

Implementation of Kinematic Web Handling

Alexander D. Sprunt, Alexander H. Slocum

Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, MA

Abstract—This paper presents simple mechanisms for kinematic web handling, including a castoring and gimbaling roller, a pinch roller, and an edge constraint. Developed as part of a system for in-situ measurement of spring probe contact resistance on virgin material, the machine uses a 51mm wide, 0.13mm thick foil, or web, of solder clad Alloy 42 as a proxy for semiconductor leadframes. Storage on a roll was the most straightforward way to manage the large area of virgin material required by the study.

I. KINEMATIC WEB HANDLING

A web is “a strip of flexible material whose width is much greater than its thickness and whose length is much greater than its width” [1]. As Blanding states, kinematic web handling can eliminate calibration, facilitate precise web placement, and unlike crowned or flanged rollers can be used to guide stiff webs. The web’s six degrees of freedom are reduced to three because it is confined to travel in the planes defined by the rollers around which it winds. The motion imposed by the feed roller further reduces the web’s degrees of freedom to two: rotation and motion perpendicular to the feed. Blanding recommends these two remaining degrees of freedom be exactly constrained with gimbaled rollers, zero constraint rollers, and edge constraints. Such rollers have been designed before (US Patents 4,221,480 and 5,244,138 are two examples), but they are not readily available and are not amenable to fabrication as singletons. For our spring probe testing machine, we designed and tested several new roller concepts, as well as a kinematic pinch roller, and a kinematic edge constraint.

II. TEST MACHINE CONCEPT

Our concept for the spring probe testing machine is shown in Figure 1. The web is wound off the supply spool, around an idler roller, past the array of spring probes being tested, through an edge constraint, around the index roller, and onto a take-up roll. The web is tensioned between a DC motor on the take-up roll shaft and a slip clutch attached to the supply roll. To advance the web, a stepper motor fixed to the index roller is incremented, breaking the equilibrium between the DC motor and the slip clutch. The index roller’s diameter makes one count on the stepper equivalent to 0.35mm of web advance.

III. FIRST BENCH LEVEL PROTOTYPE

A Bench Level Prototype (BLP) was built using universal joints to create gimbaled and castored rollers

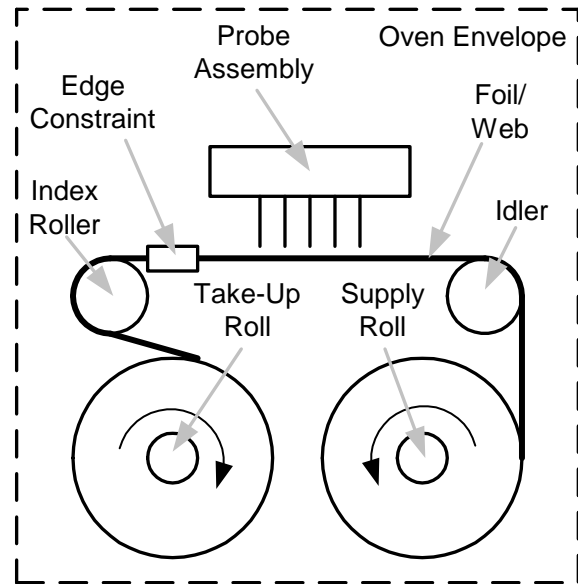


Fig. 1. Spring probe testing machine concept. High temperature testing required the whole machine be placed in an oven, a significant design constraint.

(Figures 2 & 3). Castored rollers are a type of zero-constraint roller, but instead of having a compliant surface like the rollers in the aforementioned patents, they are mounted so they may pivot about an axis normal to the web’s plane of travel (Figure 4) to self-align with the web’s path as defined by other constraints. Imagine a cart’s castored wheel aligning itself to the cart’s direction of travel, or rather to the ground’s direction of travel with respect to the cart. Gimbaled rollers are mounted to rotate about an axis parallel to the plane of the incoming web. The twist accommodated upstream of the roller relieves the web of one degree of freedom. The two orthogonal axes of the universal joint combine to gimbal and castor the attached roller.

The prototype worked, but even after the addition of counterweights, substantial web tension was required to overcome the destabilizing effect of gravity. Still more tension would have been required if the rollers had not been positioned to hang from the couplings pendulum-fashion (rather than stand inverted from them), a limitation severely constraining the configuration of the system, and preventing implementation of the concept in Figure 1.

A kinematic edge constraint (Figure 5) was designed

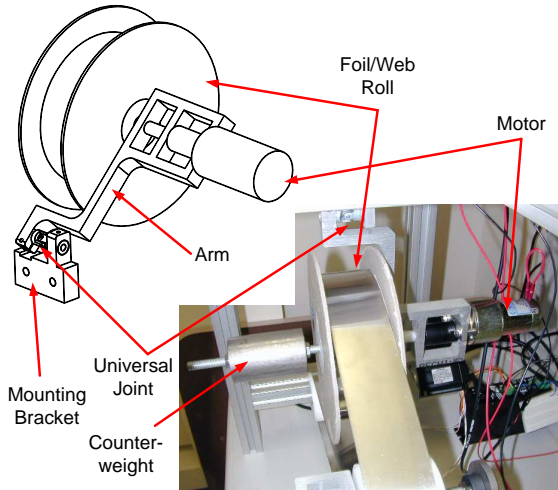


Fig. 2. A gimballing and castoring roll assembly from the first BLP. Note how the assembly hangs down from its mount.

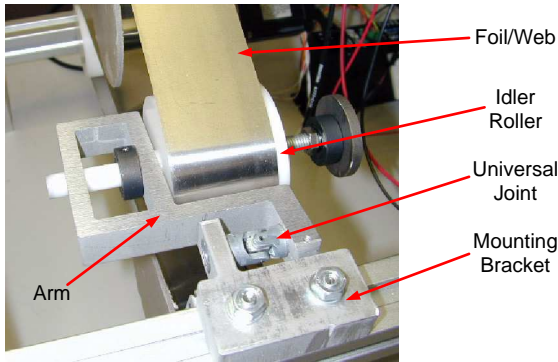


Fig. 3. An idler roller assembly from the first BLP. Note how web tension holds the assembly in position. Without the edge constraint (Figure 5, the web had a tendency to ride against the side of the arm supporting the roller).

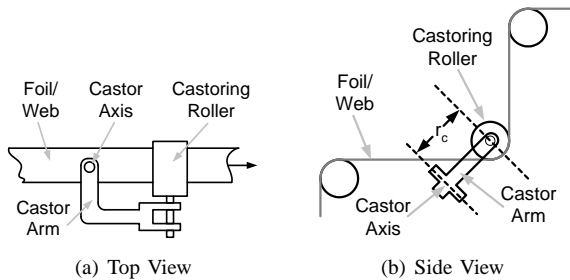


Fig. 4. Castored rollers rotate to align themselves with the path of the web. The distance the web must travel before alignment occurs is a function of the castor radius (r_c) [1].

to guide the edge of the web. One edge of the foil was pressed against a fixed cam follower by the “nesting force” of a second follower mounted on a spring arm. Concerns about lead particle generation from the solder on the foil necessitated rolling rather than sliding contact between the web and the edge constraint.

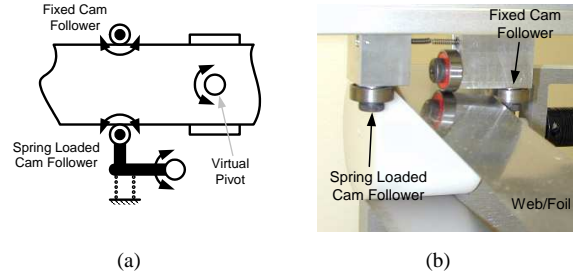


Fig. 5. A diagram and a picture showing the operation of the kinematic edge constraint. The force of the spring loaded cam follower keeps the web “nested” against the fixed cam follower. Obviously, too high a force will buckle the web.

IV. SECOND BENCH LEVEL PROTOTYPE

BLP-2 moved the universal joints from the roller arms to the rollers’ axes (Figure 6). The rollers were now supported at their center of mass while still providing gimballing and castoring axes. This prototype improved on BLP-1 by eliminating the need for counterweights, and greatly simplifying the mounting of motors, brakes, and sensors on roller shafts, but it required a disappointingly large amount of tuning; lateral misalignments tolerable in BLP-1 were unacceptable to BLP-2.

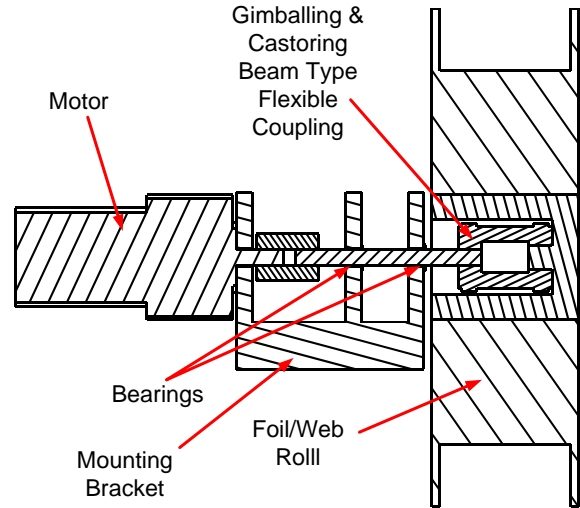


Fig. 6. Cross section of a flexible coupling mounted gimballing (and perhaps castoring) roll assembly. BLP-2 was similar, but with a universal coupling in place of the flexible coupling. This was a much more adaptable concept than the first BLP.

Replacing the universal joints with beam type flexible couplings from Helical Products solved these problems and provided a restoring force to support the rollers

after the web had been unloaded, though it was unclear whether true castoring was still occurring [2] because the castor radius (r_c) had been reduced to zero.

V. KINEMATIC PINCH ROLLER

For the testing machine, a kinematic pinch roller was added to eliminate slip between the drive roller and the web (Figures 7 & 8). Pinch rollers are not often found in kinematic web handling systems because in combination with the other rollers they invariably overconstrain the web [1]. To prevent this, the web was pinched between a compliantly mounted self-aligning bearing and a fixed roller; the foil may thus still pivot about the drive roller. This combination provided the grip of the pinched roller configuration without overconstraint.

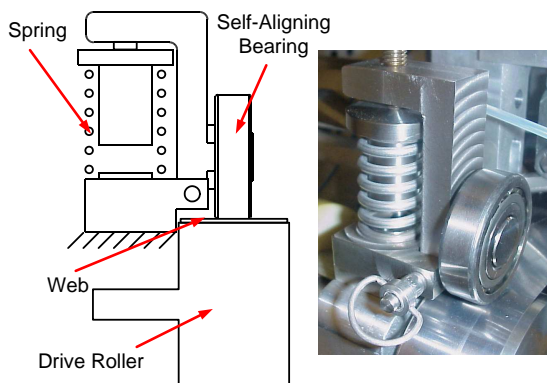


Fig. 7. The kinematic pinch roller provides the advantages of a clamped connection without overconstraint.

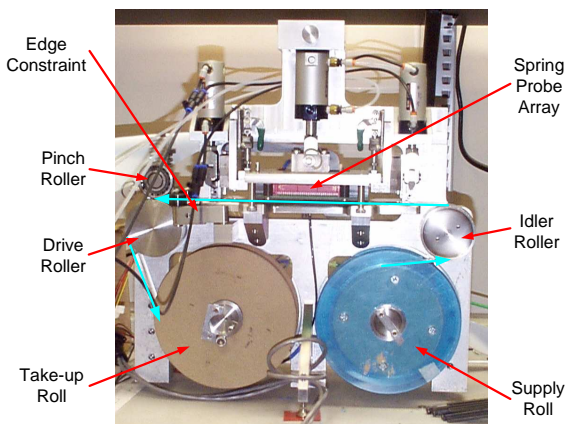


Fig. 8. The final machine. Note the foil path in blue. Over half a million trouble free cycles have been completed.

VI. CONCLUSION

The testing machine has completed over half a million trouble free cycles of advancing the web by 0.35mm, clamping the web, plunging an array of contactors into the web, and then advancing the web another 0.35mm to start the next cycle, all while intermittently measuring the contact resistance of the spring probes. Those results, an example of which can be seen in Figure 9 are described elsewhere [3]. A similar machine could readily be adapted for other tribological experiments requiring large areas of virgin material.

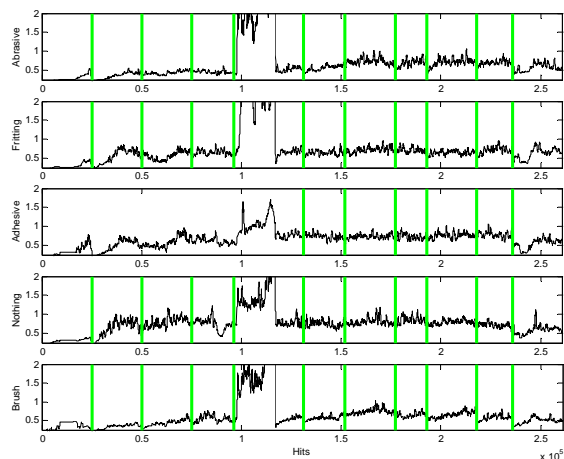


Fig. 9. One experiment run with the machine tested the effectiveness of various different cleaning techniques. The figure plots the window averaged contact resistance measurements (ohms) of probes cleaned with each different cleaning method. Fritting [4], [5] is a phenomenon exploited to lower contact resistance by forming a spark between electrodes to breakdown any intermediate oxide.

ACKNOWLEDGMENT

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