

PENNSYLVANIA STATE UNIVERSITY



Erie

The College of
Engineering

FINAL REPORTS FOR STUDENT PROJECTS

SCHOOL OF ENGINEERING

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Electrical and Computer Engineering

PROJECT TITLE: Studying Audio Protocols and Developing a Software System for Recording, Playback, and Signal Monitoring

STUDENT RESEARCHER AND SCHOOL: Matthew L. Baker, School of Engineering

AFFILIATED FACULTY MEMBER: Dr. Wen-Li Wang, Assistant Professor of Electrical and Computer Engineering

ABSTRACT:

The primary focus of this project was to study two different audio protocols: WAV and MP3, and develop an application for WAV playback, recording, and signal monitoring. The signal monitoring employs the array data structure to store the normalized audio samples that are displayed graphically to help examine and understand the audio waveform. The array data structure not only facilitates the playback at a random location, but also eases the identification of the current playback location, so a moving indicator bar can be drawn to let users visualize the real time playback progress. To yield normalized audio samples, the main variables to be considered are the sample size in bits and the number of channels. A high sample size can result in better fidelity but different sample sizes will have to further consider different data representations. For example, for 16-bit audio one needs to further deal with it being either a big or a little Endian layout in the channels, while 8-bit audio does not.

Our audio samples normalization process is adhered to different audio protocols in order to draw correct waveforms. For an 8-bit uncompressed Pulse-Code Modulation (PCM) WAV file, samples before the normalization are captured using:

$$\text{Samples}[i] = (\text{byte}) (\text{Literal} - 128) / (\text{double})128$$

where “literal” is for the i th byte value read in from the audio file. The subtraction of 128 from Literal is to introduce a sign for later waveform graphing because 8-bit samples are unsigned, i.e., all positive. For 16-bit audio, it is even more complex. Because a byte has only 8 bits, a 16-bit sample has to combine two sequential bytes using the logical OR operator. More importantly, the combination has to follow the protocol to confirm with the big or little Endian format to be correct. Once samples are available from the beginning to the end of the file, the normalization is performed to each one as below and the normalized result is stored back to the array.

$$\text{Sample}[i] = \text{Sample}[i] / 2^{n-1}$$

where n = Sample size in bits and Sample is a signed value less than 2^{n-1} .

To graph these samples, the Cartesian coordinate system is used. The y-axis is scaled relatively to the size of the canvas. The scaling is based on this derived formula:

$$\text{YValue}[i] = \text{CanvasHeight} / 2.0 - \text{Samples}[i] * \text{CanvasHeight} / 2.0$$

where CanvasHeight is the height of the drawing canvas, and Samples[i] is for each previously normalized audio sample.

While this approach works for PCM-Wave audio, it is not as straightforward for the MP3 format. MP3 files must first be decoded into a form similar to that of a PCM-WAV format audio file before they can be further processed. Recording audio in PCM-WAV is also simpler than that in MP3. Recording in PCM-WAV consists of pulling audio data from a line, such as a microphone, and storing the raw values into a byte-file. For MP3 recording, an encoding or compression technique is applied to eliminate sounds the human ear cannot hear or have a hard time hearing. It uses a 32-band polyphase quadrature (low-pass) filter in combination with the Modified Discrete Cosine Transform (MDCT) to compress the data. The Inverse Modified Discrete Cosine Transform (IMDCT) is used in the anti-aliasing procedure. Aliasing occurs when data are compressed with unwanted artifacts being introduced that can corrupt or distort the data. The IMDCT will reveal the same artifacts but the actual data become an inverse. By comparing the results of MDCT and IMDCT, the artifacts can be identified and removed during decoding.

One of the crucial components in this developed application is to achieve concurrency using threads. The thread technology gives the impression that multiple subtasks are running concurrently, not just sequentially. Therefore, during audio playback the application can simultaneously display a real time indicator bar for users to monitor the progress. In the case of recording, the system will not lock up entirely in a while loop, so the “Stop” button can be pressed to end the recording. In other words, threads allow interruptions to subtasks and intercommunications among them. In this system, all the features that require concurrency for the WAV format were implemented, but the MP3 encoder/decoder to handle compression is not yet available. The incorporation of MP3 will continuously be a future work. Currently, a great deal of information on the WAVE format and MP3 format has been collected, and the system is designed to be reusable and extensible for software evolution.

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PROJECT TITLE: A Magnetic Storage Converter

STUDENT RESEARCHER AND SCHOOL: Scott Hrinko, School of Engineering and Engineering Technology

AFFILIATED FACULTY MEMBER: Dr. Thomas Hemminger, Associate Professor of Electrical and Computer Engineering

ABSTRACT:

This project's goal was to design and implement a circuit that converts data intended for storage on an old magnetic computer tape drive to a simple format that can be used with standard 3.5" floppy disk drives. There was no intent to emulate the DOS format but rather to create a simple protocol easily implemented with a small microcontroller. An old Radio Shack computer was chosen to be used as it stores data to a magnetic tape drive and has a simple hardware interface. A major component of this project was to research how floppy drives and their controllers interact. This turned out to be a much larger task than originally anticipated primarily because there is very little information about disk drive's basic input/output protocols. Most books and articles deal with an understanding at the chip level, a higher level which was not very useful for this project. After consulting books and articles, and conducting various experiments, enough information was obtained about the disk drive's basic operation, including reading, writing, and track select. The second task was researching the microcontroller to determine whether it would be compatible and to learn its instruction set. After a great deal of research, a PIC microcontroller was chosen to implement the final design. Toward the end of the summer, a preliminary circuit was developed on paper and a portion was implemented on a circuit breadboard. At the time of this writing, there are still some tasks to be resolved; for example, a converter from logic levels one and zero to an FM sinusoidal wave, and final testing of the overall system. If time permits, a working model may be implemented by next spring. Otherwise, a substantial amount of information on disk drives, storage protocols, and the use of a microcontroller for format conversion can be reported.

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Mechanical Engineering

PROJECT TITLE: Twisting of Airfoil Sections Using Shape Memory Alloy Wire

STUDENT RESEARCHER AND SCHOOL: Andrew Detar, School of Engineering and Engineering Technology

AFFILIATED FACULTY MEMBER: Dr. Oladipo Onipede, Assistant Professor of Mechanical Engineering

ABSTRACT:

Research has shown that by twisting rotor blades, fan blades, and aircraft wings, efficiency can be improved and part life extended. Presently, rotor and fan blades are manufactured with a predetermined twist making the blade efficient at a set operating condition. Interest is now growing in controlling the twist through the entire range of operation, further improving efficiency and part life. The goal of this research was to determine the effectiveness of shape memory alloy (SMA) wire in accomplishing this task.

SMA material has the ability to “remember” its original shape and if deformed, will return to this shape in the presence of a certain amount of heat. Once heated, SMA wire can exert enough force when wrapped around a board to induce a 30 degree twist. For the research, two Nitinol wires were stretched 3-5 percent and placed inside Teflon tubes. The Teflon tube reduced the sliding friction of the wire during contraction and stretching. The board was wrapped with thermal tape at a 45° angle. This minimized the heat transfer to the board from the wires. The wires were then wrapped around the board following the thermal tape and secured in position with another layer of tape. The wires began and terminated at the center of the board and were secured with screws. The board was then centrally mounted on the stinger arm of the dynamometer. This configuration produced symmetric twist on either side of the mount thus simulating a fixed wing. Electrical leads from the screws were run along the trailing edge of the aerodynamic sleeve surrounding the stinger arm. These leads exited the wind tunnel and were connected to a power supply. The internal resistance of the wires created heat which initiated the contraction of the wires. 5.5 A were run at 9 V to obtain the activation temperature. The angle of attack of the mount was adjusted from 0 – 16° in 2° increments. The lift and drag were measured for both the flat state and twisted state at each increment. The direction of the wrapped wires twisted the end of the board 9° into the flow thus creating lift.

The research determined that the effect of the twist became less effective as the angle of attack approached the stall angle of 16°. At an angle of attack of 0°, there was a 50 percent increase in the coefficient of lift of the airfoil, but at higher angles of attack, the efficiency decreased. The average angle of attack across the wing was increased in the twisted state thus increasing the lift as compared to the flat state. But as the angle of attack increased, the twist began to produce negligible effects on the lift and even began

to reduce it. Consequently, the twist hastened the onset of stall. This trend was observed at flow speeds from 9 m/s to 19 m/s.

The effect the twist had on drag was difficult to observe. Several factors tainted the observed drag values. The electrical leads and the SMA wires themselves were the main contributors of excess drag. The board also contributed to the rise in drag. For comparison purposes, the experimental data were compared to theoretical data for a smooth airfoil. The experimental data for the coefficient of drag was ten times greater than the theoretical value.

The results did prove that SMA material can be used to produce the twist needed to alter lift and drag. Further research will be conducted where sections of the airfoil will be twisted in different directions in order to increase the angle of attack at which stall occurs.

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PROJECT TITLE: Effects of DC Current on the Stress-Strain Curve and Hardness of 6061 T6511 Aluminum

STUDENT RESEARCHER AND SCHOOL: Jarred Heigel, School of Engineering and Engineering Technology

AFFILIATED FACULTY MEMBERS: Dr. John Roth, Assistant Professor of Mechanical Engineering and Dr. Russell Warley, Assistant Professor of Mechanical Engineering

ABSTRACT:

The effects of electricity on the mechanical properties of aluminum are investigated with the ultimate goal of establishing a technique by which the mechanical energy associated with cutting a material can be reduced without requiring an increase in the material's temperature. The effects of the electricity on the mechanical properties of 6061 aluminum are investigated through both tensile and hardness testing. As the electricity is passed through the material, resistive heating occurs within the material. Therefore, the effects of non-stationary temperatures on the stress-strain behavior of 6061 aluminum are investigated with and without the electrical current flowing through the material. How the electrical effect varies based on the aluminum's temper is also investigated, along with the effects of electrical pre-treatments. The experimental results indicate that the electricity has the potential to substantially reduce the energy required to machine the material without causing significant increases in the workpiece temperature. The testing also indicates that these effects exist regardless of the temper on the material. Finally, the study found that, while not reducing the energy as substantially as when using a continuous current, an electrical pre-treat can be used to reduce the energy below that found from annealing alone.

Annealing reduced the total energy, however, electricity seems to provide an even further energy reduction than that achieved through annealing the material for several hours. Annealing creates an energy roughly equivalent to the instantaneous energy achieved through plastically deforming while electricity is running through the non-annealed workpiece. However, the effects produced by the electricity do not require the amount of time that annealing does.

Furthermore, even after completing the annealing process, electricity was found to further reduce the energy. It should be noted that by electrically pre-treating the workpieces, it is possible to also reduce the energy beyond that achieved through annealing without requiring electricity to be conducted through the workpiece while it is being deformed. However, the reductions achieved through pre-treating were not as significant as the effects due to the constant electrical current.

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PROJECT TITLE: Viability of Electrically Treating 6061 T6511 Aluminum for Use in Manufacturing Processes

STUDENT RESEARCHER AND SCHOOL: Jarred Heigel, School of Engineering and Engineering Technology

AFFILIATED FACULTY MEMBERS: Dr. John Roth, Assistant Professor of Mechanical Engineering and Dr. Ralph Ford, Professor of Electrical and Computer Engineering

ABSTRACT:

Electrical flow, applied before and during deformation is shown to reduce the specific energy and flow stress of aged 6061 T6511 aluminum; it also creates apparent macroscopic strain-weakening in the material. When applied to annealed 6061 aluminum, the electricity not only further reduces the specific energy and flow stress but also delays the onset of necking, increasing the workability of the material. The precipitates and grains of the aluminum are investigated for alterations due to either annealing or electrical flow. Both treatments are shown to affect the size and number of the precipitates and decrease the grain size. However, the electricity has an effect on the mechanical properties beyond the changes in precipitates and grains suggesting that electrical flow has the potential to reduce the forces generated in bulk deformation or material removal processes beyond the level that can be achieved by temperature alone.

By correlating the stress-strain behavior of the aluminum to the corresponding precipitate and grain analysis, the changes in the mechanical properties due to both annealing and electrical pretreating are fully addressed. However, the precipitate and grain alterations do not sufficiently account for the reductions in both the specific energy and flow stress that occur when applying an electrical current while deforming the material. This suggests that the current passing through the workpiece has an effect on the material flow that is not accounted for by the physical precipitate or grain alterations. Thus it appears that an electrical current can be applied to aluminum-based deformation and material removal processes to reduce the forces and energy required to produce a part, an issue currently being investigated. The findings also show that the effects of strain hardening are reduced or eliminated if the electricity is applied during deformation.

When analyzing the precipitates, several changes occur during the application of the electricity that are significant. When the electricity is applied during deformation, the amount, number, and size of both the Mg_2Si and the Fe_3SiAl_{12} , $Fe_2Si_2Al_9$, Mn_3SiAl_{12} , or Cr_3SiAl_{12} precipitates in the aluminum are affected. This is also true when annealing or electrically pretreating the aluminum.

In addition, applying electricity during deformation results in a greater reduction in the energy required to deform the material than can be achieved through annealing. Furthermore, it is shown that when applying electricity to an annealed material, even larger reductions in energy are possible. Moreover, it was shown that necking occurred at higher levels of strain in the specimens that were both annealed and deformed while electricity was applied than occurred in the specimens that were only annealed.

Therefore, the specific energy is reduced and the working range of the material is increased when electricity is applied to a material which has been previously annealed.

When analyzing the grains of the aluminum, a significant difference was found between the electrical effects and the annealing effects when etched. Comparing the annealed and non-annealed specimens, annealing caused the etchant to react with the aluminum. This permanent change to the aluminum, however, did not occur when the material was deformed under an applied electric current or when electrically pretreating the material.

Along those lines, as a part of this study, a comparison was completed between the viability of using electrical pretreatments of the aluminum rather than annealing to reduce the forces created during deformation or material removal processes. It is worth noting that electrical pretreatments differ from resistive heat treating with regard to temperature, duration, and transport mechanism. When comparing the electrical pretreatments to annealing, it was found that pretreatments resulted in a greater reduction in energy under the stress-strain curve, created a larger reduction in Mg_2Si precipitate amount, required less time, did not affect the grain size, and did not cause the permanent change to the aluminum that the annealing caused. Given these advantages, the use of electrical pretreatments as alternatives to annealing is currently being investigated.

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PROJECT TITLE: Automation and Optimization of Fluid Flow Simulation of Spinnaker Aerodynamics

STUDENT RESEARCHER AND SCHOOL: Amy J. McCullough, School of Engineering and Engineering Technology

AFFILIATED FACULTY MEMBER: Dr. William Lasher, Associate Professor of Mechanical Engineering

ABSTRACT:

A spinnaker is a sail used in racing yachts when the boat is in a downwind sailing situation. In order to understand better spinnaker aerodynamics, twelve sails were previously tested in a wind tunnel at varying angles of attack, and force coefficients for each model were measured. A shape identical to one of these spinnaker models was imported into Gambit (a mesh generation program) and a volume representative of the wind tunnel was created surrounding the model. This volume was then meshed and imported into Fluent, a Computational Fluid Dynamics (CFD) program. In order to reduce the time spend preparing the spinnaker model for simulation in Fluent, a command file was created that automates this process and begins the simulation in Fluent. This allows for efficient testing to determine the optimum mesh density, convergence criteria, and other solver options. Different parameters were tested in order to determine what values were needed to obtain accurate results using the least amount of computation time. Both of these objectives resulted in a more effective simulation process. Data can be generated much more easily and efficiently. This will allow for rapid analysis of sail designs beyond the original twelve.

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