N91-18192

Prepared for University of Alabama and ASNT Conference on
Nondestructive Evaluation for Aerospace Requirements
August 22-24, 1989, Huntsville Marriot, Huntsville, Alabama

REVIEW OF ACOUSTO-ULTRASONIC NDE FOR COMPOSITES

Alex Vary and Harold Kautz
NASA Lewis Research Center
Cleveland, Ohio 44135

Acousto-ultrasonics utilizes simulated stress waves to detect and quantify defect states, damage conditions, and variations of mechanical properties in fiber reinforced composites. The term "acousto-ultrasonics" denotes a combination of aspects of acoustic emission methodology with ultrasonic materials characterization. The acousto-ultrasonic approach was developed to deal primarily with evaluation of the integrated effect of minor flaws and diffuse flaw populations of subcritical flaws in composite and bonded structures. These factors singly and collectively also influence acousto-ultrasonic measurements that, in turn, correlate with dynamic response and mechanical property variations. Since it was first introduced, the acousto-ultrasonic approach has been successfully applied to a variety of materials, including polymeric, metallic, and ceramic matrix composites; adhesively bonded materials; paper and wood products; cable and rope; and also human bone. Examples of applications and limitations of the approach are reviewed. Basic methods and guidelines are discussed. The underlying hypothesis and theory development needs are indicated.

THE ACOUSTO-ULTRASONIC APPROACH

- COMBINES SOME ASPECTS OF ACOUSTIC EMMISION METHODOLOGY WITH ULTRASONIC SIMULATION OF STRESS WAVES
- CONCERNED PRIMARILY WITH ASSESSMENT OF COLLECTIVE EFFECTS OF DISCRETE AND DIFFUSE FLAW POPULATIONS
- CONCERNED WITH VARIATIONS IN AND CORRELATIONS WITH:

  MATERIAL MORPHOLOGY, MECHANICAL PROPERTIES, INTERLAMINAR AND INTERFACIAL BOND STRENGTH, DEGRADATION FROM FATIGUE, IMPACT, ETC.

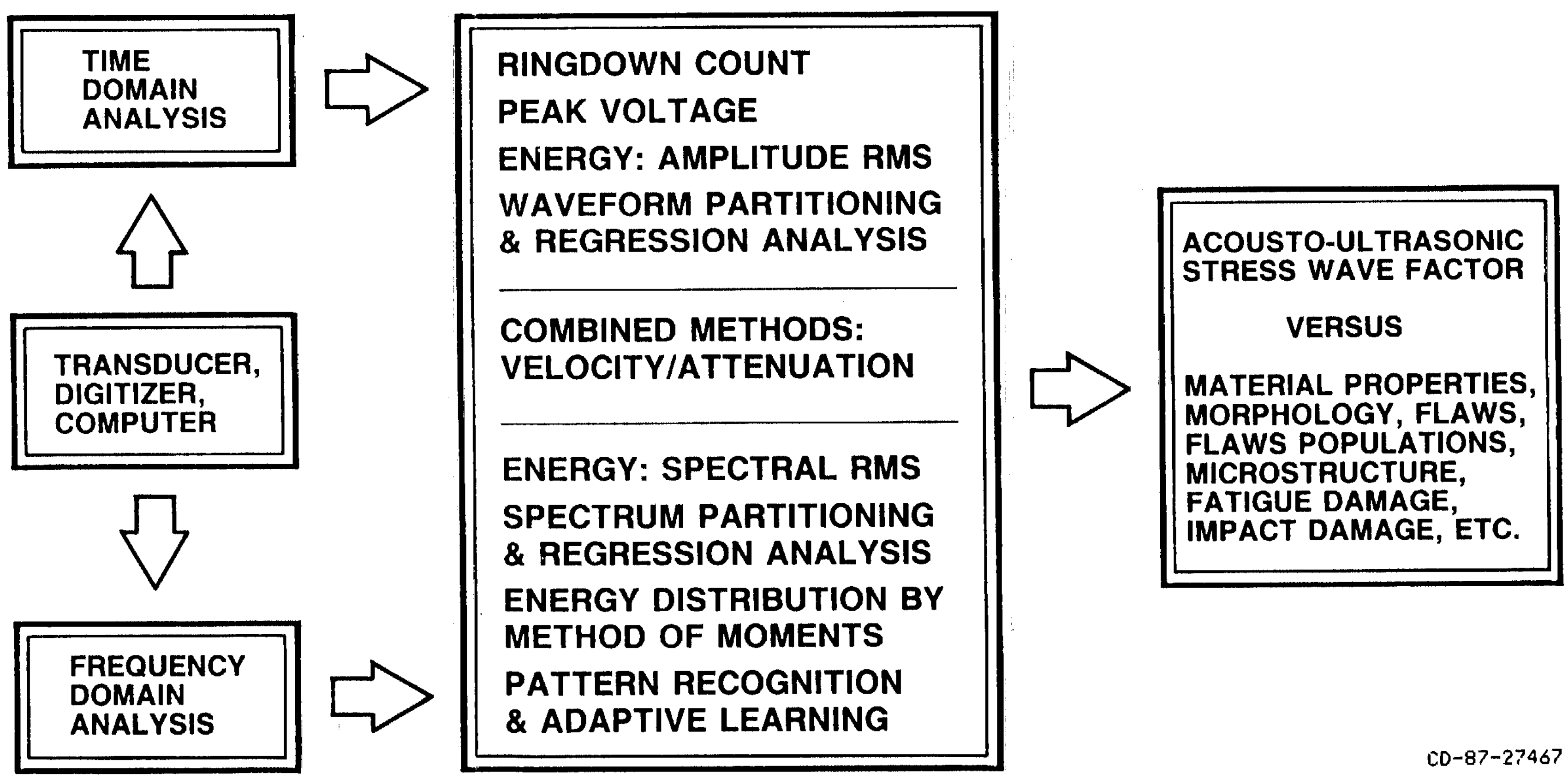
CD-87-27473

CHALLENGES

- ONLY ONE SIDE ACCESS AVAILABLE
- PULSE-ECHO APPROACH AMBIGUOUS
- LATERAL STRENGTH PROPERTIES
- NO EDGES OR EDGES INACCESSIBLE
- OBLIQUE INCIDENCE IMPRACTICAL
- BOND-LINE STRENGTH EVALUATION
- EFFECT OF FLAWS AMBIGUOUS

CD-87-27472

QUANTITATIVE SIGNAL PROCESSING FOR ACOUSTO-ULTRASONICS



CD-87-27467

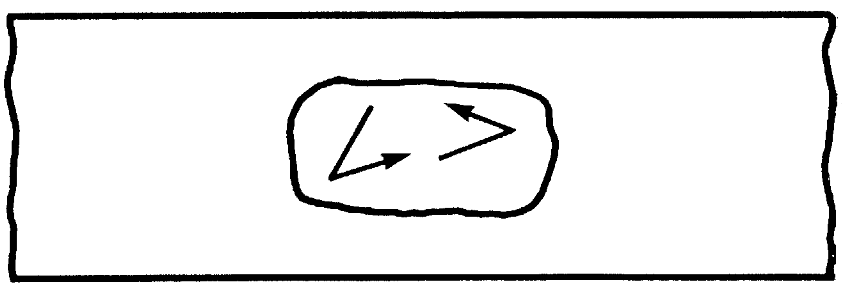
THE STRESS WAVE FACTOR

- STRESS WAVE FACTOR (SWF) QUANTIFIES ACOUSTO-ULTRASONIC SIGNALS
- DOMINANT EFFECT MEASURED BY (SWF) IS ULTRASONIC ATTENUATION
- HIGHER VALUES OF (SWF) GENERALLY CORRESPOND TO LOWER ATTENUATION

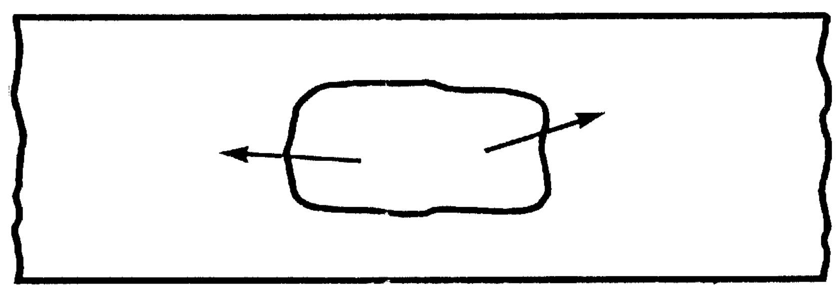
CD-87-27474

WORKING HYPOTHESES

- (SWF) MEASURES RELATIVE EFFICIENCY OF STRESS WAVE ENERGY FLOW
- BETTER ENERGY FLOW MEANS BETTER DYNAMIC STRAIN DISTRIBUTION
- PROMPT, EFFICIENT FLOW OF STRESS WAVE ENERGY AWAY FROM CRACK NUCLEATION SITES IS NEEDED TO AVOID CATASTROPIC FRACTURE WHEN THE ENERGY CANNOT BE ABSORBED LOCALLY



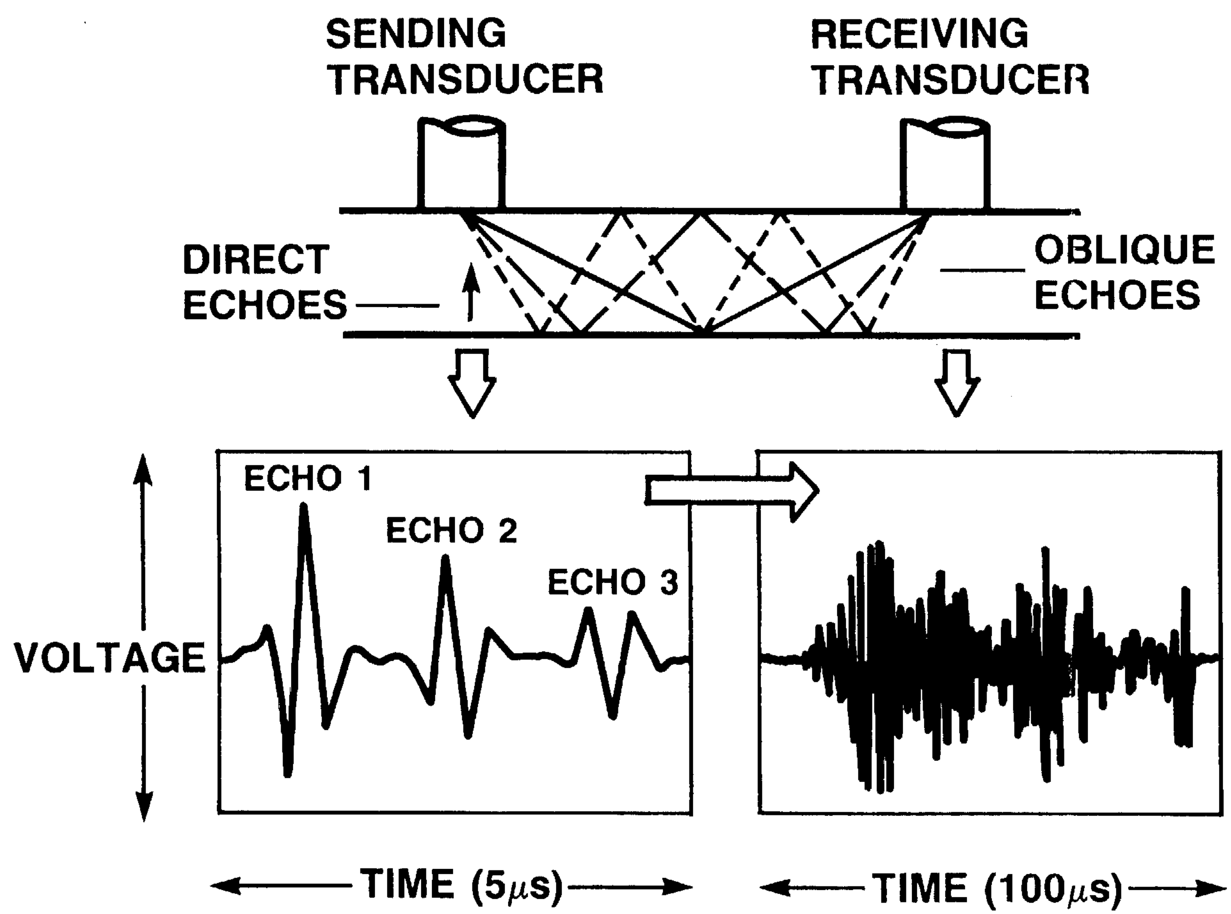
CRACK NUCLEATION ENERGY CONFINED



CRACK NUCLEATION ENERGY DISSIPATED

CD-87-27469

REPRESENTATIVE ECHO SYSTEMS FOR BASIC ACOUSTO-ULTRASONIC CONFIGURATION

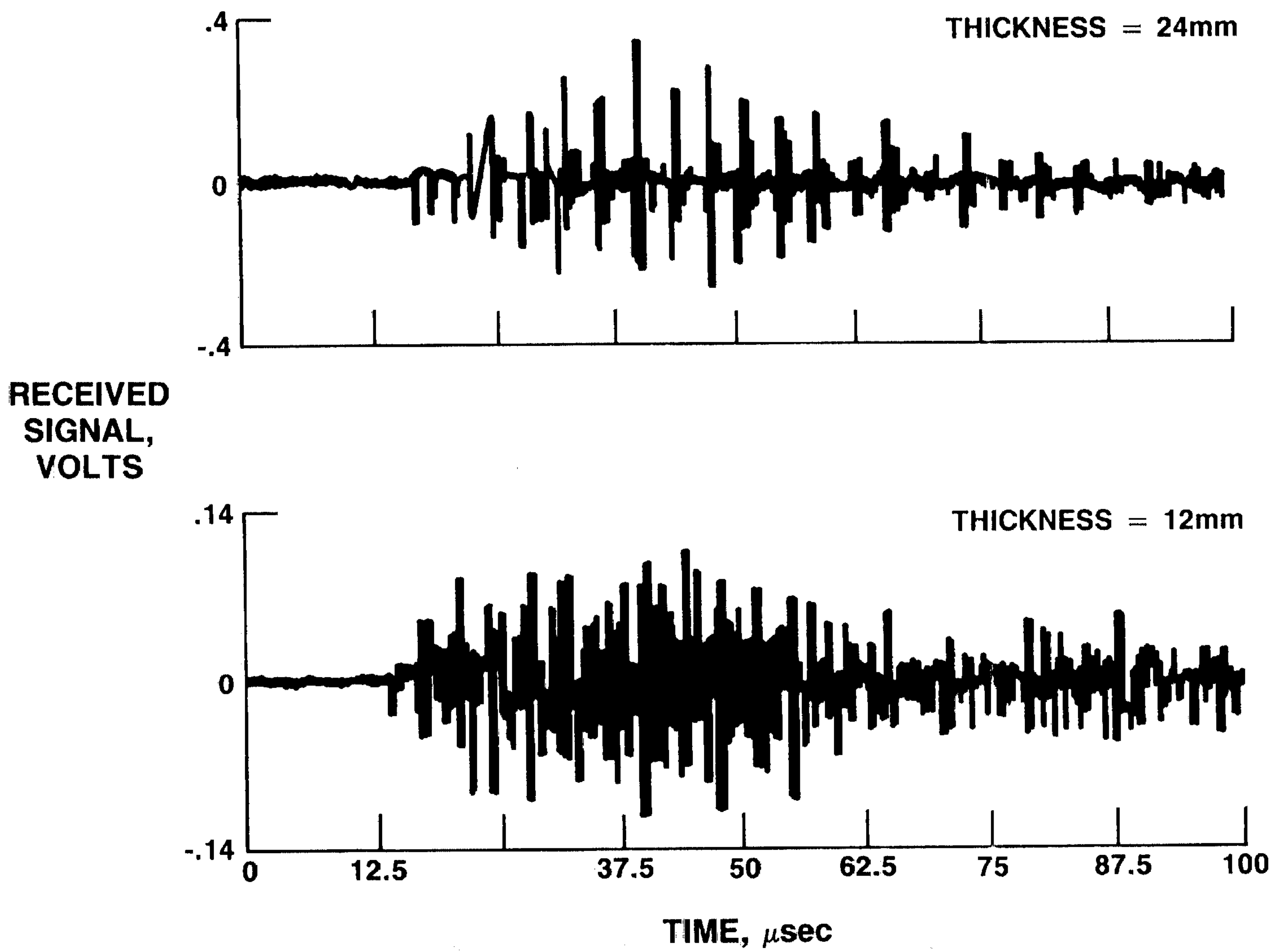


DIRECT ECHOES SEEN BY SENDING TRANSDUCER

OBLIQUE ECHOES SEEN BY RECEIVING TRANSDUCER

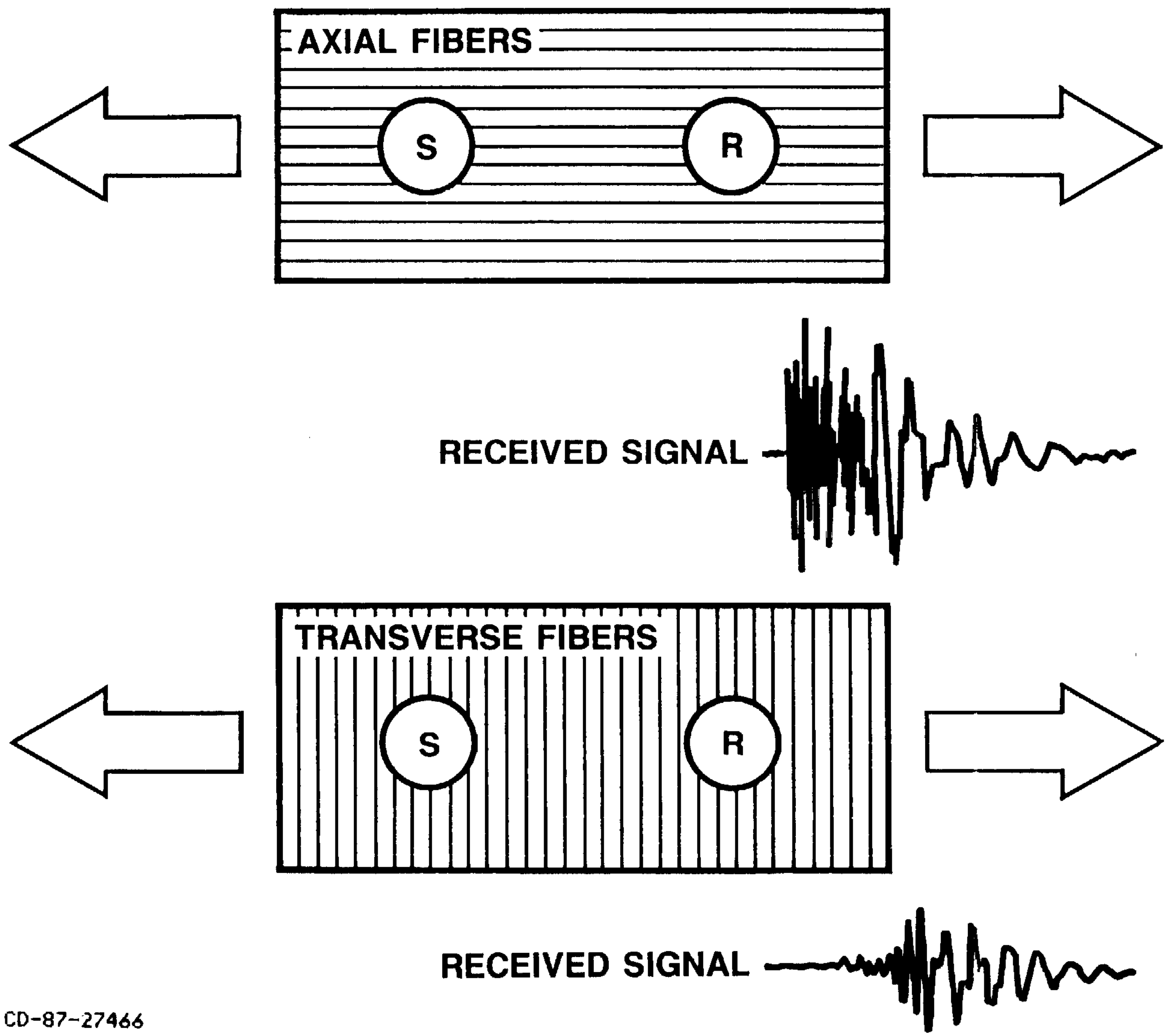
CD-87-27449

ACOUSTO-ULTRASONIC WAVEFORMS FROM ALUMINUM PLATES WITH TWO DIFFERENT THICKNESS



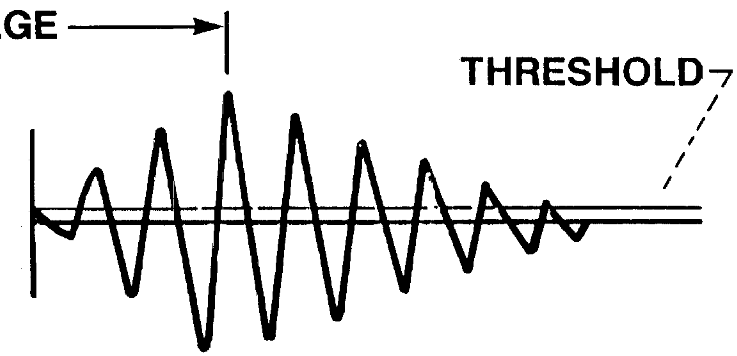
CD-87-27454

VARIATION OF ACOUSTO-ULTRASONIC SIGNAL RELATIVE TO FIBER DIRECTION IN UNDIRECTIONAL COMPOSITE LAMINATE

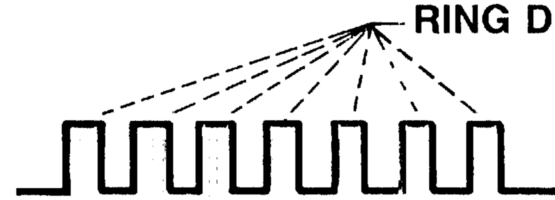


CD-87-27466

QUANTITATIVE SIGNAL PROCESSING FOR STRESS WAVE FACTOR (SWF) USING ACOUSTIC EMMISSION METHODOLOGY



PEAK VOLTAGE (SWF) = E_V = V_{max}



RINGDOWN (SWF) = E_C = PRC

P = PULSE RATE, R = RESET TIME, C = RINGDOWN COUNT

CD-87-27448

QUANTITATIVE SIGNAL PROCESSING FOR STRESS WAVE FACTOR (SWF) BY PARTITIONING OF ROOT MEAN SQUARE (rms) ENERGY

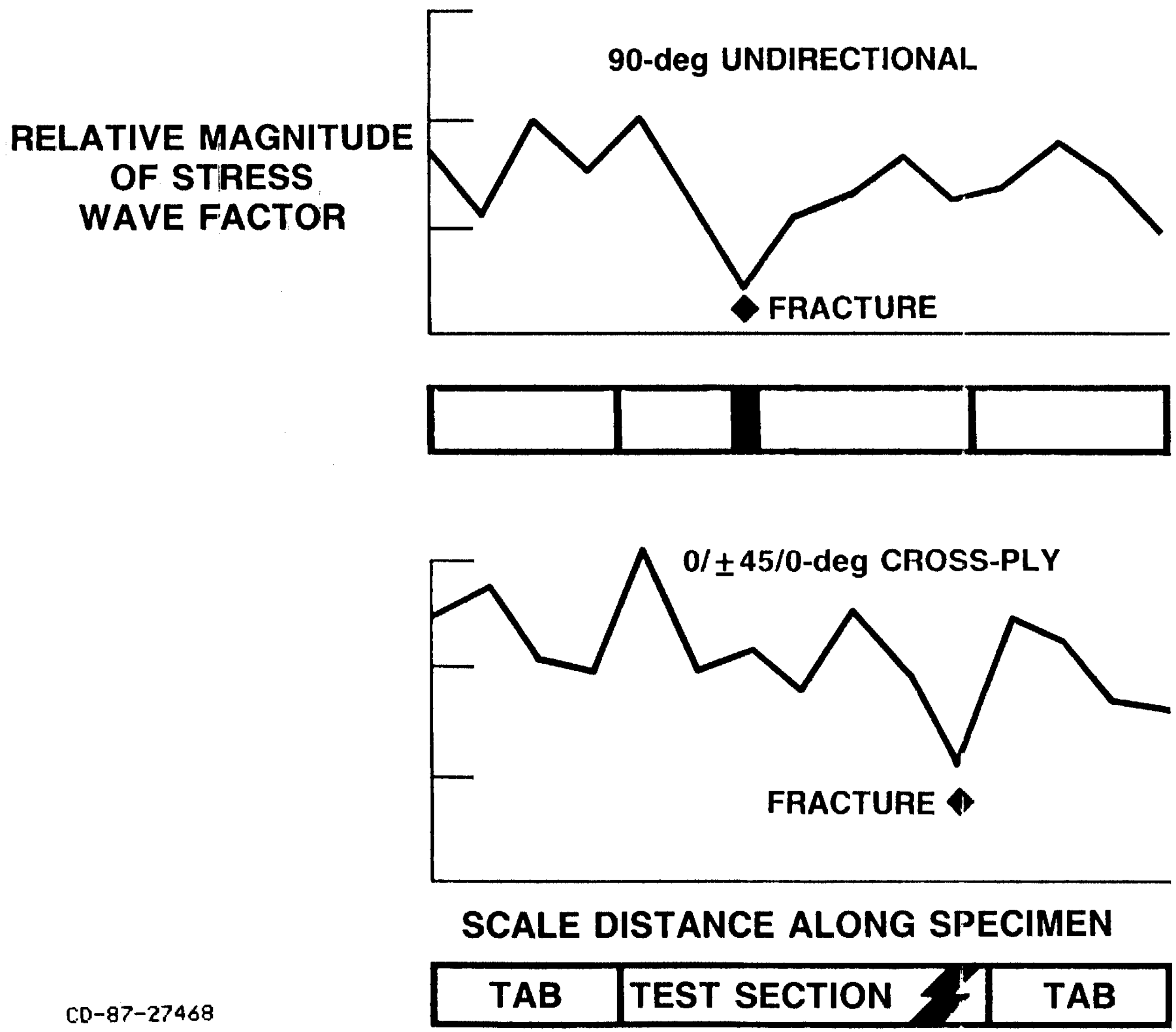
$$\text{TIME DOMAIN (SWF)} = E_t = (V_{rms})^2 = \frac{1}{T}\int_{t_1}^{t_2} v^2\,dt$$

$$\text{FREQUENCY DOMAIN (SWF)} = E_f = (S_{rms})^2 = \frac{1}{F}\int_{f_1}^{f_2} s^2\,df$$

$T = t_2 - t_1$ AND $F = f_2 - f_1$

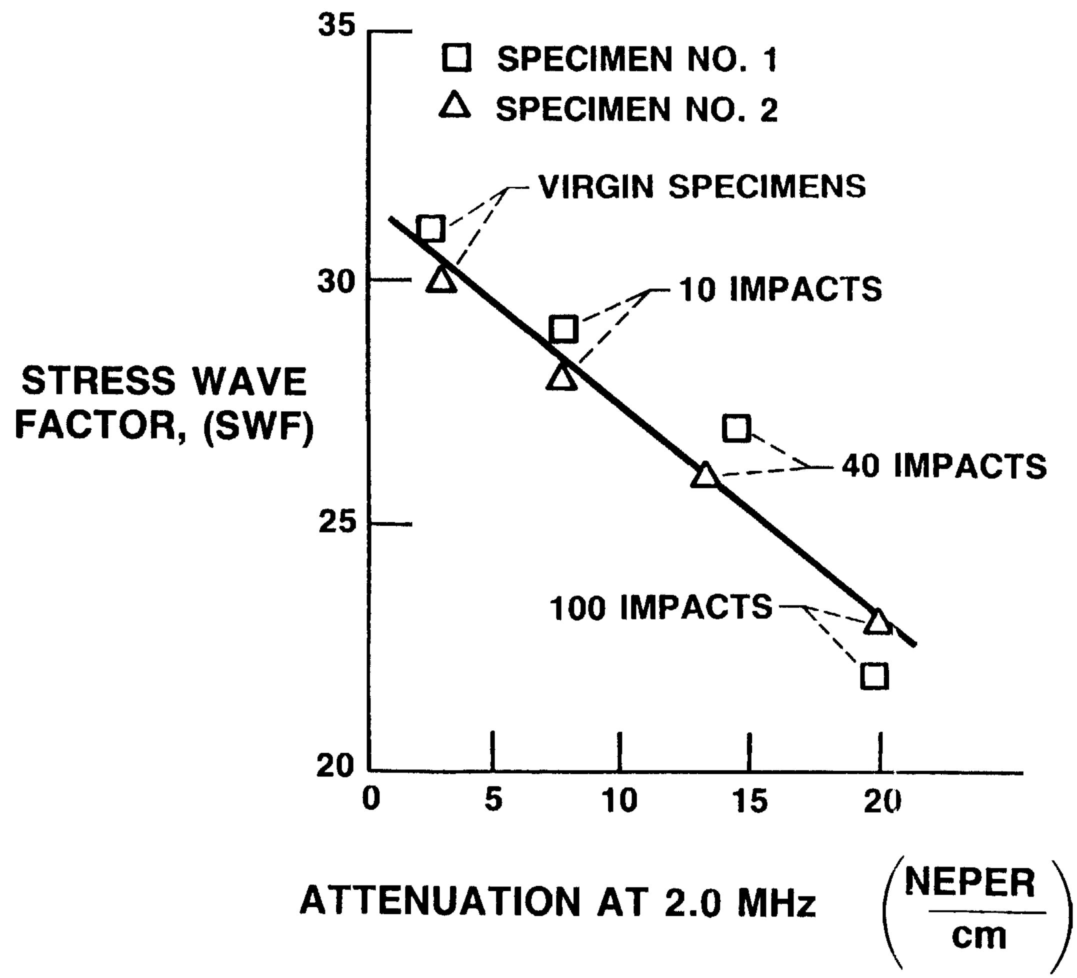
CD-87-27465

CORRELATION OF STRESS WAVE FACTOR WITH FAILURE SITES IN GRAPHITE/EPOXY TENSILE SPECIMENS



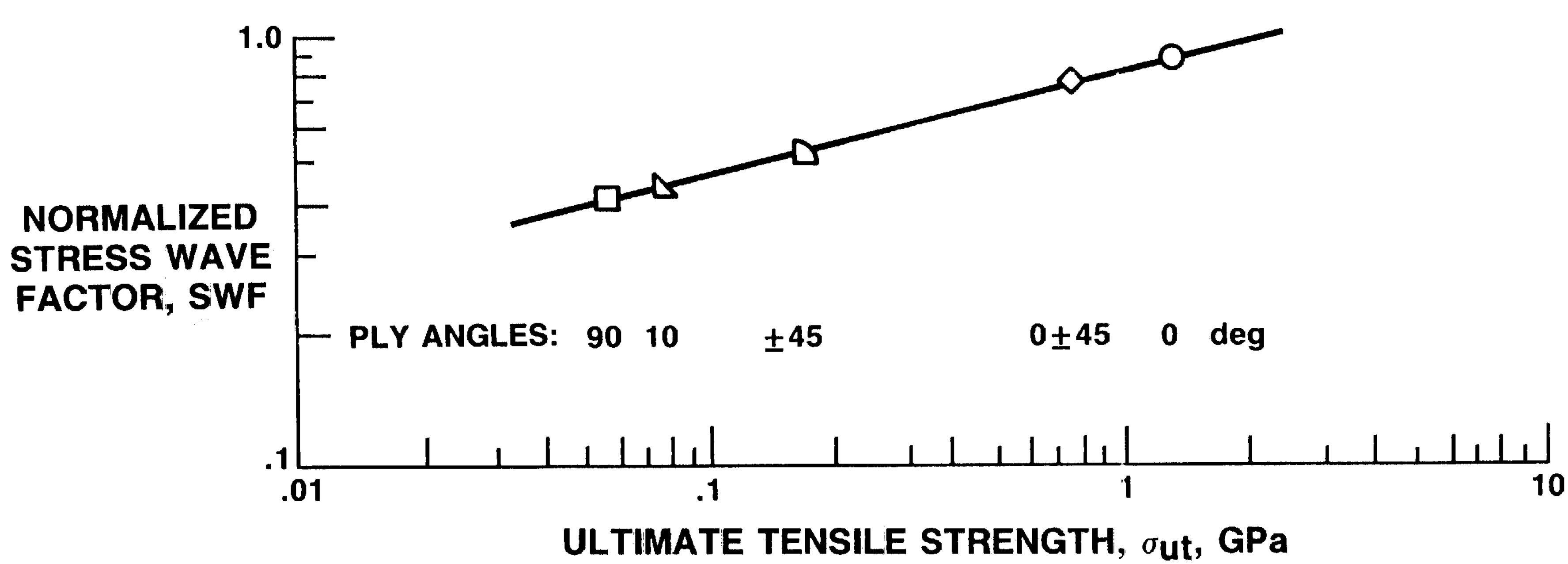
CD-87-27468

STRESS WAVE FACTOR (SWF) VERSUS THROUGH-TRANSMISSION ULTRASONIC ATTENUATION AT IMPACT SITE OF 10-PLY UNDIRECTIONAL GRAPHITE/ EPOXY COMPOSITE LAMINATE SPECIMENS



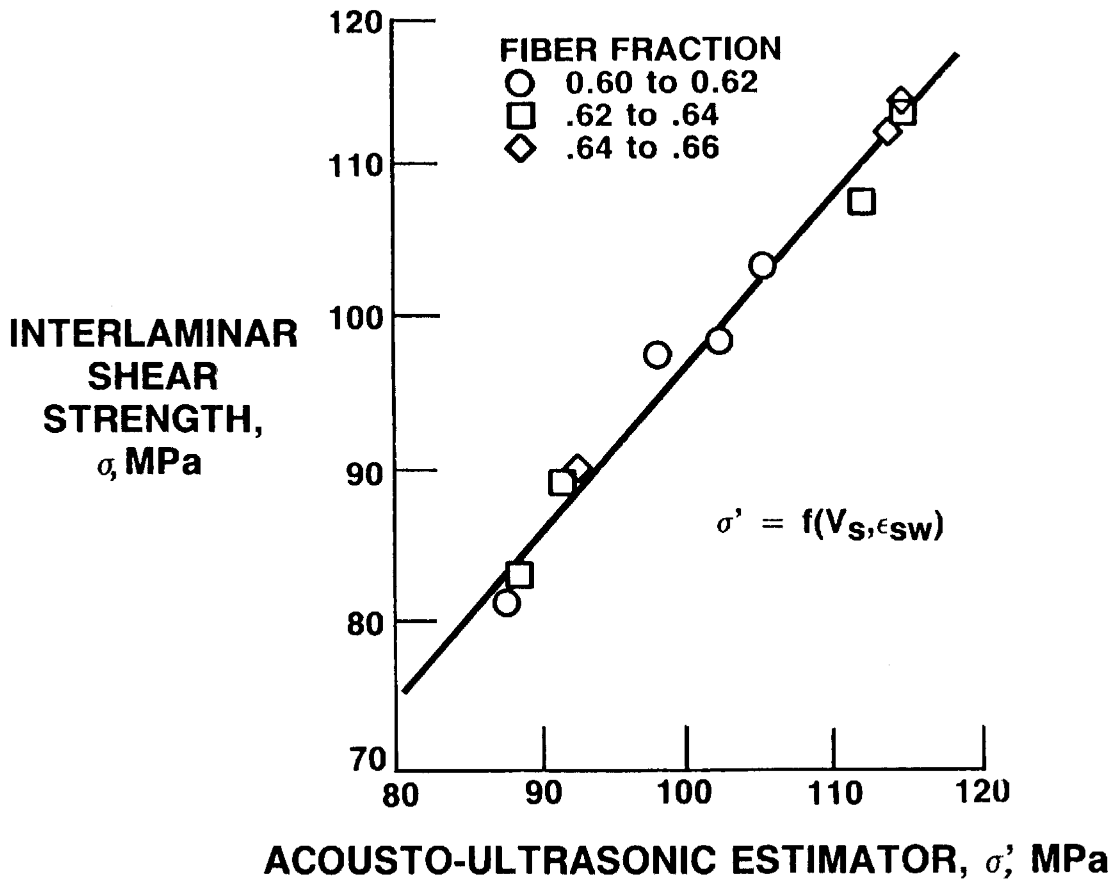
CD-87-27461

ACOUSTO-ULTRASONIC STRESS WAVE FACTOR AS CO-FUNCTION OF ULTIMATED TENSILE STRENGTH AND FIBER/PLY ANGLE IN COMPOSITE LAMINATE



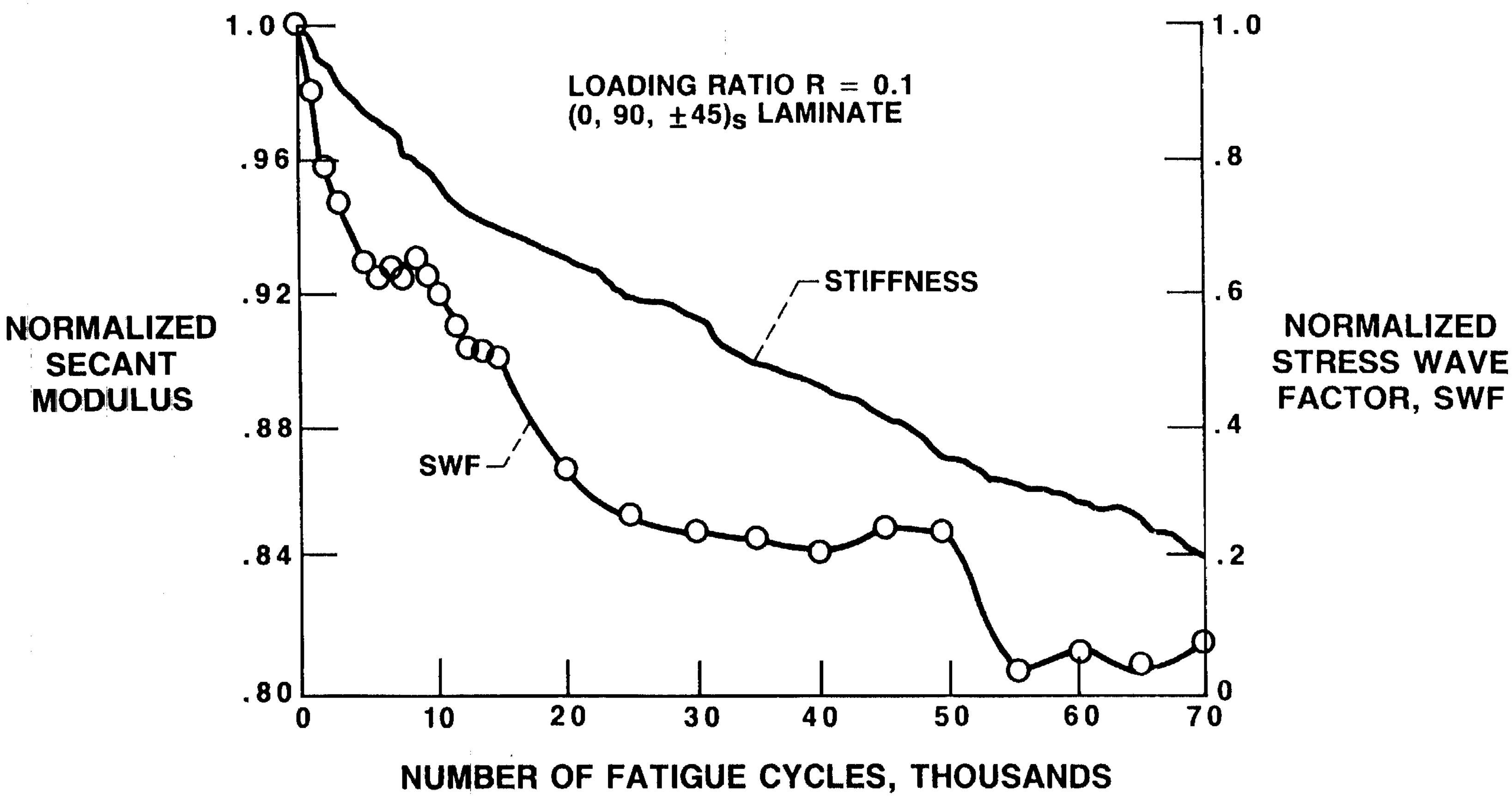
CD-87-27464

CORRELATION OF INTERLAMINAR SHEAR STRENGTH WITH THE ACOUSTO-ULTRASONIC ESTIMATOR FOR GRAPHITE/POLYIMIDE FIBER COMPOSITE LAMINATE



CD-87-27455

COVARIATION OF STRESS WAVE FACTOR AND LONGITUDINAL SECANT MODULUS WITH FATIGUE DAMAGE IN GRAPHITE/EPOXY FIBER COMPOSITE LAMINATE



DIFFERENCE IN SLOPES IS BECAUSE SECANT MODULUS IS FOR FULL GAGE LENGTH WHILE (SWF) IS FOR LOCAL ZONE ON TEST SPECIMEN

CD-87-27451

CONCLUSIONS

- UNDERLYING (SWF) HYPOTHESIS APPEARS TO BE CONFIRMED
- CAPABILITY FOR PREDICTING POTENTIAL FAILURE SITES
- MEASUREMENT OF DEGRADATION DUE TO IMPACT, FATIGUE
- CORRELATIONS WITH INTERLAMINAR, ULTIMATE STRENGTH

CD-87-27475