Flow Safe Emergency Stop (FSES)

A Water Jet Cutting Tip
Collision Detector and
Emergency Stop Activator

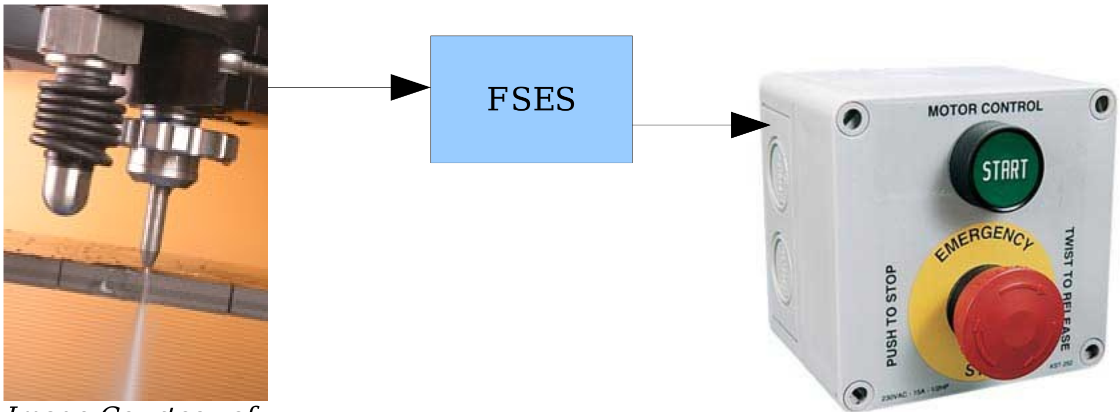

Image Courtesy of Flow International Corporation

Image Courtesy of Rockford Systems

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This proposal was prepared for Alan Selwyn, code 361. This proposal overviews the design goals and preliminary design of the proposed FSES system. This proposal details the time, funding, and personnel constraints that will be involved in the design, implementation, testing, and installation of the FSES system. Potential pitfalls are discussed and several options are presented.

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Design Goals

The primary design goal of the FSES system is to detect a nozzle collision and stop the water jet cutting machine before any damage occurs. The secondary design goal of the FSES system is to minimize damage to the water jet cutting machine in the event of a catastrophic nozzle collision or head assembly breakage.

The Dynamic Contour Follower™ & Collision Sensor from Flow Corporation is bulky and restrictive, which severely limits nozzle mobility. The Dynamic Contour Follower is also only really useful when cutting nearly flat surfaces and it does not help much at specimen edges. The Collision Sensor is not available for NSWCCD's 5-axis machine.

Ideally, the FSES system will not alter the dimensions of the nozzle or restrict its motion at all, which will retain its current freedom of motion. The FSES is a collision detector only, not a dynamic contour follower; it will not perform automatic height adjustments. It will just shut off the machine when a collision occurs in any direction.

When a nozzle collision occurs with a specimen or part of the machine itself, strain in the nozzle or head assembly should be measurable well before yield or breakage occur. If these strain measurements are performed fast enough, they can be compared with threshold values and the decision to activate the emergency stop button can be made in real-time. Strain gages are very small, which will allow the nozzle to nearly retain its existing size.

Preliminary Design

Strain Gage Placement

The placement of strain gages on the nozzle mounting bracket is key. The bracket was the point of failure during in a previous collision. The FSES system will utilize four uniaxial 350 ohm strain gages with a gage factor of at least two; two gages on each size of the nozzle mounting bracket as shown in figure 1. These stain gages will be oriented on a plane perpendicular to the nozzle-spray axis. This gage orientation and placement will allow measurement of bracket strain, at the previous point of failure, due to a vertical (z-axis) nozzle clearance problem or a horizontal (x-axis or y-axis) nozzle clearance problem, as shown in figures 2, 3, 4, and 5.

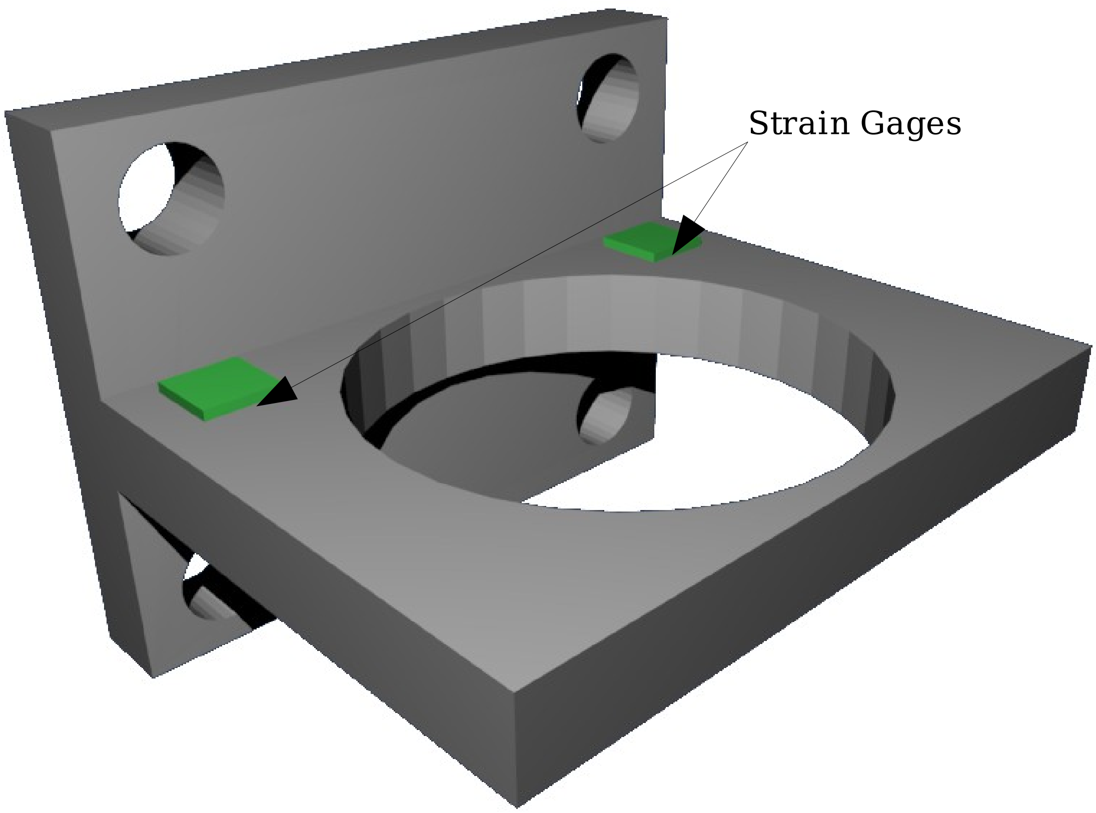

Illustration 1: Strain Gage Locations

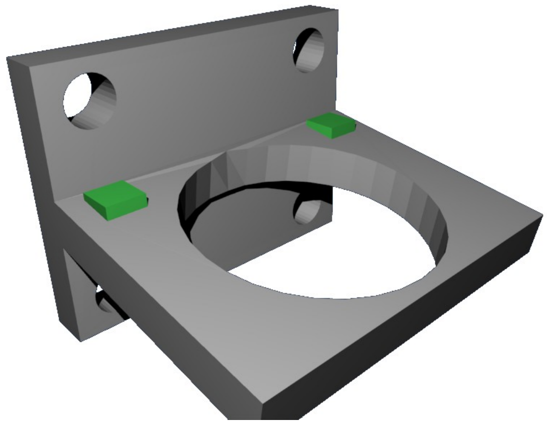

Illustration 2: Y-axis Nozzle Loading

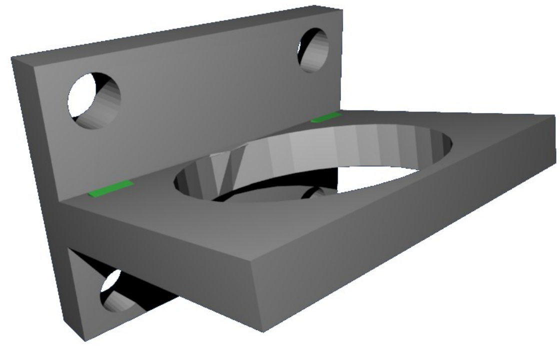

Illustration 3: Y or Z-axis Nozzle Loading

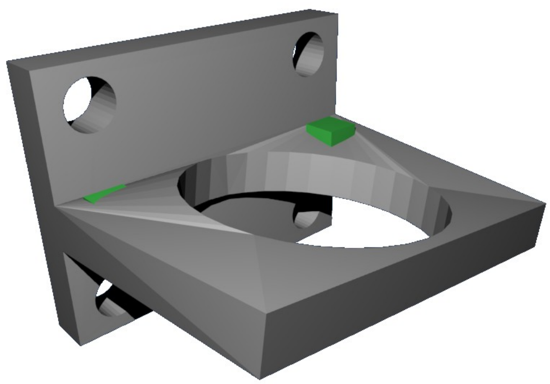

Illustration 4: X-axis Nozzle Loading

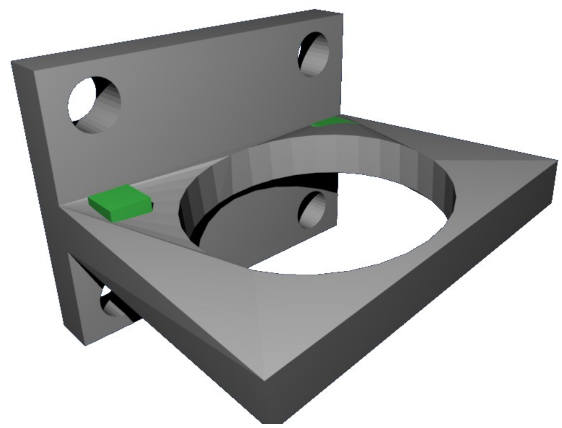

Illustration 5: X-axis Nozzle Loading

Data Acquisition

The total elapsed time between a collision event and machine stoppage is determined by two primary factors: sample rate and emergency stop latency.

The head of NSWCCD's water jet cutting machine can travel at a maximum speed of 900 inches/min, which is 15 inches/sec. If the sensors are sampled at 1000 Hz, each data sample represents 0.001 seconds. The tip would deflect 0.015 inches during that time at full speed. If the sensors are sampled at 10000 Hz, each data sample represents 0.0001 seconds. The tip would deflect 0.0015 inches during that time at full speed.

The emergency stop button latency is the amount of time that passes between button activation and complete machine stoppage. The latency is determined by the type of shutdown switch, relay open/close time, and motor inertia.

Electronics

System reliability is absolutely essential, so no personal computer components or operating system software will be used. The entire system will utilize solid state technology and run machine code on a micro controller to eliminate the possibility of software bugs and system crashes. Micro controllers are capable of running 24/7/365 without hardware or software errors; they are much more stable than a traditional personal computer running Microsoft Windows or Linux.

The power supply for the FSES controller will be either 12 or 24 VDC. A National Semiconductor LMC6484 quad-op-amp IC will be used to amplify the strain gage signals to measurable voltages. The data acquisition and decision making will be performed by a set of 1 or 4 Microchip PIC12F683 8-bit micro controllers that will be programmed in assembly language and machine code. Each PIC12F683 has 4 10-bit analog to digital converters and operates at 8MHz. A single PIC12F683 can acquire data on a single channel at over 1000Hz, so a single micro controller may suffice or one will be used for each channel if higher performance is needed. A single high-performance DC to DC converter will be used to convert from the 12 or 24 VDC to 5 VDC, which will power the micro controllers, op-amps, and strain gage excitation. Each micro controller will be capable of switching a digital output line to 5 VDC if a strain gage threshold is exceeded and collision is detected. This 5 VDC emergency stop signal will be connected to a solid state relay or a traditional relay to trigger the existing emergency stop button on the water jet machine automatically. A system layout overview is presented in figure 6.

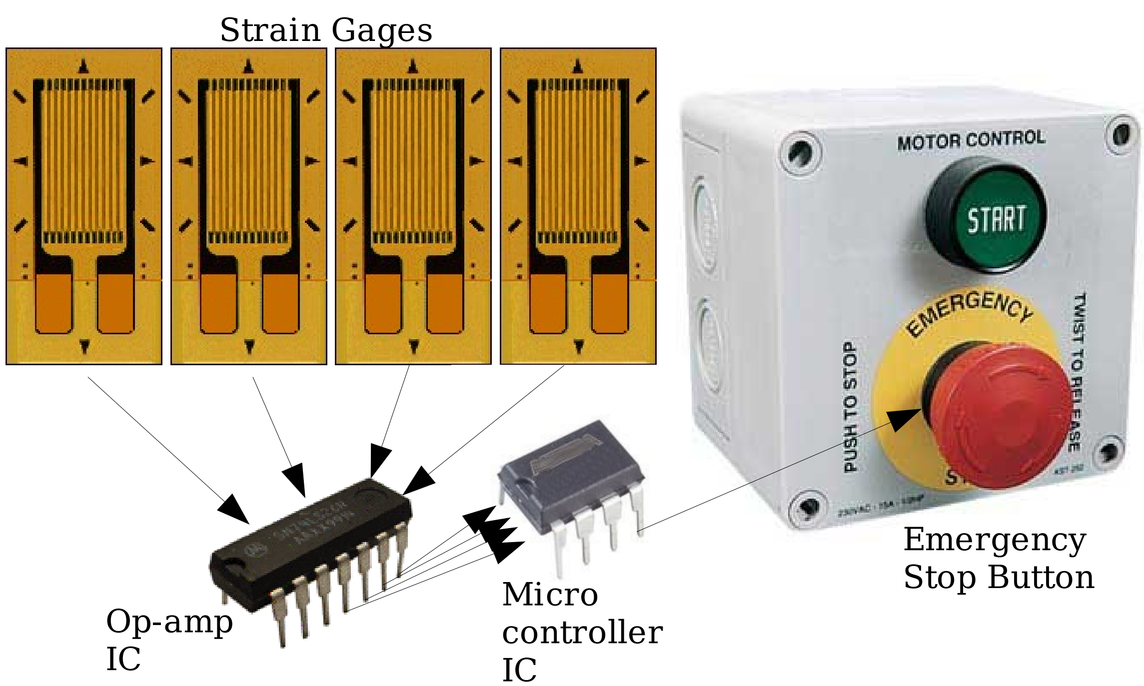

Illustration 6: System Layout Overview

Costs

The total estimated cost is about $13k for the first unit, which includes non-recurring-engineering (NRE). The NRE covers the initial design, development, and prototyping that is required for the first working unit. Additional systems could be constructed for about half of that cost, which would total about $7k each.

Item	Cost
Strain gages	$100.00
Backup nozzle bracket or removal of existing parts	$1,000.00
Strain gage installation on water jet nozzle bracket by code 653 technicians	$1,000.00
Installation of the instrumented nozzle bracket by code 361 technicians	$1,000.00
Data acquisition on instrumented nozzle bracket via traditional laptop system, while machine is operating, by an engineer at Hildstrom Engineering or code 653. This step is necessary to verify normal operating strains on the head assembly before threshold values are established.	$900.00
FSES controller parts, wiring, and electronics	$200.00
FSES micro controller code development, controller assembly, and bench testing by an engineer at Hildstrom Engineering	$4,500.00
Final installation of FSES onto water jet machine, emergency stop button interfacing, and testing by an engineer at Hildstrom Engineering	$2,250.00
Final installation assistance by code 361 technicians	$2,250.00
Grand Total Including Non-Recurring-Engineering	**$13,200.00**