Design and Development of a Torsion Testing Machine to BS EN ISO16964

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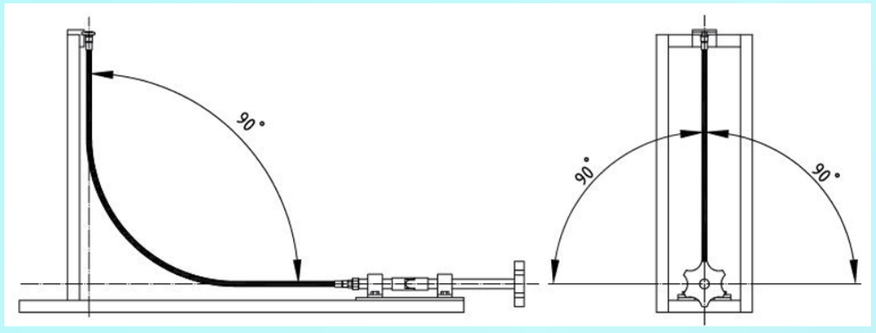
High pressure gas hoses are used in industry for many applications including cylinder filling, aerospace and fuelling. It is important that hose assemblies are tested to ensure safety. The aim of this project was the design and development of a machine capable of performing torsion testing to BS EN ISO16964.

Requirements

The Standard

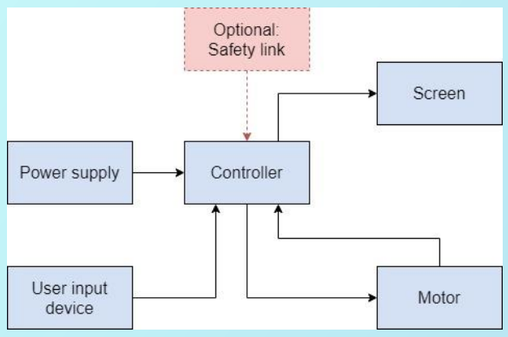
BS EN ISO requires a torsion test which consists of 30,000 cycles which turn from vertical, 90° to the left, 180° to the right then back to vertical. The cycles must be performed at a rate of 30 cycles ±2 per minute.



(BSI BS EN ISO16964)

Electronics

The electronic elements required were a screen, user input device, power supply, motor and controller. Additional safety features could be added, but were not required in the standard.



Specification

A full specification was written to provide further requirements for the machine.

Specimens

Maximum specimen length: 2m

Minimum specimen length: 300mm

Maximum specimen fitting diameter / hex: 32mm

Minimum specimen fitting diameter / hex: 15mm

Attachments: Ability to attach all types of hose end fittings, whilst preventing damage to the assembly.

Cost

Component budget: £500

Wage budget: £7500

Consumables budget: £50

Total budget: £8050

Drive

Rotational speed: 180° per sec

Angular resolution: >90°

Absolute positioning repeat accuracy: +2°, -0°

Torque: High levels of torque required, unable to test

Power

Type: Mains operated – Standard UK power socket

Supply voltage: 240V

Power consumption: Not applicable / no limit

Phase: Single phase

Frequency: 50Hz to 60 Hz

Operating Conditions

Operating environment: Indoors, temperate climate

Operating temperature range: +5°C to +40°C

Relative humidity (non-condensing): 20% to 90%

Maximum noise level: 70dB

Design

Element Selection

A weighted scoring system was used to determine the most suitable elements for the system. The scoring system is shown on the right. This determined that an inbuilt user interface, stepper motor and micro-controller were to be used for the electronics and the frame should be made from steel.

Score		
	1	Poor
	3	Medium
	5	Excellent
Weighting	0.1	Unimportant
	0.5	Medium importance
	1	Essential

User interface	Weighting	Connect to PC	Weighted connect to PC	Purely mechanical	Weighted mechanical	Pneumatic	Weighted pneumatic	Hydraulic	Weighted hydraulic	Inbuilt screen	Weighted inbuit screen
Ease of programming	0.8	3	**2.4**	1	**0.8**	1	**0.8**	1	**0.8**	4	**3.2**
Ease of design	0.7	4	**2.8**	1	**0.7**	2	**1.4**	2	**1.4**	4	**2.8**
Physical requirements	0.5	3	**1.5**	2	**1**	1	**0.5**	1	**0.5**	4	**2**
Training requirements	0.3	3	**0.9**	2	**0.6**	2	**0.6**	1	**0.3**	4	**1.2**
Safety	0.6	4	**2.4**	2	**1.2**	2	**1.2**	1	**0.6**	4	**2.4**
Cost	0.4	3	**1.2**	2	**0.8**	2	**0.8**	2	**0.8**	4	**1.6**
Total		20	**11**	10	**5.1**	10	**5.3**	8	**4.4**	24	**13**

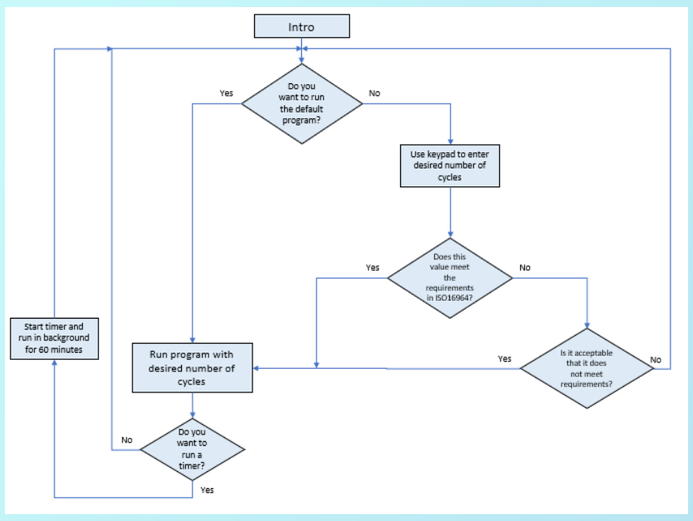
Movement	Weighting	DC motor	Weighted DC motor	Servo motor	Weighted servo motor	Stepper motor	Weighted stepper motor	Electric actuator	Weighted electric actuator	Pneumatic actuator	Weighted pneumatic actuator	Hydraulic actuator	Weighted hydraulic actuator
Ease of programming	0.6	5	**3**	4	**2.4**	3	**1.8**	2	**1.2**	1	**0.6**	1	**0.6**
Accuracy	0.8	2	**1.6**	3	**2.4**	5	**4**	2	**1.6**	2	**1.6**	2	**1.6**
Other system requirements	0.2	5	**1**	4	**0.8**	4	**0.8**	3	**0.6**	2	**0.4**	1	**0.2**
Cost	0.3	5	**1.5**	4	**1.2**	3	**0.9**	2	**0.6**	2	**0.6**	1	**0.3**
Power requirements	0.3	4	**1.2**	4	**1.2**	4	**1.2**	3	**0.9**	2	**0.6**	1	**0.3**
Safety	0.6	4	**2.4**	4	**2.4**	4	**2.4**	3	**1.8**	2	**1.2**	1	**0.6**
Torque	0.5	2	**1**	3	**1.5**	3	**1.5**	3	**1.5**	3	**1.5**	4	**2**
Total		27	**11.7**	26	**11.9**	26	**12.6**	18	**8.2**	14	**6.5**	11	**5.6**

Controller	Weighting	FPGA	Weighted FPGA	Micro-processor	Weighted micro-processor	Micro-controller	Weighted micro-controller	PLC	Weighted PLC	ASIC	Weighted ASIC	SOC	Weighted SOC
Ease of programming	0.8	2	**1.6**	4	**3.2**	4	**3.2**	4	**3.2**	1	**0.8**	1	**0.8**
Ease of updates	0.4	3	**1.2**	4	**1.6**	3	**1.2**	3	**1.2**	1	**0.4**	1	**0.4**
Cost	0.5	3	**1.5**	2	**1**	4	**2**	2	**1**	1	**0.5**	1	**0.5**
Computing capability	0.4	3	**1.2**	4	**1.6**	2	**0.8**	3	**1.2**	5	**2**	5	**2**
Security	0.3	3	**0.9**	2	**0.6**	2	**0.6**	3	**0.9**	5	**1.5**	5	**1.5**
Other requirements	0.3	2	**0.6**	3	**0.9**	4	**1.2**	3	**0.9**	1	**0.3**	1	**0.3**
Total		16	**7.0**	19	**8.9**	19	**9.0**	18	**8.4**	14	**5.5**	14	**5.5**

Frame material	Weighting	Plastic	Weighted plastic	Steel	Weighted steel	Stainless steel	Weighted stainless steel	Aluminium	Weighted aluminium	Brass	Weighted brass	Wood	Weighted wood
Ease of machining	0.6	2	**1.2**	4	**2.4**	4	**2.4**	4	**2.4**	5	**3**	2	**1.2**
Ease of joining	0.6	3	**1.8**	4	**2.4**	3	**1.8**	3	**1.8**	3	**1.8**	3	**1.8**
Strength	0.8	1	**0.8**	5	**4**	5	**4**	4	**3.2**	4	**3.2**	1	**0.8**
Corrosion resistance	0.6	5	**3**	3	**1.8**	4	**2.4**	3	**1.8**	2	**1.2**	1	**0.6**
Weight	0.5	5	**2.5**	1	**0.5**	1	**0.5**	4	**2**	3	**1.5**	5	**2.5**
Cost	0.4	4	**1.6**	3	**1.2**	1	**0.4**	2	**0.8**	2	**0.8**	5	**2**
Conductivity	0.2	5	**1**	2	**0.4**	2	**0.4**	2	**0.4**	1	**0.2**	5	**1**
Total		25	**11.9**	22	**12.7**	20	**11.9**	22	**12.4**	20	**11.7**	22	**9.9**

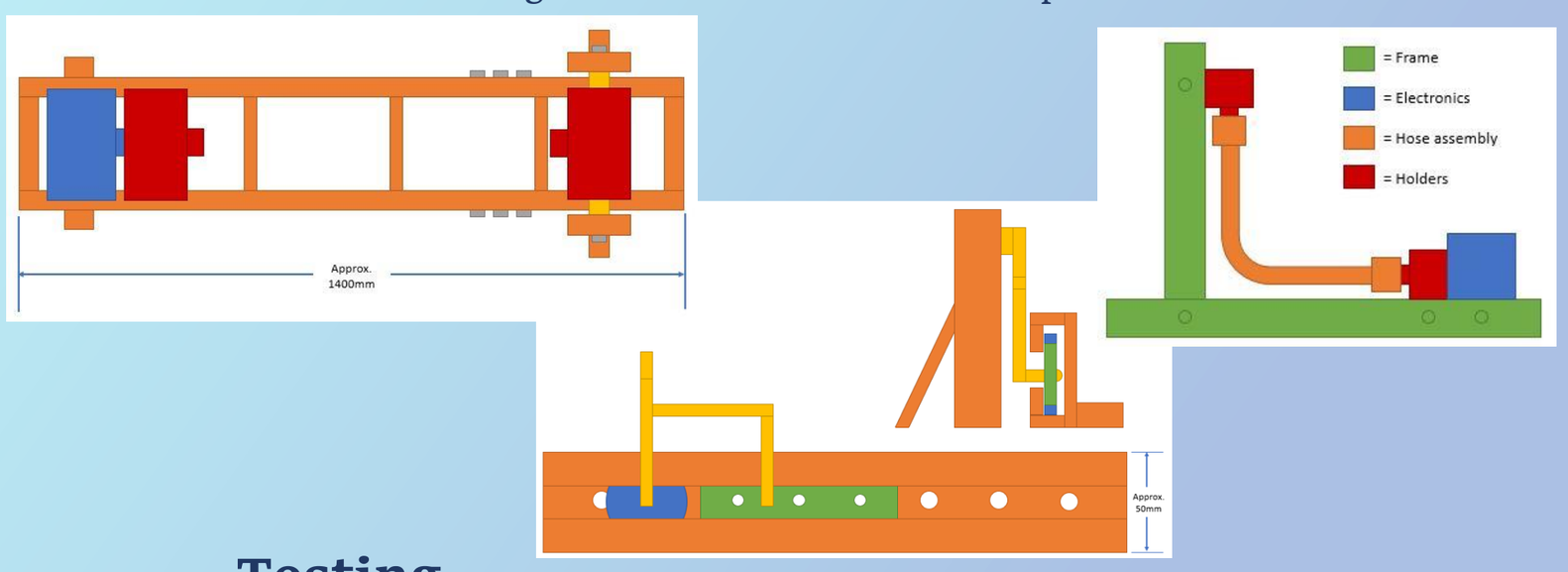
Code

The code was required to follow the process flow below.



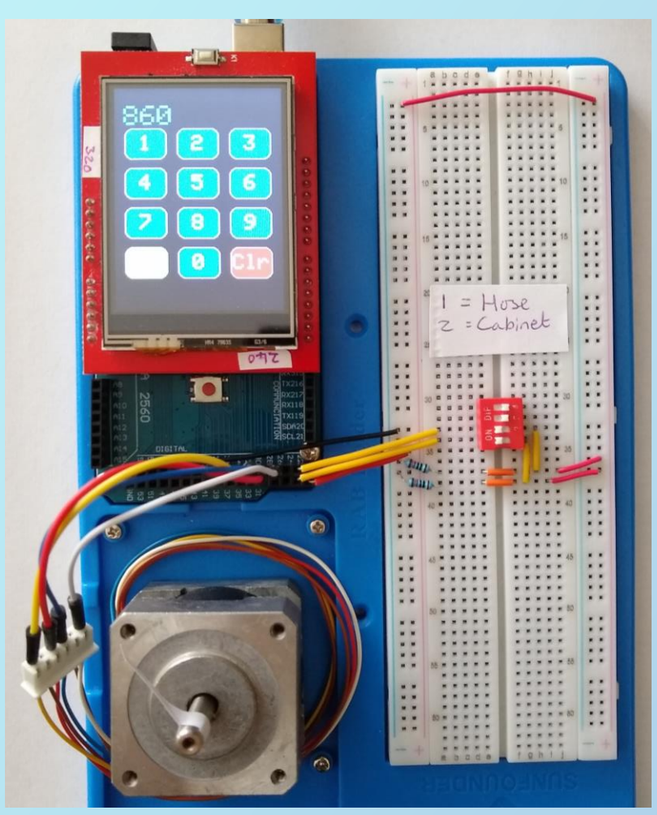
Frame Design

Sketches of the frame design and overall machine were produced.



Build

The code was written and the prototype machine was constructed on a breadboard.



Testing

Testing was performed on the prototype machine to determine whether it met the specification. Several tests were successfully performed and where tests referred to the production version of the machine these will not be able to be performed until it has been implemented.

Quality to test	Test	Expected outcome	Tools required
Voltage	Voltage at power supply and key points within the circuit. Voltage at components compared to their tolerances.	Voltage is at specified levels at key points within circuit. Voltage does not exceed limits specified in component data sheets.	Voltmeter. Component data sheets.
Current	Current at power supply and key points within the circuit. Current at components compared to their tolerances.	Current is at specified levels at key points within circuit. Current does not exceed limits specified in component data sheets.	Ammeter. Component data sheets.
Conductivity	Conductivity of material used to manufacture frame. Current and voltage present in the frame.	Conductivity of frame of machine does not reach dangerous levels whilst machine is connected to power supply.	Surface resistivity meter. Voltmeter. Ammeter.
Speed	Does machine complete 30 cycles per minute.	Machine completes 30 full cycles in one minute.	Stopwatch.
Angle	Does machine achieve 90° rotation.	Machine achieves 90° rotation from vertical in both directions.	Angle measurer. Protractor.
Accuracy	Rotation compared to required tolerance.	Rotation is mahine is within +2°, -0° accuracy.	Angle measurer. Protractor.
Force	Torsional force output.	Machine achieves torque level required to rotate hose assemblies of specified dimensions.	Torque wrench.
Noise	Noise level generated whilst machine is operating.	Noise level of machine does not exceed 70dB whilst operating.	Sound level meter.
Weight	Total weight of machine.	Machine does not exceed 35kg.	Scales.
Dimensions	Dimensions of machine.	Machine does not exceed 1800 x 1800 x 600mm.	Rule. Vernier callipers. Tape measure.
Maximum specimen length	Maximum specimen length that can be held by the machine.	Machine can hold specimens up to 2m in length.	Rule. Tape measure.
Minimum specimen length	Minimum specimen length that can be held by the machine.	Machine can hold specimens above 300mm in length.	Rule. Tape measure.
Maximum fitting diameter	Maximum specimen fitting diameter that can be held by the machine.	Machine can hold fittings up to 32mm across flats and diameter.	Vernier callipers.
Minimum fitting diameter	Minimum specimen fitting diameter that can be held by the machine.	Machine can hold fittings above 15mm across flats and diameter.	Vernier callipers.
Functionality of safety link	Does machine operate without a closed safety link.	The machine does not operate with an open link.	Visual - no tools required.
Temperature	Temperatures machine operates at.	Machine operates between +5°C and +40°C.	Thermometer. Temperature sensor.
Humidity	Relative humidity levels machine operates at.	Machine operates between 20% and 90% relative humidity.	Humidity sensor.

Conclusion

The constructed prototype consists of a full implementation of the process flow and was implemented using an Arduino micro-controller with a touch screen user interface.

Further Work

Further work will be to construct and test a production version of the machine. This will require alternate and additional components such as a more powerful motor and gearbox. The frame will then be designed and manufactured based on the dimensions of the components. Full testing will be performed on the production version and some design elements may have to be adapted to ensure compliance with the specification before it is deployed in an industrial environment.