Final Report for NAG3 - 1946

Knowledge Discovery Process for Characterization of Materials Failure Mechanism

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Below we briefly summarize the work performed under NASA grant NAG3 - 1946 during the period 1996 - 1997 for the project entitled "Knowledge Discovery Process for Characterization of Materials Failure Mechanism".

1. Problem understanding based on A. Brewer's work

   (A. R. Brewer, a thesis entitled "Acoustic Emission Techniques for the Discrimination of Damage Mechanisms in Ceramic Matrix Composites", Cleveland State University: 1994)

2. Data understanding (converting data from Labview format and writing it into Matlab format)

3. Data preparation (data cleaning, creation of an SQL database, visualization of the AE weveforms – see the attached paper presented by M. Shields at a conference organized at OAI)

4. Data mining

   - visualization of data in Matlab (each waveform can be displayed)

   - visualized Fast Fourier Transform analysis of each waveform

   - correlation analysis for waveforms from the same materials

   - wavelet analysis of the waveforms (it was found for lead braking on PMC's surface vs. edge that the ratio of the energy of the original signal to the energy of the a4 wavelet approximation of the same signal is sufficient to distinguish between surface and edge brakes – that means that ONE feature was sufficient for correct classification - on a limited test data)

ACKNOWLEDGEMENT

I would like to extend my gratitude to NASA's Technical Officer, Dr. George Baaklini, for his guidance during the period covered by the grant. It was my great honor and pleasure to work and learn from this great individual.

Visualization of AE Waveforms

Overview

It is the intent of this project to provide a platform to visualize the various data collected from stress-strain testing of composite ceramic matrix materials. The data collected from the stress-strain tests are acoustic emissions (AE). As a material is subjected to a stress-strain test, various failure mechanisms occur in the material. The recorded sounds emitted during the test may correspond to various failure mechanisms. This project, thus, will give a possible way to visualize the data and data derived from the recorded AE.

The stress-strain testing was performed on several composite matrix material combinations. Each of these tests produced anywhere from 1000 to 10,000+ AE events. For each AE event recorded, several characteristics in both the time and frequency domains are created.

This project has two goals. First, this project will provide a summation page for a selected waveform. This page will include all of the characteristics determined from the AE event waveform along with graphs of the AE event waveform and its corresponding Power Spectrum. The other function of this project is to retrieve and display selected AE event waveforms for comparison.

Tables

The waveform storage table stores the individual acoustic emission (AE) waveforms. The data dictionary is shown in Table 1. This is the main table for this project. The primary key is a combination of the name of the composite material, AE waveform test index and the vector element index of each vector element value. The main piece of data stored in this table is the individual vector element value. The composite material test name and AE waveform test index provide access to each of the remaining tables either in combination or by themselves.

ATTRIB. NAME	CONTENTS	TYPE	FORMAT	RANGES OR CHOICES	REQ'D	KEY
WVFM-IDX	waveform index number	NUMBER	(5, 0)	1 - 99999	Y	PK, FK, NN
TST-SMPL	composite matrix test sample	VARCHAR	X(8)		Y	PK, FK, NN
ELMT-IDX	vector element index	NUMBER	(5, 0)	1 - 99999	Y	PK, NN
ELMT-VAL	vector element value	NUMBER	(8, 4)		Y	NN

Table 1. AE Waveform storage table data dictionary

The waveform time domain characteristics table stores the individual acoustic emission (AE) waveform time based characteristics. The data dictionary is shown in Table 2. The primary keys are both the composite material test name and AE waveform test index. The time based characteristics of signal energy and AE event duration are stored here.

ATTRIB. NAME	CONTENTS	TYPE	FORMAT	RANGES OR CHOICES	REQ'D	KEY
WVFM-IDX	waveform index number	NUMBER	(5, 0)	1 - 99999	Y	PK, NN
TST-SMPL	composite matrix test sample	VARCHAR	X(8)		Y	PK, NN
ENT-DRTN	AE event duration (msec)	NUMBER	(10, 5)		Y	NN
ENT-ENGY	AE event energy (scalar)	NUMBER	(10, 5)		Y	NN

Table 2. AE Waveform time domain characteristics table data dictionary

The waveform frequency domain characteristics table stores the individual acoustic emission (AE) waveform frequency based characteristics. The data dictionary is shown in Table 3. The primary keys, again, are both the composite material test name and AE waveform test index. The frequencies related to the three strongest energy amounts are stored here.

ATTRIB. NAME	CONTENTS	TYPE	FORMAT	RANGES OR CHOICES	REQ'D	KEY
WVFM-IDX	waveform index number	NUMBER	(5, 0)	1 - 99999	Y	PK, NN
TST-SMPL	composite matrix test sample	VARCHAR	X(8)		Y	PK, NN
ENT-F1	AE event primary frequency	NUMBER	(10, 5)		Y	NN
ENT-F2	AE event secondary frequency	NUMBER	(10, 5)		Y	NN
ENT-F3	AE event tertiary frequency	NUMBER	(10, 5)		Y	NN

Table 3. AE Waveform frequency domain characteristics table data dictionary

The waveform classification table stores the individual acoustic emission (AE) waveforms. The data dictionary is shown in Table 4. The primary keys are both the composite material test name and AE waveform test index. The AE events waveform classifications are stored here.

ATTRIB. NAME	CONTENTS	TYPE	FORMAT	RANGES OR CHOICES	REQ'D	KEY
WVFM-IDX	waveform index number	NUMBER	(5, 0)	1 - 99999	Y	PK, NN
TST-SMPL	composite matrix test sample	VARCHAR	X(8)		Y	PK, NN
CLASS	AE event classification	NUMBER	(2)			

Table 4. AE Waveform classification table data dictionary

The final table is derived by joining the other four tables together. Table 5, the statistics table, provides the data for the AE waveform statistics screen.

ATTRIB. NAME	CONTENTS	TYPE	FORMAT	RANGES OR CHOICES	REQ'D	KEY
WVFM-IDX	waveform index number	NUMBER	(5, 0)	1 - 99999	Y	PK, FK, NN
TST-SMPL	composite matrix test sample	VARCHAR	X(8)		Y	PK, FK, NN
ELMT-IDX	vector element index	NUMBER	(5, 0)	1 - 99999	Y	PK, NN
ELMT-VAL	vector element value	NUMBER	(8, 4)		Y	NN
ENT-DRTN	AE event duration (msec)	NUMBER	(10, 5)		Y	NN
ENT-ENGY	AE event energy (scalar)	NUMBER	(10, 5)		Y	NN
ENT-F1	AE event primary frequency	NUMBER	(10, 5)		Y	NN
ENT-F2	AE event secondary frequency	NUMBER	(10, 5)		Y	NN
ENT-F3	AE event tertiary frequency	NUMBER	(10, 5)		Y	NN
CLASS	AE event classification	NUMBER	(2)			

Table 5. AE Waveform statistics table data dictionary

ER Diagrams

Figure 1 shows the base ER diagram for this project. From the main table, AE-Storage, the other tables are created using MatLab.

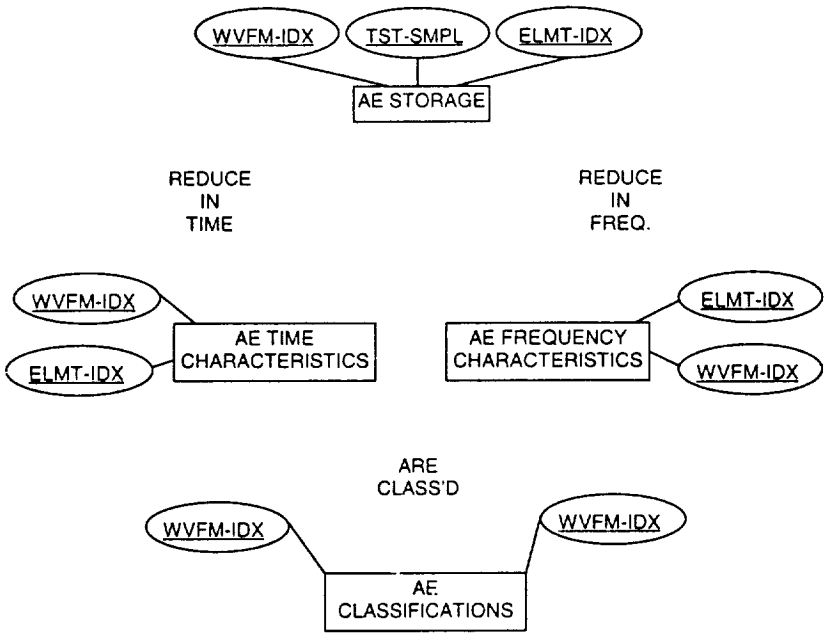

Figure 1. ER Diagram for classification

Figure 2 is the ER diagram for the AE waveform Statistics table.

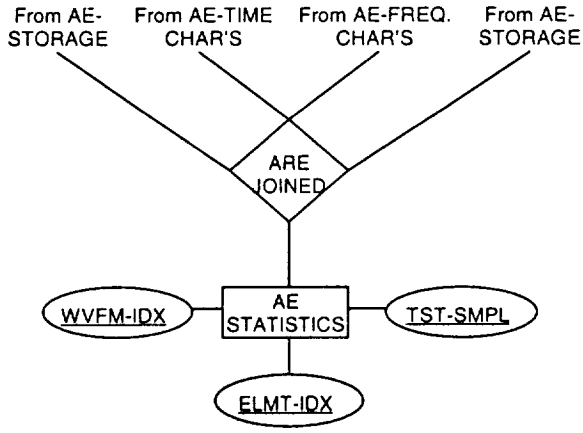

Figure 2. Statistics ER Diagram

Screens

Figure 3 shows the main screen for this project. From this screen, it is possible to retieve screens which display either the AE event waveforms or a particular AE event statistics.

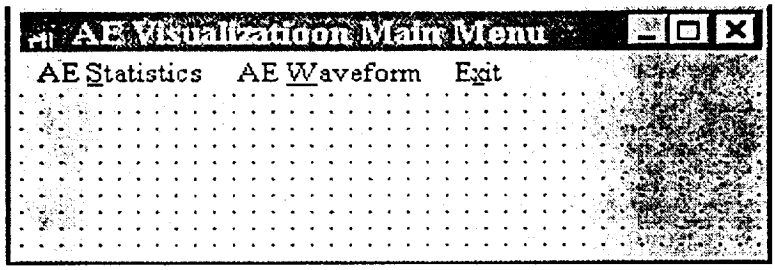

Figure 3. The main menu

Figure 4 shows the retrieve AE event waveform screen. It gives the user the ability to retrieve several AE event waveforms at the same time for comparisons.

Figure 5 displays the screen which will contain the AE event waveform.

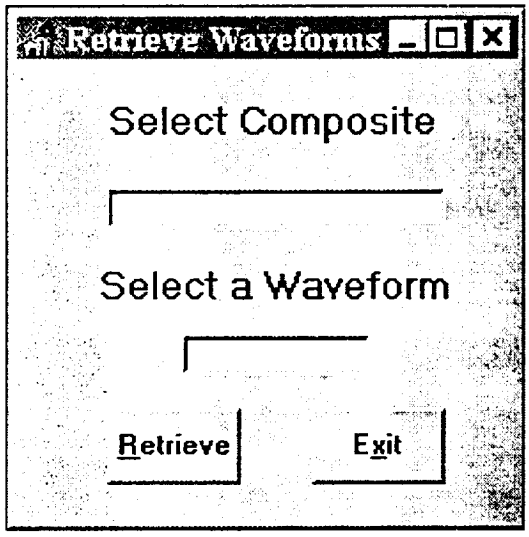

Figure 4. The retrieve waveform screen

Figure 6 shows the retrieve AE event waveform statistics screen. It gives the user the ability to retrieve several AE event waveform statistics sets at the same time for comparisons.

Figure 7 is the display of the AE waveform statistics screen.

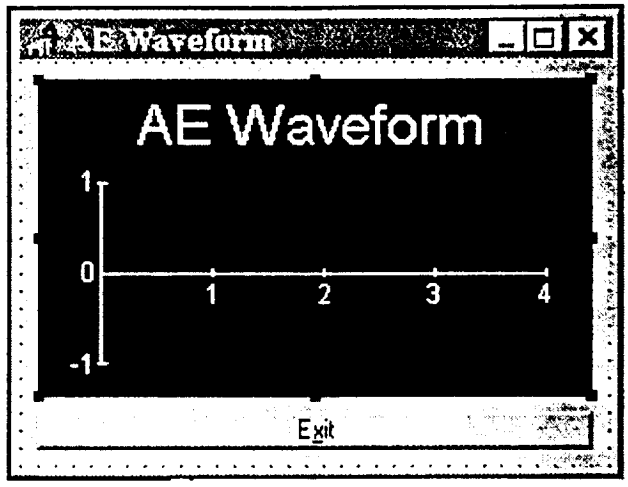

Figure 5. The AE event waveform screen

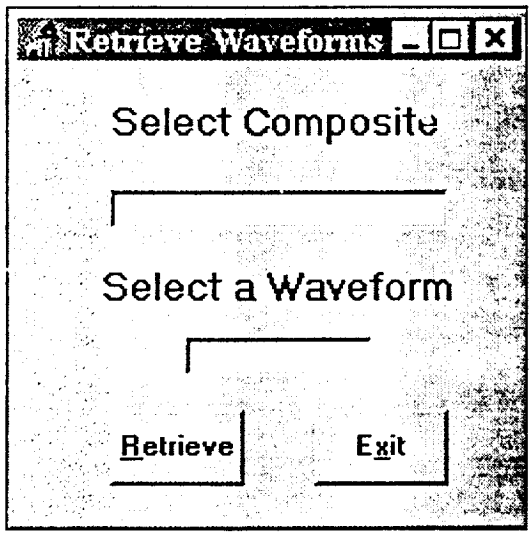

Figure 6. The retrieve waveform statistics screen

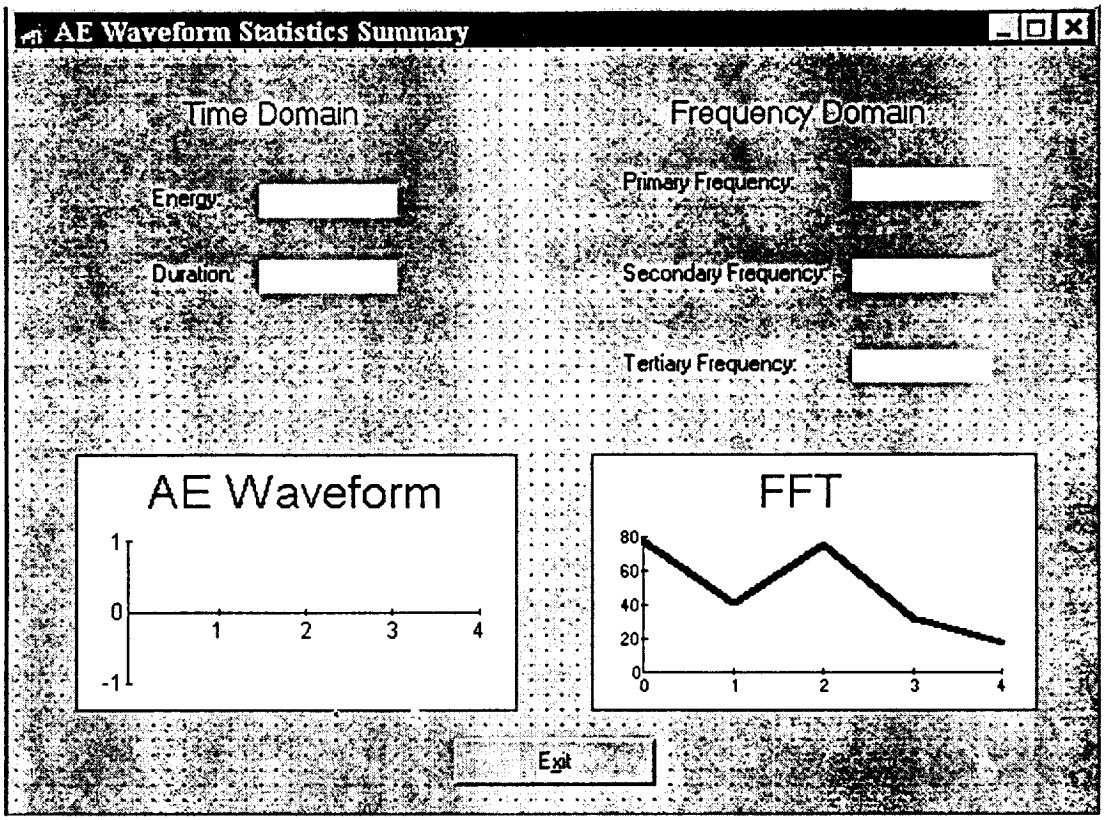

Figure 7. The AE event waveform statistics screen