

Automatic Fatigue Test Control System (AFTCS)

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ABSTRACT

Bell Helicopter's next-generation Automatic Fatigue Test Control System (AFTCS) is presented. Fatigue testing places a helicopter part or specimen under repeated, controlled cyclic loading to determine if and when it will fail. A National Instruments PXIe embedded processor and LabVIEW software are used to control up to 48 linear/rotary hydraulic actuators in real-time. The actuators apply structural loads that are sensed by up to 256 strain gauges on the helicopter specimen. The structure and instrumentation respond to prescribed cyclic loads that range in frequency from 0.5 to 30 Hz, with a minimum resolution of 0.1 Hz. The fatigue test controller design is based on the well-known Linear-Quadratic-Gaussian control (LQG) methodology. Its feedback and filter gains are computed using a state-space model of the specimen identified separately. The controller computes any necessary changes in the actuator motions (at every time sample), maintaining acceptable margin between the measured and desired strain gauge responses. The system is demonstrated on a Bell Helicopter 429 tail rotor blade.

ACRONYMS

| | |
|-----------|---|
| AFTCS | Automatic Fatigue Test Control System |
| AI | Analog Input |
| AO | Analog Output |
| D.C. | Direct Current |
| FAA | Federal Aviation Administration |
| GUI | Graphical User Interface |
| Hz | unit of frequency (1/sec) |
| LabVIEW | Laboratory Virtual Instrument Engineering |
| Workbench | |
| LQ | Linear Quadratic |
| LQG | Linear Quadratic Gaussian |
| mV/V | millivolt/Volt |
| NI | National Instrument |
| PC | Personal Computer |
| PCI | Peripheral Component Interconnect |
| PXI | PCI eXtensions for Instrumentation |
| PXIe | PXI express |
| RT | Real-Time |
| SG | Strain Gauge |
| V | Voltage |
| VI | Virtual Instrument |

NOTATION

| | |
|------------|----------------------------|
| A, B, C, D | state-space matrices |
| K | state feedback gain matrix |
| L | Kalman filter gain matrix |
| x | state vector |
| u | input vector |
| y | output vector |
| Subscript | |
| p | identified model |
| aug | augmentation model |
| c | tracking controller |

INTRODUCTION

Vibratory loads in a helicopter lead to fatigue damage of structural components, human discomfort, and pilot fatigue. For safety of flight, Bell Helicopter substantiates the fatigue life of critical helicopter parts for Federal Aviation Administration (FAA) certification. The durability and damage tolerance of these parts is also evaluated.

An automated servo-hydraulic fatigue test system has been designed at Bell Helicopter to control multiple hydraulic actuators that apply loads to a test specimen (Ref. 1). Load application must produce the desired cyclic loading at multiple strain gauges installed on the test specimen.

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