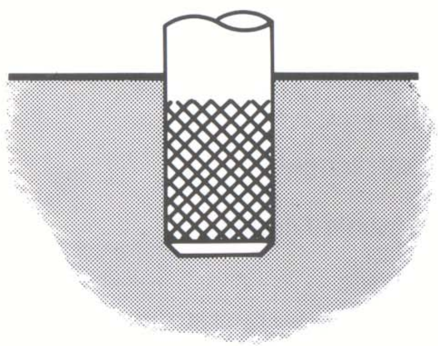


Cast-in inserts

Possible shapes of inserts and some features of design.

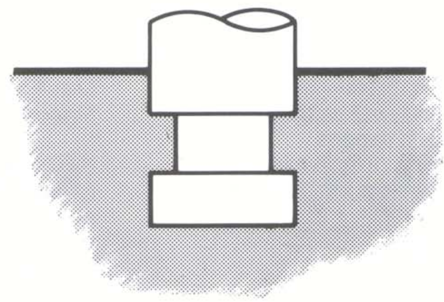
Knurled shaft

Heavy diamond knurling is preferred to give good mechanical joint between the insert and the die casting.



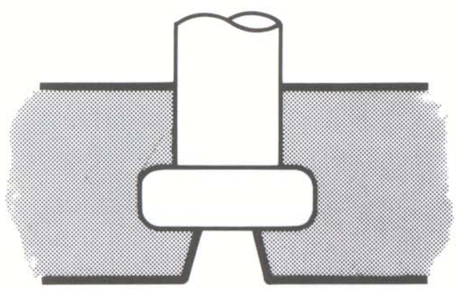
Undercut shaft

This gives a very high resistance to tension. The undercut may be either machined, rolled or cast-in.



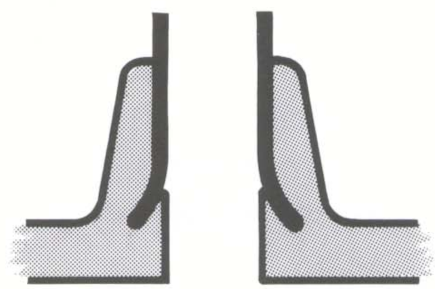
Headed shaft

Similar to undercut shaft. Heading may be preferred to machining. The diagram shows one technique for locating the insert between the two die halves by means of a projection (often a core insert or an ejector) on the opposite die half.



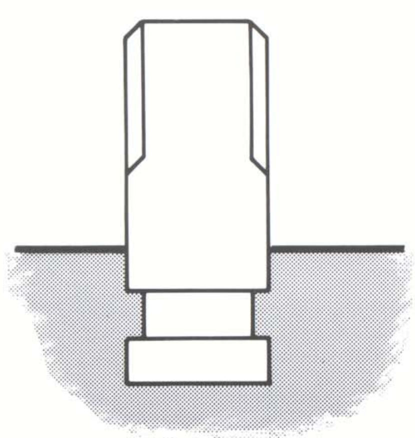
Tubular inserts

One way to ensure strength is to flare the tube. This also allows a core from the other die half to locate easily and give a good seal with the inside of the tube.



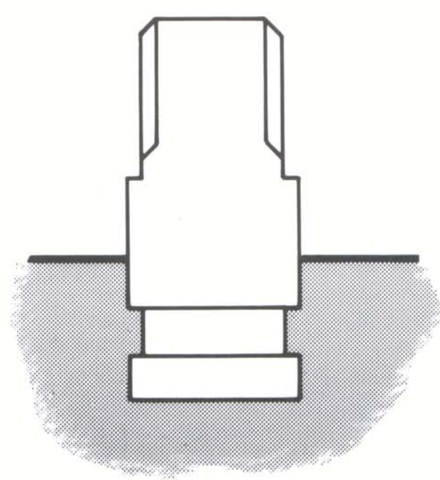
Threaded studs

Should have an unthreaded portion which will prevent molten metal entering the thread.



Shouldered studs

The shoulder will help to locate the insert in the die half prior to and during casting. It further assists in preventing molten metal getting to the threads.



Adhesive bonding

Adhesive bonding is becoming popular as an engineering assembly method. Manufacturers have a lot of information on joint design and the properties of individual adhesives. The main points to note are given below:

Types

Anaerobic
Used to lock and seal coaxial components and flanges
Typical fixing time: 10 minutes
Some types are demountable
Fill gaps up to 1mm

Modified acrylic
All types of joint
Fixing time: 5 minutes
Fill gaps to 1mm

Cyanoacrylate
All types of joint
Hardens in seconds
Usually requires close fit (0.1mm)

Epoxy
All types of joint
Range of fixing times and strengths
Can fill large gaps
Single pack types now available

Joint design

Design so that the adhesive is in compression or shear. Peel and cleavage forces must be avoided

Allow adequate overlap, eg thicken flanges
Make self aligning
Prevent spread of adhesive to unwanted areas

Preparation

Pretreatment is not always required. For highest strength the component should be solvent vapour degreased then etched in 20% hydrochloric acid for 2-4 minutes, rinsed and dried.

Performance

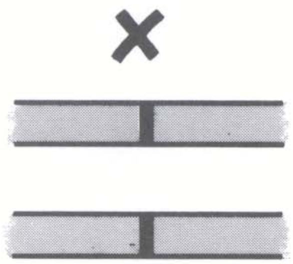
Strength varies with joining preparation and bond thickness ets. The types listed on the left can achieve shear strengths of 15-30 MPa. Epoxies and modified acrylics have peel strengths of up to 130N/25mm. Anaerobics may achieve twice this value, while cyanoacrylates give much lower peel strengths.

Cast metal joining

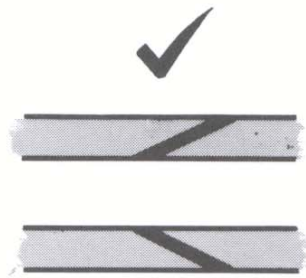
Die casting can be used to join two or more non-die cast parts. Here the inserts are the most important part of the component and the cast metal itself only provides the joint. Very high production rates can be achieved using special machines.

Problem/Application	Solution	Advantages
Terminate wire or cable	Inject zinc alloy terminal of desired shape into wire or cable	Eliminate machining, stocking and feeding of terminal. Terminal stronger than cable
Small stud in thin plate	Zinc alloy hub in hole around stud	Eliminate staking, bushing or shoulder. Relax size and positional tolerance of hole
Metal hub required in 0.015in thick rubber diaphragm	Zinc hub hole in diaphragm	Eliminate hub manufacture and handling
Gear, shaft and pinion	Zinc alloy hub with integral pinion	Eliminate machining of pinion or shaft from pinion stock. Relax tolerance. Concentricity between gear, pinion and shaft controlled by tool
Assemble ceramic part to steel	Zinc alloy hub or other locking configuration	Eliminate fracture, etc caused by staking. Only one fixture. Faster than adhesive bonding (no cure time)
Assemble laminations	Several zinc alloy rivets injected in place with one shot. Runner may be removed or left in place as functional shape	Eliminate manufacture, stocking and feeding rivets. Eliminate some rivet operations. Rivets conform to hole shape, size and position.
Assemble shading coil into laminations	Zinc alloy shading coils injected in place with one shot	Eliminate brass or copper coils and brazing operations. Fast. Design freedom as to shape and cross-section of shading coil
Assemble several parts at intervals onto flexible or rigid shaft	Either: a) Inject zinc alloy shape in place or: b) Lock machined part onto shaft with small zinc alloy hub	a) Eliminate machining stocking and feeding or part Stronger joint. Shapes may be identical or different b) Wider tolerances. Stronger joint. Machined part and hub can be identical or different

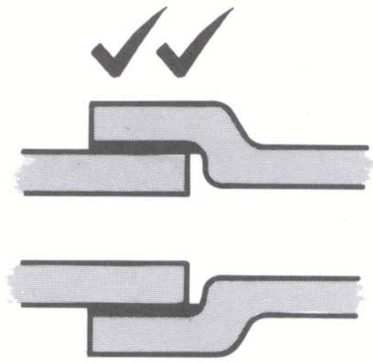
Adhesive bonded joints



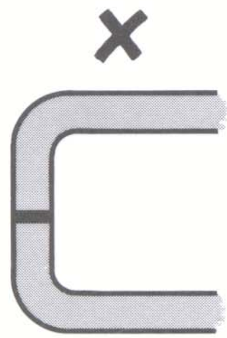
Butt joint



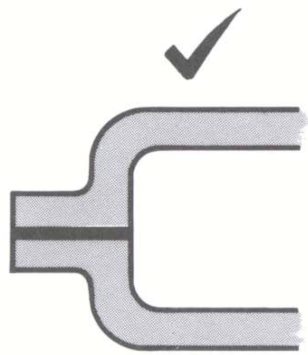
Scarf joint



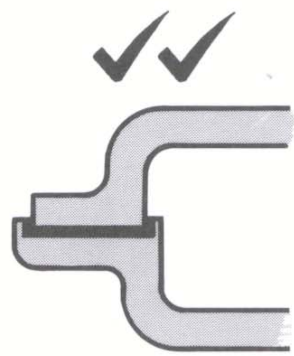
Double lap joint



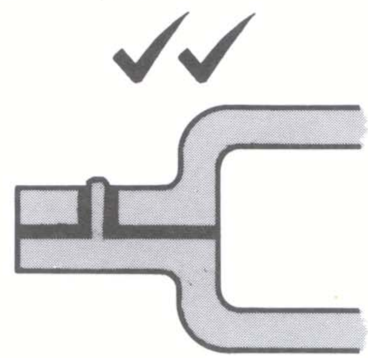
Butt joint



Extended butt joint

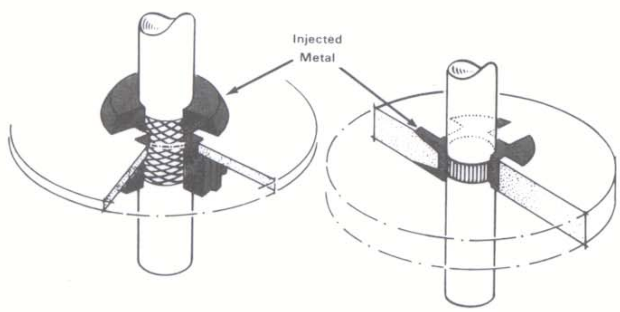


Extended butt joint with location and channel for adhesive

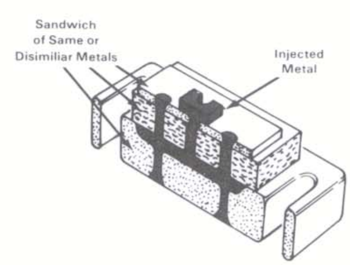


Extended butt joint with pin and spigot location

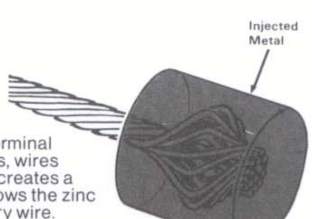
Examples of cast metal joining



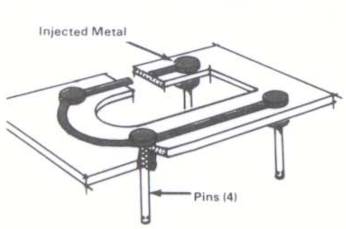
Shrinking a zinc alloy hub onto four keys and a knurl locks a disc and shaft into a permanent assembly (left). A pinion is made into an integral part of the zinc hub, which eliminates machining it from stock. Another zinc injection configuration has the hub flush with the faces of the disc (right). The four keys still provide the locking surfaces.



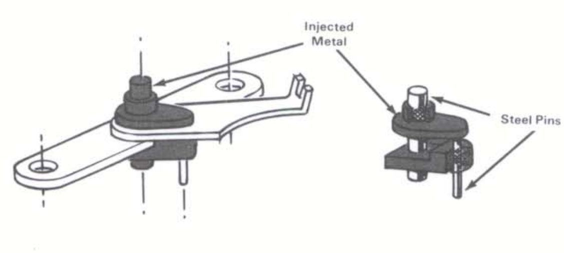
Dissimilar materials can be easily sandwiched by injecting zinc alloy rivets. Note the functional bridge on top, the internal channel which permits several rivets to be injected simultaneously, and how the holes do not need to be closely aligned nor of the same size.



Almost any shape of zinc alloy terminal can be injected directly to cables, wires springs, etc. A simple operation creates a 'rosebud' on the cable which allows the zinc to flow around and between every wire.



Four brass pins are locked into a thin sheetmetal plate with an injected runner and four hubs.
The runner can be functional or removed.



Two stampings, two steel pins and two staking bushings would normally be staked to form this assembly. Cast metal joining can eliminate both the pins and bushings as shown on left or lock steel pins into the plates and eliminate only the bushings.