Course	Agricultural Science II
Unit	Agricultural Mechanics II
Subunit	Arc Welding
Lesson	Controlling Distortion in Arc Welding
Estimated Time	50 minutes

Student Outcome

Describe the procedures used to control distortion during arc welding.

Learning Objectives

1. Describe the effects of temperature change on metal.
2. Explain the causes and examples of distortion in arc welding.
3. Describe what techniques can be used to control and correct distortion.
4. Explain what residual stress is and how can it be controlled and corrected.

Grade Level Expectations

SC/ME/1/D/09-11/a SC/ME/1/D/09-11/b

Resources, Supplies & Equipment, and Supplemental Information

Resources

1. PowerPoint Slides
   - ☐ PPt 1 – Distortion in Welding
   - ☐ PPt 2 – Welding Techniques to Control Distortion
   - ☐ PPt 3 – Distortion and Residual Stress
2. *Agricultural Mechanics Unit for Agricultural Science II* (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 2002.
3. *Curriculum Enhancement for Agricultural Mechanics Unit for Agricultural Science II*, "Unit II – Arc Welding." University of Missouri-Columbia: Instructional Materials Laboratory, 2004.

Supplemental Information

1. Internet Sites
   - ❑ American Welding Society. Accessed October 2, 2007, from http://www.aws.org.
   - ❑ Welding Calculators. Accessed October 2, 2007, from http://www.millerwelds.com/education/calculators/.
2. Print
   - ❑ Althouse, A., C. Turnquist, W. Bowditch, and K. Bowditch. *Modern Welding.* Tinley Park, IL: Goodheart-Willcox, 2000.
   - ❑ Jeffus, L. *Welding Principles and Applications*. 5th ed. Clifton Park, NY: Thomson-Delmar Learning, 2004.
   - ❑ Phipps, L., and G. Miller. *Introduction to Agricultural Mechanics.* Upper Saddle River, NJ: Prentice Hall Interstate, 2004.

Interest Approach

Show students examples of well-made and distorted joints that they should be familiar with from Agricultural Mechanics I. Have students discuss their experiences making these joints. Did they have trouble with distortion? What do they think was the cause of the distortion? Were they able to straighten any distorted welds or improve their technique to avoid distortion on welds they made later? If so, how?

Communicate the Learning Objectives

1. Describe the effects of temperature change on metal.
2. Explain the causes and examples of distortion in arc welding.
3. Describe what techniques can be used to control and correct distortion.
4. Explain what residual stress is and how can it be controlled and corrected.

Instructor Directions	Content Outline
Objective 1 *Discuss factors that cause welded metal to warp. Refer to PPt 1.* ☐ PPt 1 – Distortion in Welding	**Describe the effects of temperature change on metal.** Metal expands when it is heated and contracts as it cools. If metal is heated evenly and is cooled evenly, it can return to its original shape. If metal does not heat and cool evenly, it may distort.
Objective 2	**Explain the causes and examples of distortion in arc welding.** The metal is not heated evenly. Metal is much hotter at the point being welded than at an area not being welded. The weld bead itself restricts movement. Examples of distortion – an upward curve in a previously flat piece, a bend in a previously straight piece, and a vertical piece pulling away from the weld.
Objective 3 *Distortion can be an obstacle to producing good welds, but steps can be taken before, during, and after the welding process to control it. Refer to PPt 2.*	**Describe what techniques can be used to control and correct distortion.** Before welding 1. Heat treating – The whole piece of metal can be heated before welding (preheating) and during welding (interpass heating). The process of raising and maintaining the temperature of the whole piece and allowing it to cool slowly promotes uniform expansion and contraction.

Instructor Directions	Content Outline
☐ PPt 2 – Welding Techniques to Control Distortion	2. Positioning – By setting the pieces slightly out of alignment opposite the pull of contraction, the contraction force can be used to pull the pieces into position and eliminate distortion. 3. Tack welding – Small welds can be made along the seam to hold the pieces in place. The number of tack welds needed depends on the length of the weld. 4. Prebending – Pieces can be bent prior to welding so that the contraction force pulls them into position. 5. Using welding jigs and fixtures – Jigs and fixtures can be used to hold pieces in place. During welding 1. Limiting the number of passes to as few as possible and not adding excessive material – Additional passes and filler add more heat to the weld, increasing the potential for distortion. 2. Back-step welding – The joint as a whole is completed from left to right, but it is made up of smaller beads put down from right to left. 3. Alternating sides – By welding on both sides of the material, the contraction forces on one side offset those on the other. After welding 1. Shrinkage – The piece is alternately heated and cooled to counteract distortion. 2. Shrink welding – Beads are added to the opposite side of the distorted weld. This added weld and the contraction force it produces as it cools help to pull the original weld into alignment. The additional beads can then be ground off, if desired. 3. Peening – Hammering is used to offset distortion. While peening can be done by hand, use of a pneumatic hammer with a suitable tool fitted in it is preferred. Peening can be completed faster with a pneumatic hammer and the hammering is consistent and more easily controlled. Whatever method is used, care should be taken to not overpeen the piece, which can cause cracks or new stresses. Combining methods – Methods can be used together or in sequence to control distortion.

Instructor Directions	Content Outline
Objective 4 *Welds can also be distorted by residual stress. Refer to PPt 3.* ☐ PPt 3 – Distortion and Residual Stress	**Explain what residual stress is and how can it be controlled and corrected.** Residual stress is the force that remains after welding is completed. It can cause cracks or distortion at the weld as well as elsewhere on the piece. Residual stress may not be apparent. A joint may be distorted but have no residual stress, or it may seem sound but have a great deal of internal stress. This force can cause the metal to distort at some later time. Residual stress can be controlled and corrected by preheating, postheating, and peening.
Application:	Other activities 1. Arrange a field trip to a welding shop to give students firsthand knowledge of a commercial operation using arc welding. Have the students pay particular attention to safety procedures and devices used and available at the job site.
Closure/Summary	Welded metal may distort when it is unevenly heated or cooled. Examples of distortion are a curve in a flat piece, a bend in a straight piece, and weld separation. Use any of several techniques to avoid distortion. Heat treating, positioning, tack welding, and prebending can be used before welding. During welding, limit passes, alternate sides, or apply back-step welding. After welding, employ shrinkage, shrink welding, or peening. Residual stress, which causes cracks or distortion after welding, can be controlled or corrected by preheating, postheating, or peening.
Evaluation: Quiz	Answers: 1. a 2. c 3. Residual stress is the force remaining after welding is completed. It can cause cracks or distortion at the weld or elsewhere on the piece. 4. Answers should include six of the following or others at instructor's discretion if discussed in class. a. Heat treating (preheating, interpass heating) b. Positioning c. Tack welding d. Prebending

Instructor Directions	Content Outline
	e. Using clamps, jigs, or fixtures f. Using as few passes as possible g. Avoiding adding excessive material to the weld h. Back-step welding i. Alternating sides (welding on both sides of the piece) j. Shrinkage k. Shrink welding l. Peening 5. Answers will vary. 6. Contraction force can be used to pull pieces into alignment. Students might also give examples, such as positioning pieces out of alignment so the contraction force pulls them together, prebending pieces, welding on alternate sides, positioning work slightly out of alignment in clamps or fixtures, or shrink welding. 7. Overpeening can cause cracks or new stresses in the work.