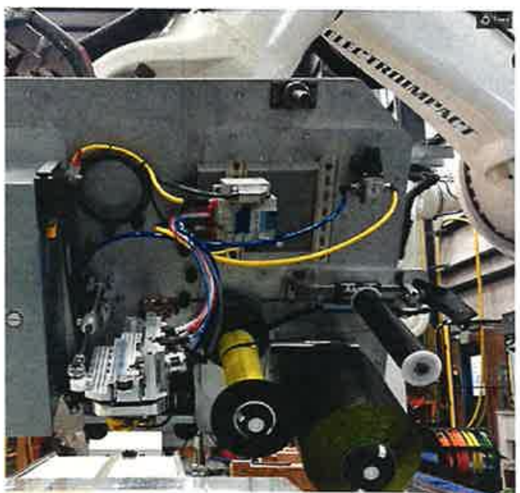


Tool changer testing

Abstract

On a rudimentary test bench, tests were done using the Animatics SM23165DT motor on a 10:1 reduction for large carbon spools. Results were promising and a new test bench was with tool changer was designed to be used on a robot. Minor adjustments were also made to the business end to allow for a more convenient tow path.

Key Changes

New gearbox.

A new gearbox with the same 10:1 reduction ratio was used in order to simplify the material spindle assembly. The flange output of the HPG-20 although much larger, can withstand moment loading during C axis rotation at full speed with a full spool of material. Thus, the bearing assembly used to resolve moments can be eliminated.

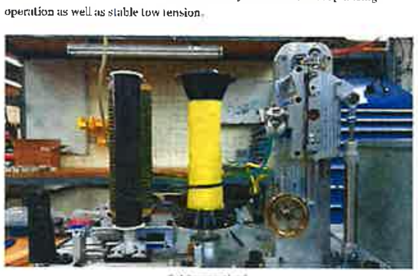
New material spindle.

The new design allows the material spindle to directly mount to the HPG-20 gear box, thereby reducing wobble from imbalance.

Furthermore, the previous bearing assembly has been eliminated along withe the plastic hose.

Tool changer integrated test bench.

In order to have a more realistic test, the test bench has a tool changer adapter on the bottom side allowing for it to be mounted to a robot. Payout tests will be conducted on a flat tool first to ensure stability of the control loop during operation as well as stable tow tension.



Tool changer test bench

Full speed tests

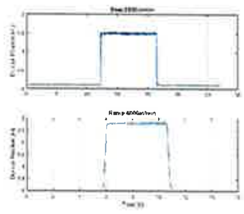
Since the system has changed slightly in terms of the spindle and dancer layouts, the same tests will be conducted. A main worry is that the larger gearbox may adversely affect the dynamics of the system or tuning.

An unforeseen issue was that since the dancer layout was designed to be close to the business end, during parts of the payout the tow would form a large angle with the redirect. This would cause slipping, which changed the dynamics of the system. This was fixed by mounting the dancer further away from the redirect.

However, preliminary tests show that the system performs as expected after the dancer position was changed and business end was operated in extend.

Although the control was fixed to perform as expected, the sounds caused by tow slipping on the dancer can be easily heard during the 2000in/min payout test video below. Notice that when the angle is less extreme, the operation is significantly quieter.

Although the slipping effects on dancer position were not tested deliberately, the 2000in/min test was conducted with tow angles that caused more slipping. The corresponding data shown below shows that the variance in dancer position was larger for the 2000in/min test than the 4000in/min test. Longer tests will be conducted in order to test the stability further.



PLC Profibus configuration

Troubleshooting

Profibus connection

During the initial phases the Profibus cable was only loosely connected to the terminal blocks, not allowing the signal to be transferred. Motor configuration and PLC configuration was relatively straight forward after the cable issue was fixed.

Initial setup of S7

After archiving the code, Chris P. guided me through the process of setting up S7. Initially, the IP address must be added to the computer chosen to be 196.168.51.219. Then the PG/PC interface was set. Loading the code, connecting via "Access Address" command allows communication via Profibus to the to motor via setting register values.

Commands

A wide array of SmartMotor commands can be called directly from Siemens PLC via setting command action bits combined with command data.

A 3 word input is sent to the Animatics motor via the registers for communication. **The primary command of interest is the "GOSUB" command which allows the PLC to interrupt code execution and run a subroutine.** The exact details of priority must be studied before implementation on the machine.

Below is the example code run on the Animatics motor, looping infinitely with a subroutine dubbed "C20" that can be executed when the PLC runs a specific command. The subroutine simply runs the motor in one direction at 1500RPM for 1 second then in the other direction at 1500RPM for another second before stopping.

```
EIGN(2)
EIGN(3)

a = 1500
ZS

ADT = 1000
MV

'GOSUB20

WHILE 1

LOOP

END

C20

' Move at 1500
VT = ((a*RES)/(60.0*SAMP))*65536
G


WAIT = 1000
' Move a -1500
VT = -((a*RES)/(60.0*SAMP))*65536
G

WAIT = 1000
S

RETURN
```

The PLC must request the command by inputting the following 3 words shown below:

0x0500 0x000 0x0014

The meaning of this string is to call GOSUB (0x0500) to C20 which in HEX is 0x0014. Thus, the command is in the first two digits of the leading word with **14** in this case being the data.

Subroutine call from Siemens PLC using S7 Scratchpad

This test although simple shows the feasibility of a main mode of operation existing in a while loop using subroutines to change state variables to different modes. An example architecture would be branches that exist within a main infinite loop shown below.

```
WHILE 1

IF STATE == 1
' Mode 1
ELSEIF STATE == 2
' Mode 2
ELSE
' Mode 3
END

LOOP

C10
      STATE = 1
RETURN

C20
      STATE = 2
RETURN

C30
      STATE = 0
RETURN
```

The strength of this implementation is that during the main loop execution states can be changed without switching modes prematurely before all data and variables are completely updated. That is, there is no possibility that some temporary variable "a" during Mode 1 will have bad values used in Mode 2 causing malfunctions.

Pneumatics

Scott D. help debug the valve block from the old two tow head. Pilot air in port "X" should also be connected to pressure. At this point once shop air (150psi) is connected to port "P" in the current set up, cut, clamp and feed modules can all be actuated. The manual pressure adjustment is only to provide adjustable force to the extend cylinder. It should not affect any of the modules.

Tool changer setup with pneumatics

Currently, A side is retract and B side is extend for all modules. The clamp module has no B side and is normally extended. It only retracts when actuated to its A side. This is a suggestion from Scott D. since we want the tow to be clamped even without an applied voltage or manual button presses.

Feed motor control

Previously, the Parker Drive (AR-08CE) had been driven via a laptop through Ethernet. In order to create a realistic test, a program was written to take 4 digital inputs from the Siemens PLC in order to a select a speed. Although it is possible to communicate with the AR-08CE via Ethernet, it was advised against by Parker Motion Technical support as connection is flaky.

Code was written in AcroBasic, to create 16 discrete speeds from 0-2000in/min. The main loop which polls the inputs and selects a speed runs on boot up. If the drive has an error, it can therefore be power cycled until the main status light turns green.

Signal	Pin
Input 0+	1
Input 0–	14
Input 1+	2
Input 1–	15
Input 2+	3
Input 2–	16
High-Speed Input 4+	4
High-Speed Input 4–	17
High-Speed Input 5+ (or Auxiliary Encoder A+) *	5
High-Speed Input 5– (or Auxiliary Encoder A-) *	18
High-Speed Input 6+ (or Auxiliary Encoder B+) *	6
High-Speed Input 6– (or Auxiliary Encoder B-) *	19
Input 3+	7
Input 3–	20

Digital inputs wired to PLC (Input 1-4)

Drive I/O Connector

The 25-pin Drive I/O connector has seven inputs and four outputs, which are described below. All drive input and output signals are optically isolated.

- Four general purpose inputs with both Anodes (+) and Cathodes (–) available
- Three high-speed inputs with both Anodes (+) and Cathodes (–) available
- Four General Purpose outputs

Figure 13 Drive I/O Connector

Manual feed tests

After making modifications to old head code, the Siemens S7-300 PLC could send commands to the feed motor and feed extend piston after receiving inputs from the push button panel.

The performance emulates what was seen on the test bench. However, it is important to note that a very slight modification to the code was necessary. **The gain had to be reduced from a factor of 1.2 to 1.0.** This allowed the system to maintain projected linearity since over-current limits were being hit previously.

However, the exact cause of the over current to occur on RCADE versus the test bench is unknown. Increasing the gain has the advantage of requiring a shorter stroke while maintaining a first order response to step outputs at the business end. Thus, it is important to understand the reason why the gain must be reduced and what can be done to increase it to its safe limit.

Below an example of the overshoot occurring when the gain was scaled by a factor of 1.2. Although the overshoot deceptively appears to be a normal second order response, this is very different than what was seen on the test bench. **Furthermore, calculations had been done to build a controller that would create a first order response to payout, which is why such results were suspect initially.**

Development: The gain factor was set too high and had to be reduced in order for first order performance.

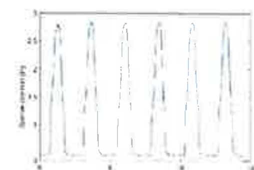
Tow payout

In order to test the performance of the 1 tow head, the business end will lay carbon the flat tool. Since there is no heater, the carbon cannot stick to the tool without adhesive, so double sided tape is placed where the course begins.

The first successful payout onto the tool is shown below done at a very slow speed of 120in/min.

The fastest test done was at 4000in/min with 2000in/min adds. This is currently faster than the 3600in/min limit we see on 777X Spars. However, the speed was only sustained for a short period of time since the tool was short. The system performed as expected and there were no dancer bottom out issues. The data is shown in a plot below, the last bit of the test shows a bottom out however, this was due to a splice break.

4000in/min peak speed payout test



Reliability

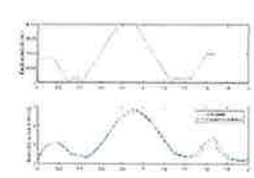
Although we attempted to test reliability, the business end would always run into jamming issues. Out of all tests done so far (total around 600 tows) there have been no observed failures caused by the servo creel. However, proper gain calculation is necessary for better response times and shorter dancer travel.

The worst performance observed due to testing a very large gain that would cause current/torque saturation. This causes non-linearity and subsequent instability, which is likely the most dangerous failure mode of the servo creel. However, this was induced in a experimental setting only.

Spar Simulation Test

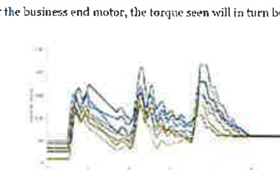
Using the test bench to simulate a payout similar to the profiles on Spars was used to test the performance and consistency of system.

Tension was maintained for speeds test (up to 4000in/min) with accelerations of 0.5G and step velocities up to 1600in/min.



In comparison typical dancer position profiles on the current machines are much more difficult to control and settle (dancer settling in roughly 2s).

Comparatively the new system can bring the dancer into equilibrium in roughly 0.25s. At the business end motor, the torque seen will in turn be consistent.



Typical performance taken from Spars machine