Proposed Optimization of a Pin Joint Machining and Assembly Process

Dana Ingalsbe
Jacksonville State University
ingalsbe@jsu.edu

Chris Marker
Jacksonville State University
cmarker@jsu.edu

Abstract

The manufacturing process for assembling pin joints on fixtures and round parts requires precision machining for critical press or slip fits. The process can be particularly costly when working with metals that do not lend themselves to complex machining and welding. The purpose of this study is to propose new ways to reduce the time and cost of manufacturing these type of joints.

There are several ways pin joints can be assembled. These are usually dependent upon the materials used and the tolerance of the joint location. Screw connection, press fit, pinned connection and retaining compound are the common methods. Each joint type has its benefits and disadvantages. Screw connections may not be possible in very hard materials while press fit joints may loosen in heat cyclic applications. Pinned joints require many manufacturing steps and can be quite costly. Retaining compounds must be selected properly and require the correct base materials, geometry, preparation, and assembly procedures to function correctly. This paper proposes the use of a combination of joint types to create a hybrid physical and chemical bond to evaluate if a joint can be developed with simple manufacturing procedures, reducing the possibility for error in manufacturing and assembly. The end goal is to increase the reliability of the joint while reducing the cost of production.

The joint types explored are applicable to non-weldable, dissimilar precision joints used in a heat cyclic environment. The obstacles to overcome are: expansion and contraction of dissimilar metals, reduction of steps in the manufacturing process, and non-uniform or incorrect compound thickness application.

Introduction

Press fit pins are used to locate parts requiring high precision positioning. Press fit (also called interference fit) pins may also be used to permanently affix two or more parts together. When a pin is used for location purposes, that pin is permanently affixed to a stationary host on one side of the joint. The other side of the joint consists of a removable member that is attached using a slip fit joint, which is the hole that accommodates the pin, as shown in Figure 1. This is the common configuration for jigs and fixtures that require accurate placement over repeated use.

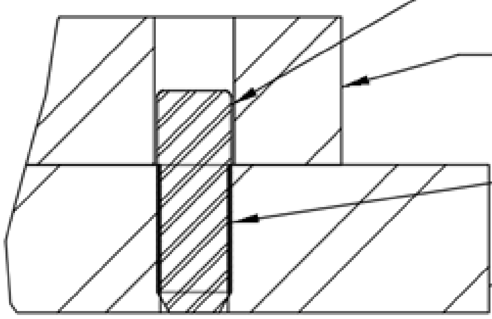

Figure 1. Typical Press Fit/Slip Fit Pin Joint

On the slip fit side (removable half) of the joint, the hole accommodating the pin will be slightly larger than the outer diameter (OD) of the pin itself. This allows the part to slide on and off while at the same time maintaining the correct location. The slip fit gap is determined by the size of the pin used in the joint and the level of required precision. Typical slip fit gap dimensions are on the order of thousandths of an inch, while slip fit gap tolerances are on the order of ten-thousandths of an inch.

Due to these narrow tolerances, the precision machining that is necessary to achieve accurate fit and joint placement increases the cost of producing fixtures and jigs with pin joints. When the joint is exposed to cyclic temperature conditions, the press fit can be compromised, weakening the joint by allowing it to move or pull out. Current practice demands a more complex joint, such as a cross-pinned joint, to maintain joint placement. It is therefore worthwhile to explore alternate methods for the production of joints with reduced manufacturing effort while maintaining or improving the accuracy of the joint fit.

Literature Review

The focus of the literature regarding press fit pin joints seems to be upon the optimization of joint strength (axial and torsional) rather than the achievement of precise pin placement. For example, a study by Croccolo *et al* [1] explored the use of industrial retaining compound in press-fitted joints (hybrid joints of aluminum and steel). The use of the adhesive was effective in increasing the performance of the joint when the coupling pressure of the joint was within the typical range of 40 MPa. In another study, Sekercioglu [2], used a genetic algorithm approach to determine that many variables, including surface roughness, temperature, and interference fit, among others, independently influence the shear bonding strength in an adhesively bonded, tubular joint. In an investigation examining the static strength of interference fit hybrid joints, Croccolo *et al* [3] confirmed that the contribution of adhesive compound is indeed a significant contributor to the strength of the joint. The researchers in this case measured the static strength of interference fit couplings assembled with and without adhesive compound.

While the focus of this proposed study is not upon the strength properties of the pin joint, per se, the effectiveness of using a retaining compound is of interest to the authors. In the case of the current proposed study, application of a retaining compound may help to maintain or improve the integrity of the joint, while at the same time decreasing the cost of joint assembly by reducing the amount of machining necessary.

Motivation/Industry Need

The need for a precision joint with reduced cost and error prevention qualities extends across most manufacturing industries. Pin joints are used primarily for location of removable parts that must maintain their original position after reassembly, eliminating the need for operator adjustment. The pins within the joint are permanently affixed to the host part. The pins then closely slip into the holes on the removable part, maintaining the correct location. This type of joint is commonly found in punch and die blocks used in presses and multi-piece molds used in the manufacturing of plastic parts. The largest application of pin joints however, is in the manufacturing of machined and welded assemblies and the assembly of multi-part products. Pins do not necessarily carry a load but are used to correctly locate the removable part with the host part.

Pins may wear and become damaged while functioning in the manufacturing environment. As a result, they must be periodically replaced, and this maintenance function causes downtime. Pins that move or are damaged result in bad parts or damaged equipment, a costly event for a simple part. A faster, lower cost method for designing and building a secure pin joint is therefore needed to reduce the cost of building fixtures and jigs, as well as to improve the accuracy of positioning and reliability of the joint.

Manufacturing the joint can quickly become a costly operation. By its very nature, the joint is a precision feature, requiring time-consuming processes such as reaming. As punches and dies are often made of high grade, difficult-to-machine materials, operations like threading become impractical. Many press and mold operations involve assembling the joints under high pressure and temperature. High temperature operations, such as welding, make a simple press fit inadequate. All of these scenarios demand a more complex joint geometry and drive the cost of manufacturing upwards.

Joint complexity determines the amount of time and effort required to replace the pin or pinned parts. There are a number of methods for attaching the pin to the host portion of the joint. Each of these methods can be accomplished several ways, determined by part geometry and material. Each method has its unique benefits and drawbacks, as summarized in Table 1.

Table 1. Summary of Joint Connection Types

Joint Connection	Benefits	Drawbacks
Screw	Easily removed/replaced	Does not withstand temperature cycling Requires more space
Press Fit	Simple machining process Accurate alignment	May not withstand temperature cycling
Retaining Compound	Reduced machining Resists temperature cycling	Ideal gap size necessary Precision alignment difficult
Cross-Pin	Allows accurate alignment Resists temperature cycling	Extensive machining necessary (expensive)

A screw connection may be used in easily accessible and machinable parts. It requires more space on the host than other joint types, and additional features such as countersinks are necessary for accuracy. Using a screw connection requires machining operations for drilling, tapping, and countersinking. Screw connections have a tendency to become loose under vibration and cyclic temperatures, however, screw connections are often used because they are easily removed and replaced.

The most common joint connection is the typical press fit, which uses a precision ground dowel pressed into a smaller precision bored hole. The pin is held in place via friction caused by the compressive force of the part upon the pin. This is also called an interference fit. The accommodating hole is slightly smaller than the pin. The pin causes the host part to undergo plastic deformation as it is pressed in, greatly increasing the friction on the pin. Interference dimensions are dictated by the size of the joint and the material of the part and pin with a typical interference of 0.0002" for most steels. The location of the hole is critical as well as the tolerance of the hole which is usually in the ten thousandths of an inch range. Standard tables, such as those developed by ANSI [4] have been developed that define the press fit tolerance for most materials. When dissimilar metals are used, a press fit hole may not be sufficient to retain a pin when cyclic temperatures are encountered, or where the pin is subject to repeated tensile forces. Press fits are desirable because the machining process is relatively simple in comparison to other joint types.

Retaining compound joint connections use a chemical bond to hold the pin in place. The joint is a slip fit joint, with the gap of the joint determined by the retaining compound used. The compound proposed for this study is Loctite 620 green retaining compound. The retaining compound must be selected based on several factors, such as component materials, thickness range of the compound (which determines the ideal gap depth), and the operating temperature range of the joint. Helpful information regarding these variables may be obtained from the technical data sheets provided by the manufacturer [5]. A primer may be applied to increase the chemical bond strength when non-reactive metals such as nickel alloys are used. One benefit of using a retaining compound is its ability to withstand

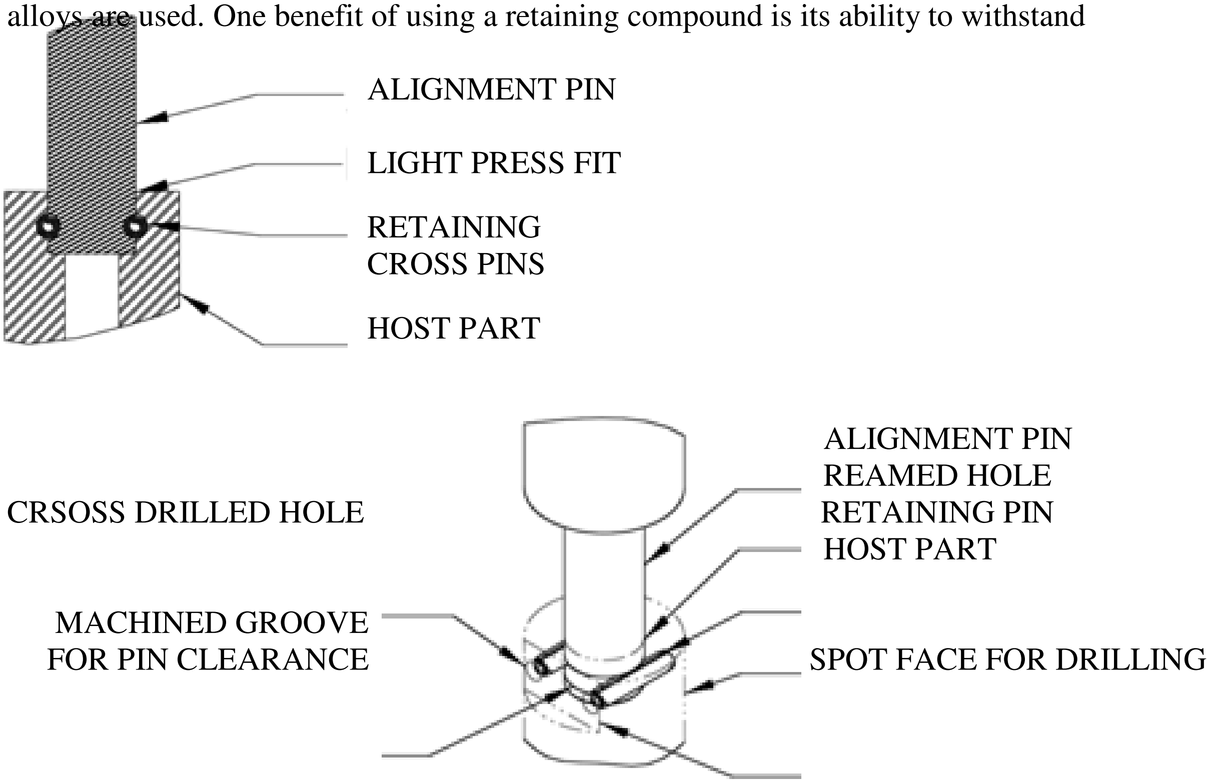

Figure 2. Cross-Pin Joint Construction

temperature cycling and another is the reduced machining necessary. However, in the case of parts requiring precision press fits, retaining compound does not allow for precision pin alignment.

A cross-pinned joint connection may be used when the geometry allows the alignment pin to lock in place, as shown in Figure 2. This joint style is stable in cyclic temperature environments but is costly to produce due to the extensive machining that is required. The initial pin hole is drilled as a light press fit or tight slip fit where the hole OD and the pin nominal OD may be of equal dimensions or share a gap of 0.0005". One or two cross-pin holes are then drilled through the part. A corresponding groove is turned on the pin. The alignment pin is seated into the hole, and then a roll pin is pressed into the cross-drilled holes to lock the alignment pin in place. This type of joint is only used when necessary as the joint requires three pins and multiple fabrication steps.

For the purpose of assembling a pin joint in the most accurate yet economical way possible, none of these methods alone provides both accuracy and economy. For this reason, it is necessary to propose a hybrid joint that combines the benefits of different joint connection types.

Proposed Joint Construction

A proposed hybrid press fit and retaining compound (hybrid) joint is anticipated to incorporate the alignment properties of a press fit joint in conjunction with the retaining compound's ability to resist loosening under cyclic temperature conditions. The joint must incorporate simple, low cost manufacturing techniques that allow the joint to be used in the same space-constrained areas where a standard press fit joint can be used.
The hybrid joint is designed with standard dowel pin geometry, as shown in Figure 3. A light press fit at each end of the joint will be used to maintain true alignment. The OD of the pin will follow standard dowel pin size and tolerance. The hole will be drilled and reamed to standard press fit dowel pin dimensions.
In order to incorporate retaining compound, a series of lands that will act as pockets will be added to the alignment pin. The lands will be simple, flat-bottomed grooves, turned or ground into the face of the cylindrical surface. The lands will be turned to the optimal depth of the retaining compound to be used, as recommended by the manufacturer, and will provide for a controlled, even retaining compound thickness. In this case, a retaining compound depth of 0.008" for Loctite 620 is recommended by Loctite's technical data sheet [5].
The hole will be drilled as a press fit. The pin will be coated with the retaining compound and then pressed into the hole. The retaining compound will then be allowed to cure for the time period recommended by the manufacturer.

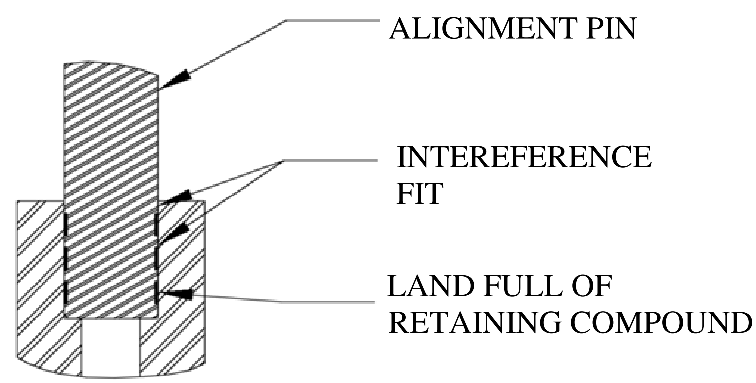

Figure 3. Proposed Hybrid Joint Design

Conclusion

The proposed hybrid press fit and retaining compound (hybrid) joint should exhibit the best traits of both joint types. The hybrid joint should be superior to the standard retaining compound joint because it will allow accurate placement of the pin, which is not possible when using retaining compound alone (due to larger hole dimensions). The film thickness

ISBN 978-1-60643-379-9

will be controlled because of the lands on the pin, allowing the retaining compound to have even geometry for more controlled contact.

The proposed hybrid joint will be far superior to the screw joint due to its ability to withstand cyclic temperatures and its superior alignment properties.

While the cross-pin joint provides optimal accuracy, its weakness lies in its cost and manufacturability. Manufacturing this joint is difficult under some circumstances due to the lack of access to cross-drilled features. A hybrid joint will provide a greater ease of manufacturing while maintaining optimal accuracy of pin placement.

The cost of the machining process for the proposed hybrid joint will be on the order of that of a press fit pin joint. One additional turning operation will be required to create the lands on the pin. This is a simple and inexpensive operation when compared to the machining steps required to create a cross-pinned joint. When comparing the hybrid joint to a cross-pinned joint, the elimination of the roll pins and simplified assembly steps provide additional manufacturing cost savings. The next phase of this study will include a manufacturing cost comparison between the hybrid joint and the other types of joints discussed, particularly the cross-pinned joint, in order to quantify the cost savings experienced due to the proposed hybrid joint.

In order to evaluate the ability of the proposed hybrid joint to maintain its accurate placement during heat cycling conditions, future work will involve exposing hybrid joints to temperature cycling that reflects industrial conditions while determining if the pin placement remains intact during this testing. Hybrid joints will be evaluated alongside cross-pinned joints to ensure that the accuracy of pin placement is reliable even during robust temperature conditions.

Although it is anticipated that the proposed hybrid joint will exhibit the best traits of both cross-pinned joints and retaining compound joints, future work will involve testing to evaluate the hybrid joint properties. For example, while curing time is greatly affected by the gap size, no information is available which relates gap size to the ultimate strength of the joint [5].

Mechanical testing to be conducted in the next phase of this study will determine if the addition of the lands adversely affects the joints by weakening the pins. Additionally, testing will be used to optimize the land size and geometry for obtaining maximum strength from the joint. A series of pin pullout tests will be performed to evaluate the retaining strength on the stationary side of the joint. A baseline series of tests will be performed using an MTS fatigue tester on a set of pins installed using the standard accepted practices of manufacturing. Comparative baseline tests will be performed on pins installed via: press fit, cross-pinned, and seated with retaining compound. These test results will be compared to the results of the same test performed on the new hybrid joint.

The changes proposed to mechanical joint design and assembly discussed in this study may have substantial impact in terms of cost savings realized in the forms of increased manufacturability, decreased maintenance-related downtime, and improved product design.

References

[1] Croccolo, D., De Agostinis, M., and Vincezi, N. (2011) Experimental Analysis of Static and Fatigue Strength Properties in Press-Fitted and Adhesively Bonded Steel-Aluminum Components. *Journal of Adhesion Science and Technology*, 25, 2521-2538.

[2] Sekercioglu, T. (2005) Shear strength estimation of adhesively bonded cylindrical components under static loading using the genetic algorithm approach. *International Journal of Adhesion & Adhesives*, 25, 352-357.

[3] Croccolo, D., De Agostinis, M., Mauri, P.,and Vincezi, N. (2012) Influence of Assembly Techniques on the Static Strength of Interference Fit and Adhesively Bonded Pin and Collar Specimens. 15th International Conference on Experimental Mechanics.

[4] Preferred Limits and Fits for Cylindrical Parts, ANSI/ASME B4.1-1967 (R2009). (n.d.). , Retrieved from http://webstore.ansi.org/RecordDetail.aspx?sku=ANSI%2fASME+B4.1-1967+(R2009)

[5] LOCTITE 620 Retaining Compound High Temperature. (n.d.). Retrieved from http://na.henkel-adhesives.com/adhesives/product-search-1554.htm?nodeid=8797714120705&msdsLanguage=EN_US&selectedTab=technical

Biographies

DANA INGALSBE is currently an associate professor in the Department of Applied Engineering at Jacksonville State University (JSU). Dr. Ingalsbe serves as the coordinator of the graduate program in Manufacturing Systems Technology. She teaches a wide variety of courses at both the graduate and undergraduate levels at JSU.

CHRIS MARKER is currently the manufacturing engineer for the Department of Applied Engineering at Jacksonville State University (JSU). Mr. Marker worked for 20+ years as an engineer in the manufacturing sector prior to joining JSU and has significant experiences in machine design.