Feasibility of Nodestructively Evaluating the M140 Recoil Piston Head Weld

Roy L. Buckrop
United States Department of Defense
Feasibility of Nodestructively Evaluating the M140 Recoil Piston Head Weld

Abstract
The application of nondestructive testing (NDT) to a weld cracking problem on the M140 Recoil Piston is discussed. Addressed in the presentation is the technique used for screening recoil pistons for crack sensitive weld filler metal and the inspection of piston welds for flaw discontinuities.

Keywords
Nondestructive Evaluation

Disciplines
Materials Science and Engineering
FEASIBILITY OF NONDESTRUCTIVELY EVALUATING
THE M140 RECOIL PISTON HEAD WELD

Roy L. Buckrop
Product Assurance Directorate
U.S. Army Armament Command
Rock Island, Illinois 61299

ABSTRACT

The application of nondestructive testing (NDT) to a weld cracking problem on the M140 Recoil Piston is discussed. Addressed in the presentation is the technique used for screening recoil pistons for crack sensitive weld filler metal and the inspection of piston welds for flaw discontinuities.

INTRODUCTION

Test Date and Place: 15-18 January and 5-8 February 1980, Shop M and L, Rock Island Arsenal.

Object: To establish feasibility of utilizing Nondestructive Testing to identify weld bead alloy and evaluate weld material integrity (soundness) of the M140 Recoil Piston Head Weldment (Fig. 1).

Scope: During routine machining, longitudinal and transverse surface cracks were observed in the M140 Recoil Piston Head Weld. Test specimens cut from a defective piston also revealed extensive weld root cracking which extended into the weld bead along the weld's longitudinal axis. The cause for both the surface and sub-surface cracking was postulated as resulting from two sources: one being the weld filler material (rod) and the other control of the welding process. This study is concerned with the screening of pistons as to weld filler material (one filler material is suspect of being crack sensitive) and the nondestructive evaluation of M140 Recoil Piston Head Welds for flaw discontinuities.

Approach: There were three NDT (Nondestructive Testing Techniques) considered for this investigation: ultrasonics, magnetic particle, and eddy current.

Test Specimens: Two categories of test specimens were used; type one (Fig. 2) consisted of four fabricated inverted tee (\( \perp \)) weldments, two heat treated and two as welded. The weld joint for these was a "J" preparation, the same as the piston head. Two were welded with 4130 welding rod, one heat treated and one as welded. The other two were welded with the suspect (crack sensitive) rod L6M (4340), one heat treated and one as welded. The test specimens' weld beads were machined to approximately a 125 finish to accommodate eddy current test probe coupling. These test specimens were used for weld bead alloy evaluations. Type two test specimens (Fig. 3) were used for discontinuity detection and evaluation and consisted of various select sections cut from rough machined defective piston weldments. For the magnetic particle test, .043-inch diameter simulated flaws (holes) were drilled along the longitudinal axis of the weld, starting from the edges and drilling 3/4-inch deep toward the specimen center. The holes were located below the center of the weld face at varying depths of .030 inch, starting at .060 inch. These test specimens were used to evaluate subsurface material discontinuities. The above test specimens were also used for the eddy current discontinuity depth tests. Centered in the specimen weld face, slots approximately .007-inch wide by 1/4-inch long were machined at .025, .050 and .075-inch deep, along the longitudinal axis of the weld (Fig. 3).
Fig. 2 Type One Test Specimens (Fabricated Weld Samples)

Fig. 3 Type Two Test Specimens (Sections from Defective Pistons)
TEST #1: ULTRASONIC PULSE ECHO

Theory: Angle beam ultrasonic energy transmitted into the outer surface of the weldment, along its longitudinal axis, from the head end, will be reflected from the inner surface of the piston, back into the welded area, allowing for internal inspection of the weld. Discontinuities present in the weld area will reflect a portion of the transmitted sound energy back to the inspection probe. The probe (transducer) will convert the reflection to an electric signal proportional in amplitude to the intensity of the ultrasonic signal. This in turn will be displayed on a cathode ray tube for interpretation.

Equipment: Automation Industries, Inc. Reflectoscope UM 721. One 45° angle beam search unit, 5MHz.

Procedure: Following instrument warm up and stabilization, a known cracked test specimen (Fig. 4) was coated with oil couplant and a 45° angle beam search unit used to qualitatively scan the defective weld. Signal amplitude was adjusted to full scale for a signal reflection from the corner of a reference block.

Results: Hand scanning produced erratic results and was difficult to control, demonstrating a need for test probe fixturing. Appropriate flaw reference standards would need to be established for discontinuity evaluation.

Conclusion: Due to time limitations, this technique was abandoned. However, it does have enough promise to warrant further development for future application.

Fig. 4 Piston Section Cracked in Production

TEST #2: MAGNETIC PARTICLE

Theory: Ferro-magnetic materials, when exposed to intense and highly concentrated electromagnetic fields, can be made to reveal sub-surface internal discontinuities. Related external leakage fields caused by discontinuities will attract and hold an iron particle media (either dry as powder or in a liquid suspension) revealing their presence and plainer location.

Equipment: Two rectified DC magnetic particle test machines: wet, 5000 amp max capacity with magnetizing coil and dry 1400 amp max capacity with prods.

Procedure: A cursory dry magnetic particle test was performed on a specimen cut from a rough machined defective piston (Fig. 4). The specimen was severely cracked along the weld longitudinal axis, extending from the root nearly through the weld, stopping near the surface. Successful detection of this subsurface crack was followed by a progressive evaluation of fabricated flaws (holes) placed into the edges of test specimens cut from a rough machined defective piston (Fig. 3).

A hole (one) was drilled in from each side of a specimen (two holes per specimen). Starting at .060 inch below the weld surface, the holes were alternately placed at .030-inch increments below the surface down to .270 inch. Both the wet and dry magnetic particle tests were evaluated. The current used was continuous and approximately 3800 ampers for the wet method, which used a coil for magnetization. The specimen was positioned directly on the inner surface of the coil during energizing. For the dry technique, approximately 1400 continuous ampers were used for magnetization, using prods placed at each end of the weld.

Results: Both the wet and dry magnetic tests were able to show sub-surface discontinuity indications on the sectioned test specimen cracked during production welding (Fig. 4). Both methods were also capable of detecting simulated flaws (holes) down to .090 inch below the weld surface (Fig. 4). The dry (powder) method appeared to be somewhat more positive. Further increases in magnetizing force (higher currents) may make it possible to detect discontinuities even deeper below the weld surface. However, for each material there is a practical depth sensitivity limit based on ferric induction characteristics. The degree of sensitivity experienced, however, appeared to result from limited magnetizing force (current) and not necessarily to ferric induction limits of the weld material.

Conclusion: The continuous magnetization method, with both the wet and dry magnetic particle tests, demonstrated the capability of revealing weld material discontinuities approximately one-tenth of an inch below the surface. Discontinuity detection, deeper than one-tenth inch, may be possible with larger magnetizing forces (currents). The dry magnetic particle test demonstrated the strongest sensitivity for the deepest detectable discontinuity (drilled hole).
TEST #3: EDDY CURRENT

Theory: The consideration of eddy current testing for this study is based primarily on its adaptation to metal sorting. However, the response of eddy currents to material discontinuities was used to evaluate the depth of flaw indications located by magnetic particle inspection. The test instrument utilizes a probe coil which is excited by an oscillating electric current. The probe, with its associated field, induces eddy currents in the test part (an electrical conductor) which will reflect changes in material permeability and electrical conductivity according to structure variations. The test signal can be monitored for both amplitude and phase variations.

Equipment: Automation Industries, Inc. Eddy Current Tester, EM 3300 with two probes (Black and Green) both suitable for operation at the selected test frequency of 400 KHz.

Procedure: The eddy current instrument was allowed to warm up and stabilize prior to testing. An operating frequency of 200 KHz was set on the frequency counter display with an appropriate probe connected to the instrument. 200 KHz was used for the weld material evaluation and 400 KHz for the flaw depth test. The instrument was electrically balanced (nullled). The trace was adjusted to the center of the display and a favorable phase reference angle selected for first quadrant presentation. Two tests were run, one to detect the presence of 4130 or 4340 (L6M) weld material and the other to quantitatively evaluate the depth of surface flaws detected by magnetic particle testing. For the differentiation of weld material, the probe was placed on the machined surface of referenced specimen welds (Fig. 2) and the resulting display trace compared to traces obtained from suspect weld material. For the flaw depth test, the probe was moved (scanned) across suspect flaws. Any surface discontinuity scanned across will produce a blip on the display, projecting out from the basic material trace proportional in amplitude to its perpendicular depth beneath the material surface. Signals obtained from surface discontinuities are then evaluated by comparing them to signals obtained from referenced slots of known depths (Fig. 3).

Results: The eddy current test was able to distinguish between the 4130 and L6M (4340 alloy) weld material. (See eddy current material response displays in Fig. 5.) The eddy current measurements of surface discontinuity depths by comparison to referenced slots are affected by several factors, such as: Actual cracks will produce deflection signals approximately one-half that of signals produced by referenced slots. Cracks may not cause deflections at the same phase angle as referenced slots. Signals from surface discontinuities will be proportional to their depth as measured perpendicular to the surface, not the dimension of a flaw extending into a material angled away from a perpendicular axis to its surface. Residual magnetism and permeability variations in ferro-magnetic material affect the eddy current response. Because of the above factors, eddy current test techniques for depth evaluations of surface discontinuities must be validated by physical sectioning (destructive tests) or other NDT techniques.

Conclusion: The identification of weld material as to which alloy is present (4130 or L6M) using the eddy current technique is considered feasible. The evaluation of surface discontinuity depths must be approached with caution and each application must be individually validated by either other non-destructive techniques or destructive tests.

Instrument Control Settings - EM3300:
- freq = 200 KHz - Pos. 4
- R = 456
- X = 590
- Ø = 132.5
- SENS. = 04
- VERT. = 1 Volt/Div
- HORIZ. = 0.5 Volt/Div

Fig. 5 Eddy Current Response-RIA Weld Samples 4130 and L6M

4130 - Upper Trace/L6M - Lower Trace

Instrument Control Settings - EM3300:
- freq = 200 KHz - Pos. 4
- R = 600
- X = 814
- Ø = 132.5
- SENS. = 09
- VERT. = 1 Volt/Div
- HORIZ. = 0.5 Volt/Div

Fig. 5 Eddy Current Response-RIA Weld Samples 4130 and L6M
ACKNOWLEDGMENTS

This feasibility study was performed in an atmosphere of emergency, and could not have succeeded without the assistance of Harold Hatch, US Army Materials and Mechanics Research Center, Watertown, MA; Charles Hopper, Ron Paper, Jim Dahms, Tom Behr, and Kim Schluenz, Rock Island Arsenal Quality Assurance; and representatives from Rock Island Arsenal Engineering and Rock Island Arsenal Manufacturing. Mr. Hatch's support and personal commitment was especially appreciated.