Improve Energy Efficiency and Weld Quality by Eliminating Expulsion Welds on Automobile Assembly Line

Kelvin Shih
Lawrence Technological University
Southfield, Michigan 48075

Introduction

- Elihu Thomson invented resistance welding in 1891.
- Automobile body consists of large number of stamped sheet metals welded together by resistance spot welding.
- Welding is the most important parameter in determine the integrity and crush worthiness of the car.
- Average automobile has 4,500-6,500 welds to hold them together.
- Aircraft, appliances and ships and many other industries also uses spot welding to build their products.

Conventional AC Welding System

- Nearly 95% of the resistance welders in use today in the world are still AC welders.
- AC welding uses SCR phase control in the primary of the step-down transformer to adjust the current and weld time.
- AC welder efficiency from line to weld caps is about 26%.
- The weld can only be terminated after a complete cycle.
- After the weld lobes are found the weld schedule is selected between the two weld lobes.
- Easier to have expulsion than MFDC welding.

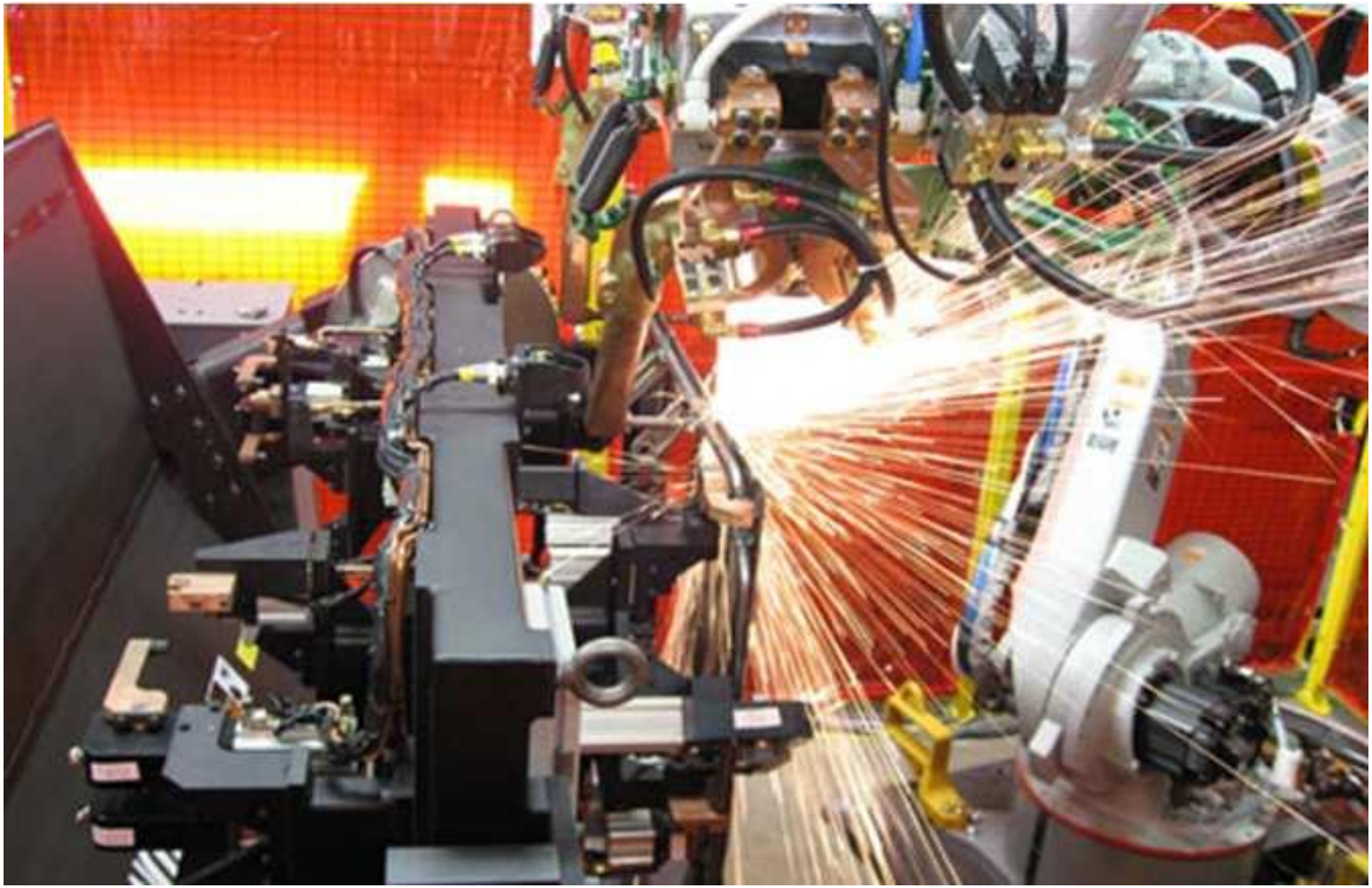
MFDC Welding (Mid Frequency Direct Current)

- Three phase AC is rectified to high voltage DC.
- Using IGBT (isolated gate bipolar transistor) to generate a PWM (pulse width modulation) signal.
- This PWM signal controls the current and on off of the welder.
- The efficiency of MFDC welder is about 37%.
- Because you can terminate the weld at any time, this welder is much easier to control.
- If the weld schedule is not set correctly expulsion could happen.

Three Problems That Plagued Automotive Industry Today

1. Expulsion
2. On line real time inspection.
3. Current stepper.

Expulsion!



Expulsion on A Automotive Assembly Line

What Is Expulsion?

- Expulsion is the eruption of molten metal from the weld joint burned in the air.
- This phenomena causes the deterioration in quality of the weld nugget and at the same time wastes a lot of energy.
- For most of the users, programming the weld schedule is an empirical process, adjusting parameters more or less at random until a good weld is obtained.
- High current and long weld time will cause expulsion.
- High current alone may cause expulsion even the energy is within limit.
- Weld engineer & electrician use expulsion as a visual feedback of a weld. So some of them intentionally adjust the current and time beyond the expulsion limit just to have visual feedback.
- Expulsion when welding thin metal sheets could burn a hole through the metal. This phenomenon is called expulsion/burn through.

On Line Verification of the Welds

- The most reliable verification methods to find out the existence and quality of the weld are destructive and after the fact.
- U.S. automobile manufacturers pull one or two body-in-white each day off the production line and use hammer and chisel to verify the weld quality.
- It normally takes 4 to 5 hours to validate all the welds in one car.
- By the time a weld problem is identified, hundreds of cars have already been manufactured and gone for good.
- Both the destructive and nondestructive tests to evaluate weld quality are predominantly off-line or end-of-line processes.
- While this test information may provide useful and valuable for quality and process monitoring, it cannot be utilized in process control because of the significant delays that are associated with the off-line test analysis.

Current Stepper

- When a new pair of weld caps are installed it contact area is at its minimum. Reset the weld counter to zero.
- When the welding starts the contact area increases and the weld current steps up based upon the weld counts and stepper schedule.
- Linear stepper usually increase the current linearly within a given weld count range.
- The weld time normally doesn't change. And the current can only increase not decrease.
- If the current increased at the end of cap life by 40% the energy fed into the nugget doubles.
- After one expulsion the weld caps are pitted and area decreases and current still increases more expulsion will follow.

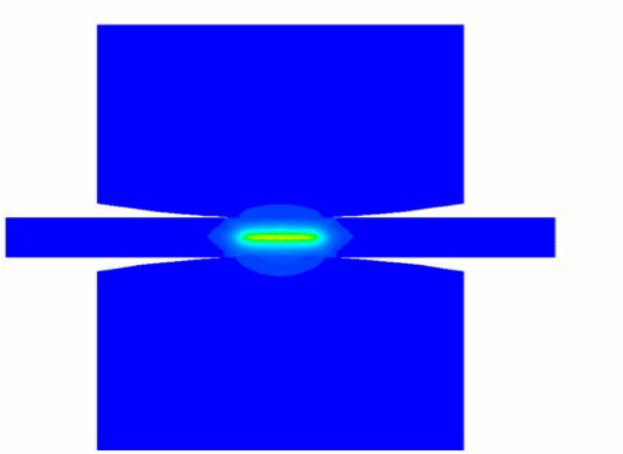
Parameters That Influence The Weld

1. Force
2. Current
3. Time
4. Contact resistance (a function of force)
5. Materials properties such as resistivity, TC of resistivity, specific heat, latent heat, thermal conductivity, thermal capacity, melting temperature etc.
6. Surface coating.
7. Geometry and dimensions. (the thickness of number of layers of the stack)
8. Weld caps geometry and size.
9. Weld gun.

Simulation Of A Weld

- Using all the parameters that influence the weld and a simulation program we can simulate and predict (after the fact) the nugget size of the weld.
- Record the force, current, voltage signals during the weld. Measure and record the nugget size after the weld.
- Compare the predicted nugget diameter to the real nugget diameter to determine how successful the nugget prediction algorithm is.
- Many programs are available to simulate a weld.
- Abacus, Matlab, MathCad, Maple, Excel can be used to simulate a weld.
- Sorpas by Swantec is a dedicated simulation program to simulate a weld.
- All simulations on welds are after the fact and off the line “prediction” that doesn’t influence the quality of welds on an assembly line in real time.

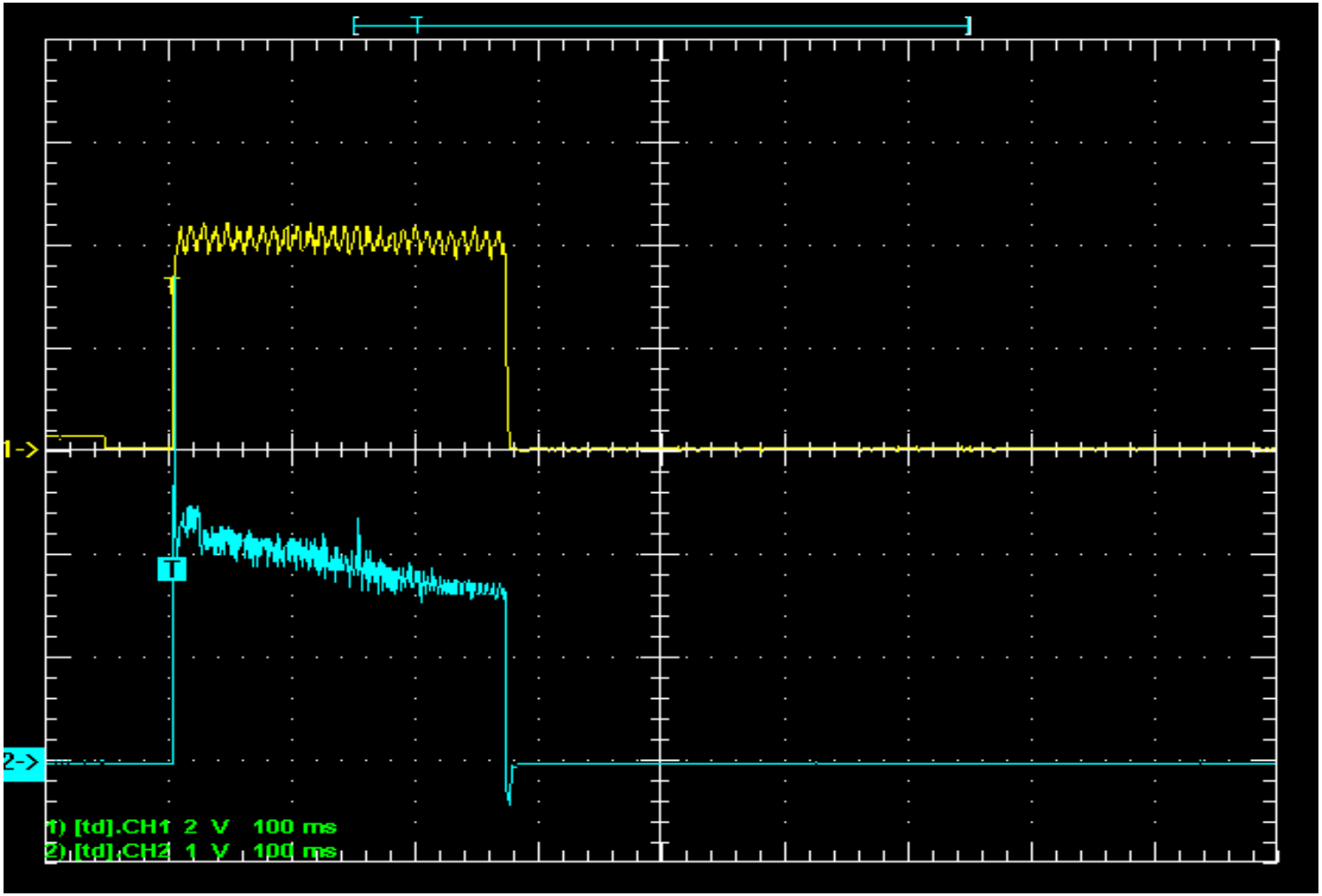
Simulation of A Weld using Sorpas (Swantec)



A New Intelligent Weld Controller That Solve All Three Welding Problems

- By studying all parameters that influence the an accurate thermal-electric model of the weld can be constructed.
- With only the voltage feedback signal and an algorithm designed based on this model, this intelligent welder welds free of expulsion.
- All the nuggets produced with this algorithm are extremely close to each other in their diameters. As a matter of fact I can predict the diameter of the nugget before the weld not after the weld.
- This welder also generates a flash (with white LEDs) to give the operator a visual feedback to indicate that a weld is initiated.
- It also turns on a green light for a good weld and red light for a bad weld to provide the weld quality control information.
- Within a fraction of second when a weld problem is identified on the assembly line the central control room will be notified.
- It adjust the current automatically based upon the weld cap condition so the stepper and tip dresser are no longer needed.

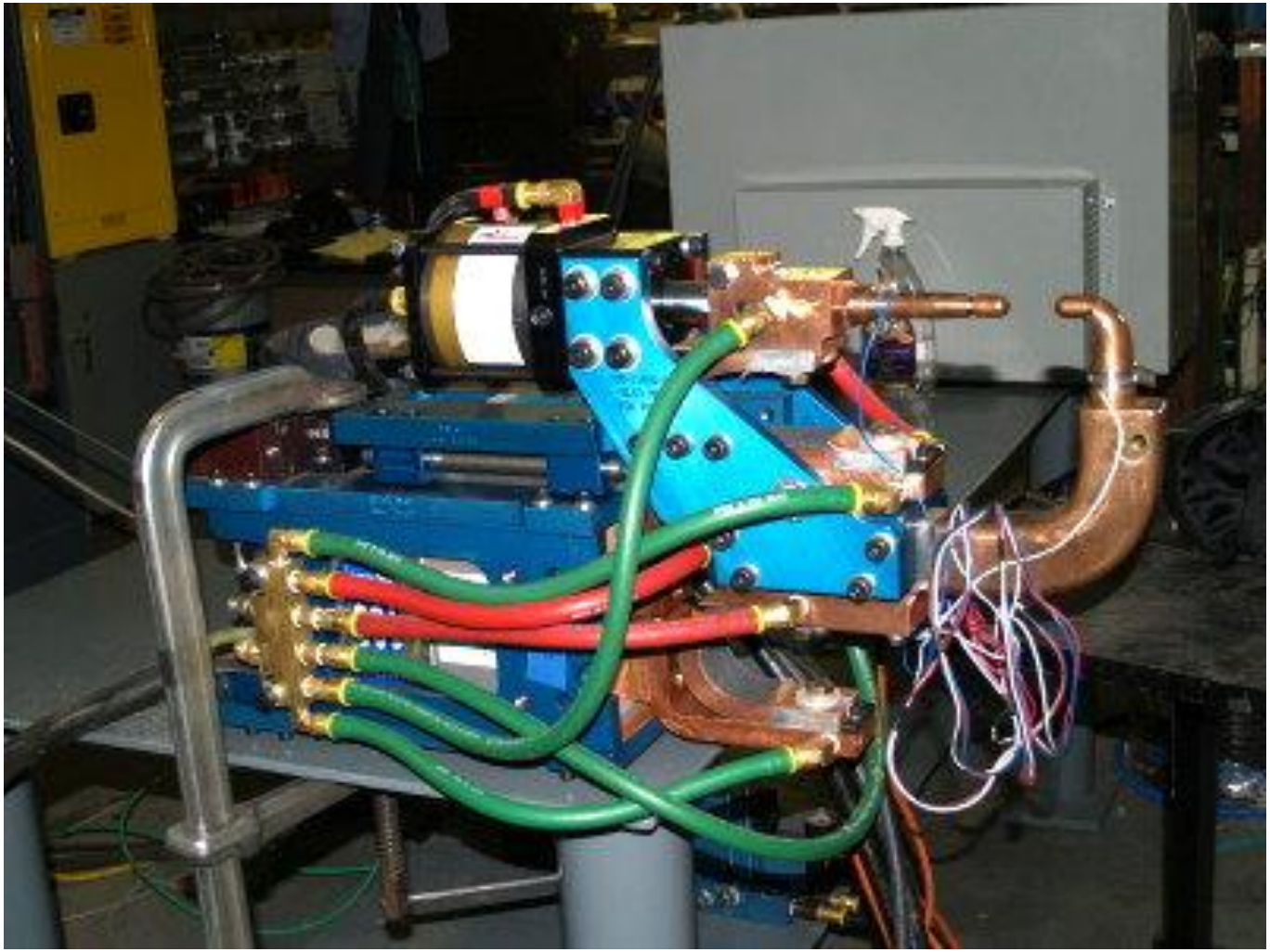
Voltage and Current Waveform Of A Weld



The Weld System I Have to Perform The Experiments

1. A C-gun provided by Milco Manufacturing, Warren, Michigan
2. Bosch Rexroth PSI 6100 power unit that can provide up to 20 kA current.
3. Electric Panel built by Stegner Controls, Auburn Hills, Michigan.
4. A intelligent control with expulsion free algorithm build by me.

My Weld Gun



Electric Panel

Bosch Rexroth PSI 6100 Power Unit

Rexroth PSI 6100
MF Converter, 3 - 20 kA

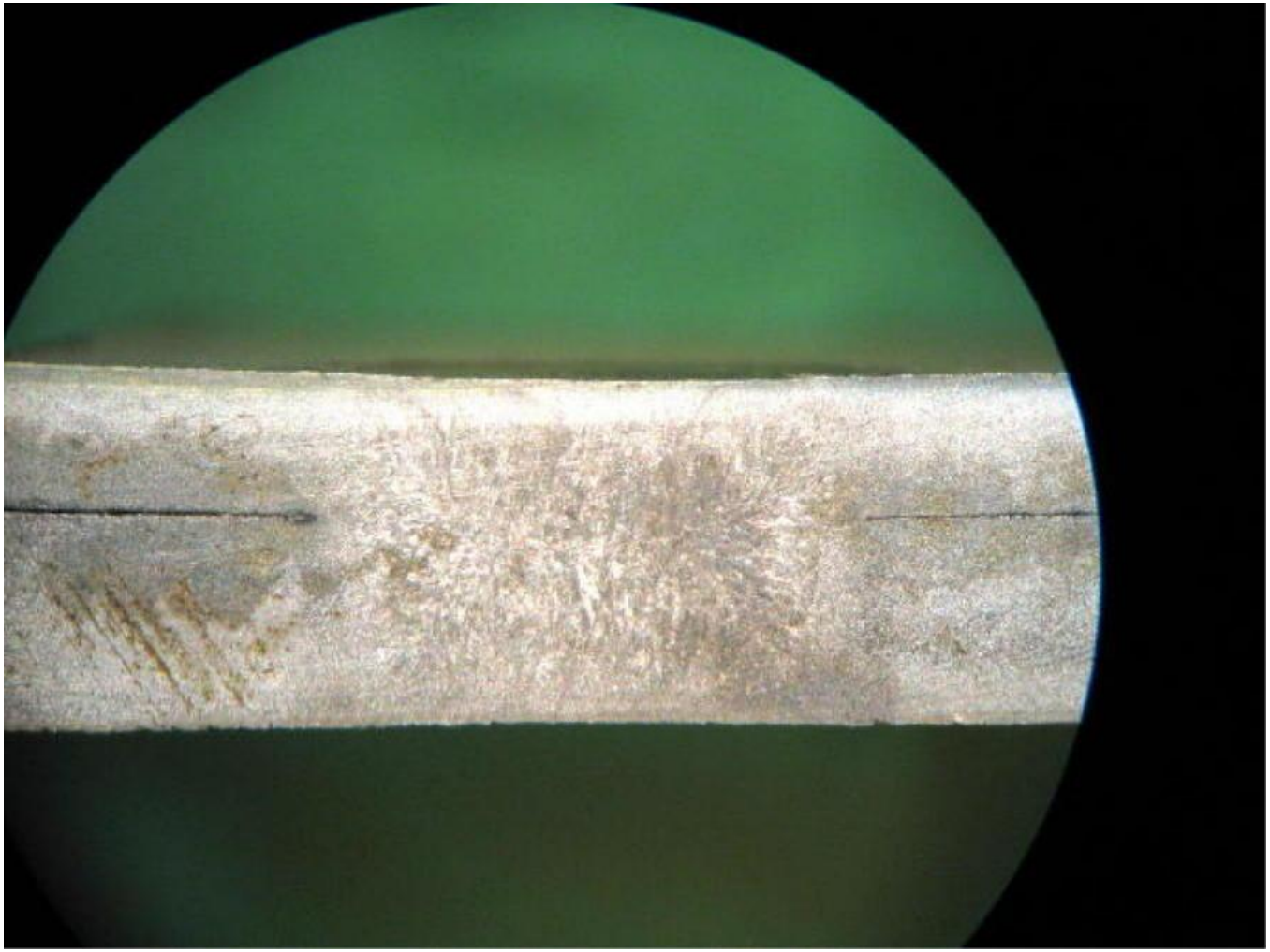
My Intelligent Welding Control Board with expulsion free algorithm

Picture Of Good Welds

Experiment Result

- Five thousand welds were performed with the intelligent welder to verify the repeatability of nugget size while using this cap wear compensation scheme.
- Picture on the last slide shows three coupons welded with this intelligent welder
- Coupon #1 has three welds with diameter 5.85 mm, 5.83 mm and 5.84 mm
- Coupon #10 has three welds with diameter 5.90 mm, 5.88 mm and 5.62 mm
- Coupon #19 has three welds with diameter 5.75 mm, 5.79 mm and 5.52 mm
- There are thirteen hundred weld between coupon #1 and coupon #10
- There are 4900 welds between coupon #1 and coupon #19
- The average diameter is 5.78 mm
- The largest deviations from the mean is -4.42% to +2.15%
- On the same 3”x6” coupon I have also welded 10 welds in 30 seconds and right after the weld the coupon is barely warm when I hold it.
- This experiment highlights the high energy efficient of this weld controller.

The Cross-section of a Weld



The Cross-sectional Picture In The Last Slide

- Last slide shows a micrograph of a weld joint created with the intelligent weld controller.
- Two layers of steel welded with new algorithm.
- The top layer is much thinner than the bottom layer.
- The nugget has fine grain, very little distortion and sheet separations.
- It also has very shallow indention.
- This weld produced by the intelligent welder uses approximately 35% of the energy of an AC welder as yet it produced a much better weld.

Why is My Intelligent Weld Controller Better?

- Free of expulsion.
- It is also a on line real time monitoring system.
- It gives a white flash when a weld is initiated.
- It shows a green light for a good weld.
- It shows a red light for a bad weld.
- The weld quality data add a time stamp and station ID can be transmitted to a central control room for statistical process control.
- Any weld problem detected will be displayed at the central control room computer screen within milliseconds.
- It only uses 35% of the energy of AC welder without expulsion.

How much energy can we save if everybody use this intelligent welder?

- Assume average weld consume 2,500 J at the weld tip.
- Average car has 5,000 welds.
- Energy usage to weld a car with AC welder is 26.8 KWH
- Energy usage to weld a car with intelligent welder is 9.38 KWH
- The saving of energy usage per car is 17.43 KWH.
- If the energy cost is $0.05 per KWH the energy saving of using intelligent welder equal $0.05*17.43=$0.87 per car.
- In 2009 there are 51,971,328 cars made in the world.
- Total energy saving if everybody uses this welder is 905,000,000 KWH.
- Each KWH produces 0.524 lbs of carbon dioxide, this convert to 474,220,000 lbs less carbon dioxide release to the air.
- If you currently weld with expulsion the saving could be even more.

Contact information

- Contact information: kelvinshih@comcast.net

Thank you!