The principle sets the weld interface. Abruptly halting the vibration and pressing the work pieces against the coupon under a final load or forging pressure sets the weld interface.

**Abstract**: A linear friction welding method and linear friction welding apparatus for joining two work pieces. The method involves vibrating a third weld component, or "coupon" between the two principle work pieces under a welding pressure. Friction between the coupon and work pieces causes the material at the weld surfaces to plasticize. Abruptly halting the vibration and pressing the work pieces against the coupon under a final load or forging pressure sets the weld interface.
LINEAR FRICTION WELDING METHOD

This application claims the benefit of U.S. Provisional Patent Application, Serial No. 61/630,130 filed December 5, 2011, the entirety of which is incorporated by reference herein.

This invention relates to a method for bonding to two work pieces together using linear friction welding, and in particular bonding a third component between the two work pieces.

Background and Summary of the Invention

Linear friction welding (LFW) is a process of joining two components which may be made from the same or different materials. The LFW process typically involves pressing the two components together under a large amount of force and rapidly vibrating the components with respect to one another to generate friction at the interface between the two components. The pressure and movement generate sufficient heat to cause the material at the interface to plasticize. Once the material at the interface begins to plasticize, the vibration is stopped and an increased force is applied. As the plasticized material of both components cools in this static condition, the components are bonded together and a weld is formed. While LFW is suitable in many applications, heretofore, LFW has not been practical for repair welds.

The present invention provides a linear friction welding method and linear friction welding apparatus for joining two work pieces. The method involves vibrating a third weld component, or "coupon" between the two principle work pieces under a welding pressure. The vibration of the weld coupon is facilitated and controlled by a linear friction welding (LFW) machine, such as the ones available from APCI, Inc. of South Bend, Indiana. Friction between the coupon and work pieces causes the material at the weld surfaces to plasticize. Abruptly halting the vibration and pressing the work pieces against the coupon under a final load or
forging pressure sets the weld interface.

The apparatus and method of the present invention may take form in various systems and components, as well as the arrangement of those systems and components. The above described features and advantages, as well as others, will become more readily apparent to those of ordinary skill in the art by reference to the following detailed description and accompanying drawings. The drawings are only for purposes of illustrating exemplary embodiments and are not to be construed as limiting the invention.

**Brief Description of the Drawings**

The drawings illustrate the present invention, in which:

Fig. 1 is side view of the weld coupon positioned between two work pieces showing an initial step of the method of this invention using a linear friction welding machine;

Fig. 2 is a side view of the two work pieces being pressed against the weld coupon as the weld coupon is vibrated to form the weld interface using the method of this invention.

**Description of the Preferred Embodiment**

Referring now to the drawings, Figs. 1-2 illustrate an embodiment of the method of this invention for welding two work pieces 10 and 10' using a linear friction welding (LFW) machine (not shown). The LFW method of this invention is illustrated and explained hereinafter by way of example in the joining of two components end to end, although, those skilled in the art may readily adapt and apply the teaching of this invention to other applications. In addition, the linear friction welding (LFW) repair method of this invention can be used to join ferrous work pieces regardless of configuration or metal composition.

*LFW Machine & Fixtures*
While the method of this invention may employ the use of any linear friction welding (LFW) equipment, machine or apparatus, the method is best employed using linear friction welding (LFW) linear friction welding (LFW) apparatus, fixtures and machines, such as the ones developed by APCI, Inc. in South Bend, Indiana and described in U.S. Patent Application Serial Number 12/868,623 filed August 25, 2010, which issued as U.S. Patent Number 8,070,039 on December 6, 2011. The LFW apparatus, fixtures and machines from APCI are ideal for the repair process of this invention because of their ability to control the amplitude, frequency and termination of the weld oscillation, as well as the weld and force pressures during the weld process. The teachings of the U.S. Patent Number 8,070,039 are incorporated herein by reference. The LFW machine generally includes a pressing assembly, which provides the weld and forge pressure to the components being bonded and a vibrating assembly, which vibrates the components to generate friction between the components. For simplicity of illustration and explanation, the press assembly and the vibration assembly of the LFW machine are not shown.

The LFW repair method of this invention begins with providing a mating weld block or "weld coupon" 20. The weld coupon is generally cast, formed or machined from the same material as work pieces 10 and 10' or a compatible material for bonding to the work pieces. Weld coupon 20 generally provides some new material to the bonded work piece assembly. Consequently, the thickness of coupon 20 is configured to provide the desired thickness for the particular weld application. In addition, weld coupon 20 is configured to have a corresponding shape and profile of that of the work pieces.

When the weld is formed, weld coupon 20 is held in a mounting fixture 22 and work pieces 10 and 10' are held in mounting fixtures 12 and 12' of the LFW machine. Coupon fixture
22 is operatively connected to vibration assembly 120 of the LFW machine. Work pieces 10 and 10' are held in mounting fixtures 12 and 12' respectively. At least one of fixtures 12 and 12' are operatively connected to the press assembly of the LFW machine. Once the weld coupon 20 and both work pieces 10 and 10'' are properly seated and secured in the mounting fixtures of the LFW machine, the LFW machine vibrates coupon 20 while pressing work pieces 10 and 10' axially together against the coupon under an initial load or "weld pressure" (Figs. 5, 6 and 8). Friction caused by the vibration and the weld pressure causes the material at the weld surfaces to plasticize. The vibration is then abruptly stopped and work pieces 10 and 10' are pressed together against weld coupon 20 under a final load or forging pressure, which forms the weld interface. Once the weld interface is formed, the joined work assembly can be removed from the LFW machine and further machined as necessary to finish the final component.

The embodiment of the present invention herein described and illustrated is not intended to be exhaustive or to limit the invention to the precise form disclosed. It is presented to explain the invention so that others skilled in the art might utilize its teachings. The embodiment of the present invention may be modified within the scope of the following claims.
I claim:

Claim 1. A method for welding two work pieces together using linear friction welding, the method comprising:

a. Providing an intermediate weld coupon having a first weld surface for contacting the first of the two work pieces and a second weld surface for contacting the second of the two work pieces;

b. Pressing the first of the two work pieces against the first weld surface of the weld coupon and pressing the second of the two work pieces against the second weld surface of the weld coupon under a first load;

e. Rapidly vibrating the weld coupon laterally relative to the two work pieces whereby the friction between the weld coupon and the two work pieces plasticizes the material of the weld coupon and the work piece; and

e. Pressing the two work pieces against the weld coupon under a second load to form a weld interface between the two weld pieces and the weld coupon.

Claim 2. A linear friction welding machine comprising:

a first fixture for holding a first work piece;

a second fixture for holding a second work piece;

a third fixture for holding a weld coupon in shiftable abutting engagement between the first work piece and the second work piece;

means operatively connected to the first fixture and the second fixture for pressing the first work piece and the second work piece axially against the weld coupon under selective loads;
and

means operatively connected to the third fixture for vibrating the weld coupon laterally
between the first work piece and the second work piece to generate friction between the weld
coupon, the first work piece and the second work piece.
### INTERNATIONAL SEARCH REPORT

**International application No.**
PCT/US20 12/067840

#### A. CLASSIFICATION OF SUBJECT MATTER

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According to International Patent Classification (IPC) or to both national classification and IPC

#### B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

**CPC** - B23K 20/1285; B29C 65/06, 65/0618 (2013.01)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PatBase, Google Patents, Google

#### C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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