BellSim Features and Specification

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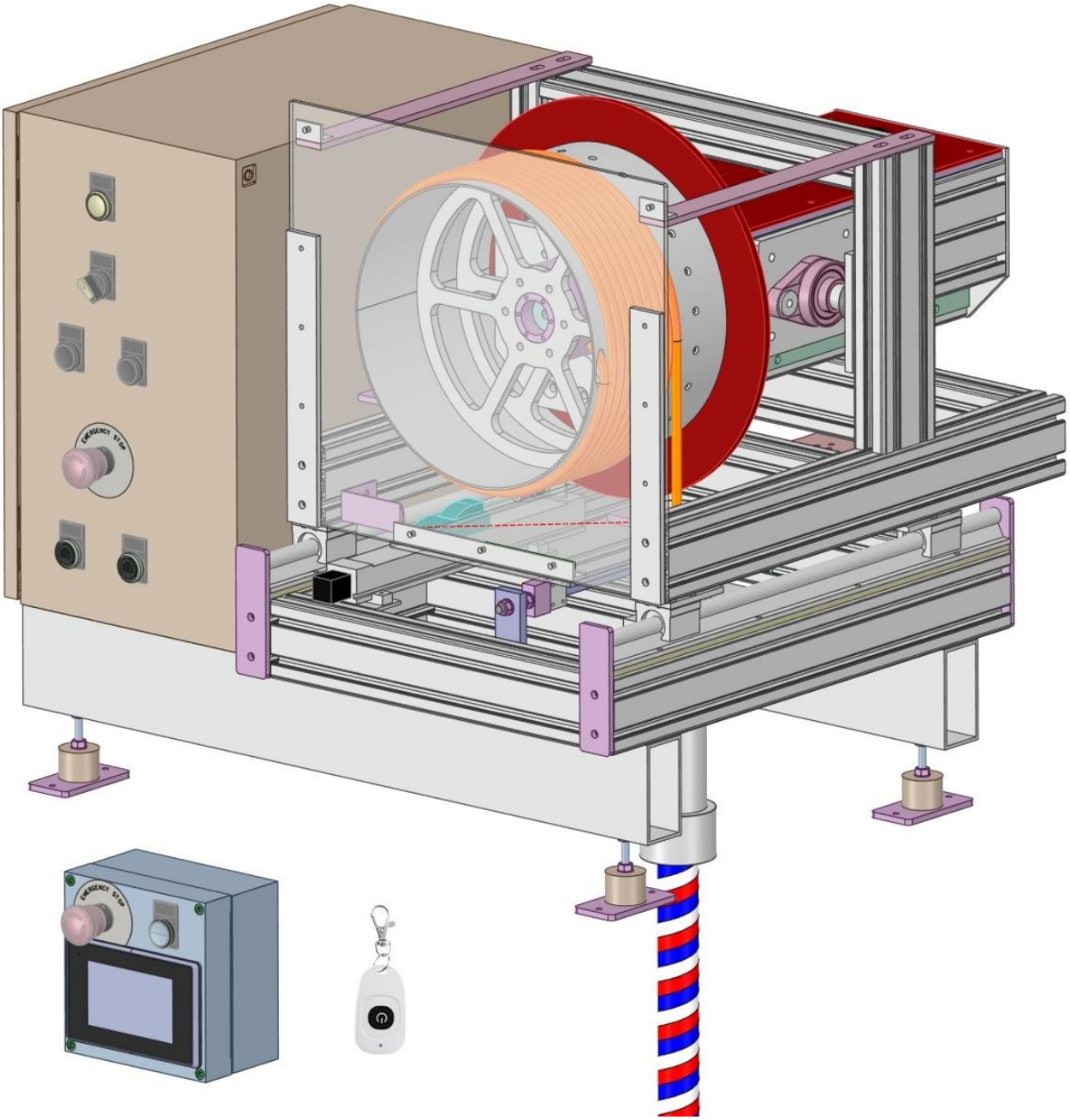
Overview

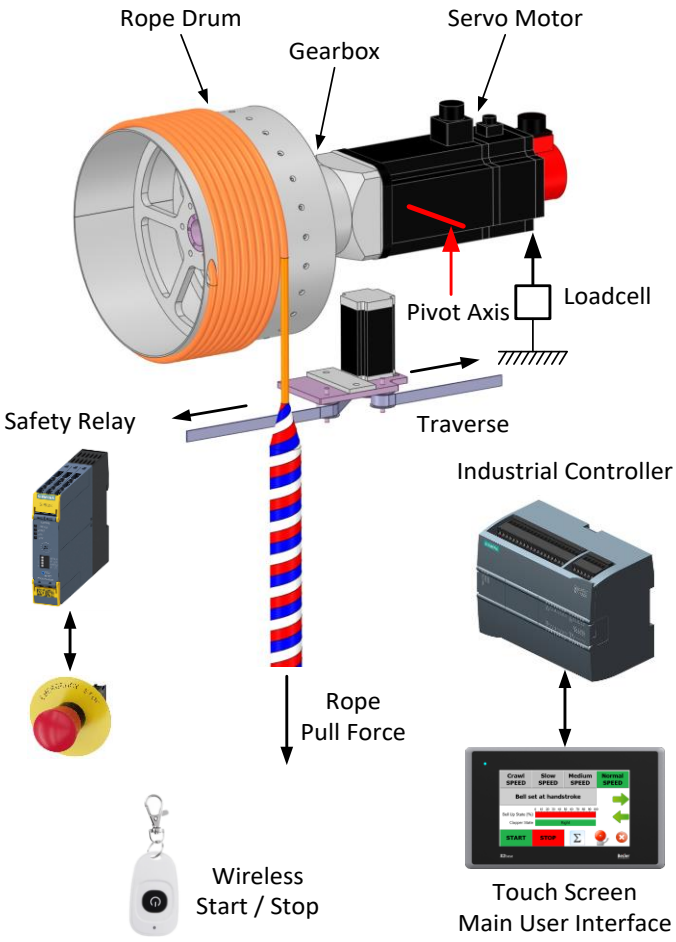
BellSim is an advanced electrically driven true simulator for demonstrating and teaching the art of English Church Bellringing in a safe and controlled environment. An actual bell rope is used while BellSim provides realistic rope motion and forces associated with the weight and characteristics of real church bells rung using the full circle English style.

This document provides basic information and specification of the BellSim device.



Description

The actual church bell with the associated rope wheel is replaced with a small drum upon which the bell rope is wound and this in turn is driven by a high performance servo motor and in-line gearbox.



Bell motion is modelled in software by solving the equations of motion of both bell and striking clapper within a small industrial controller to provide an instantaneous angular position in real time.

Further transposition functions convert the angular position of the bell into the actual position of the rope which is then used to control the servo motor.

The rope force is measured using a strain gauge load cell with the force signal fed back into the bell equations of motion such that the bell speed and position are modified in a similar way to an actual church bell.

The drum and motor assembly are mounted on a sliding traverse carriage, position controlled by a small motor to ensure correct helical winding of the rope around the drum.

An integrated mechanical brake is used to prevent the rope from unwinding due to the rope weight when the system is not powered. The brake is released when the servo motor is active and controlling the rope motion. When the system is stopped and the brake active, pulling on the rope cannot cause rope motion.

The bell stay is modelled within the system software such that the bell can be set at the hand stroke or back stroke positions in a similar way to an actual bell. There is no risk of physical stay breakage while learning the art since the included stay break function is entirely implemented in software.

The clapper is modelled within the system software and the bell strike points provide a signal for an external sound generator.

A touch screen user interface (HMI) is used to control all functions of the simulator and an additional wireless fob allows remote start / stop for enhanced convenience while teaching the art of bell ringing.

A hard wired safety relay is included to implement a rapid stop of all rope motion on demand or in case of unexpected events during operation.

All church bell functions can be realistically replicated including steady speed ringing, change ringing, ringing the bell up, ringing the bell down and chiming in the down position.

For beginners to the art, the ability of the instructor to stop rope motion at any time promotes confidence and the lack of a physical wooden stay prevents damage to historic bell hardware due to over pulling the rope while learning.

Operational functions

The following table shows general operational functions controlled by the touch screen HMI interface or the wireless fob.

Item	Value
System start:	Three stage start using touch screen HMI or wireless fob and audible alarm. Provides protection against accidental start-up.
System stop:	Via touch screen HMI or wireless fob. Stops all rope motion within 1 second in case the rope becomes uncontrolled during the teaching process.
Auto stop:	Automatic stop if not in use after a pre-set time for enhanced safety.
Bell speed selection:	Allows operation at reduced rope speeds for teaching purposes. Four pre-settable speeds are selectable from the touch screen HMI: • Crawl: 25% of normal rope speed. • Slow: 50% of normal rope speed. • Medium: 75% of normal rope speed. • Normal: 100% Normal rope speed. The bell responds to the rope pull at all times.
Start-up bell states:	The following start-up bell states are selectable from the HMI: • Start with the bell on the stay at the hand stroke position. • Start with the bell on the stay at the back stroke position. • Start with the bell in the down position. • Move the rope to the park position, out of reach. The rope automatically moves to the correct position during the start-up dependent on bell state selection and the bell is then ready for ringing. The system automatically stops when rope parking is completed.
Rope length adjustment:	Rope jog up or jog down to set the correct rope length to suit the ringer. Stand on boxes or physically adjusting the rope tail end are not required.
Start-up clapper states:	The following start-up clapper states are selectable from the HMI: • Start with the clapper on the correct side of the bell (right). • Start with the clapper on the incorrect side of the bell (wrong).
Clapper strike test:	HMI button to test the bell sound simulator.
Bell stay disable:	Allows demonstration of ringing a bell without a stay.
Clapper state indication:	User indication of clapper right and wrong state.
Bell up state indication:	User indication of bell up state; 0% is down, 100% is fully up.
Wireless fob enable:	Use of the wireless fob for start / stop must be confirmed by the user.
Rope force indication:	Instantaneous indication of actual rope force applied by the ringer.
Bell parameters:	Common adjustments for demonstration and training purposes: • Adjustable parameter to demonstrate odd struck bells. • Friction settings to demonstrate easy and difficult ringing bells. • Bell set angle to demonstrate fine and deep set bells.
Events and alarms:	Display of event and fault trips to simplify diagnostics. Two stage reset function for the safety relay.
System settings:	Touch screen HMI variables to adjust system parameters.
Rope length force factor:	Adds constant rope force due to a pre-defined length of rope.
Rope stretch function:	Simulates ringing bells with stretchy ropes.

Safety and Convenience

The following table shows emergency stop and out of range detection systems:

Item	Value
Emergency stop:	Emergency stop via dual channel hard wired twist lock buttons and associated safety relay: • Stops all rope motion in <300mS from maximum speed. • Servo motor power converter power cut off after 500mS.
Safety relay reset:	Hard wired illuminated push button to reset the safety relay. Button is illuminated when the safety relay is reset.
Safety relay trip:	Allows the safety relay to be tripped by the control system if faults or unexpected operation detected.
Unexpected rope force (Ringing):	System emergency stop if unexpected rope forces detected while ringing such as the ringer not releasing the rope sally from the hand stroke position.
Unexpected rope force (Start-Up or Park):	System emergency stop if rope forces detected while the rope moving to position during start-up or parking.
Loose rope detection:	System emergency stop if loose rope detected on the drum. Protects against tangle ups if the ringer does not pull the rope correctly from the back stroke position.
Stay break detection:	System emergency stop if the simulated bell stay force exceeds pre-set limits. Simulates the effect of a stay break with no resultant damage.
Bell motion limit detection:	System emergency stop if the bell angular position exceeds set limits. This can occur if the stay is disabled and the rope is not controlled by the ringer.
Rogue simulation stop:	System stop if the bell parameters cannot be simulated correctly. Detects parameterisation errors within the bell recipe system.
System fault stop:	System emergency stop in case of any fault or equipment failure which would result in loss of rope control.
System stop:	The brake is applied and pulling on the rope cannot cause rope motion.
Rope overtravel limit:	System emergency stop if the rope travel exceeds limits.
Traverse overtravel limit:	System emergency stop if the rope traverse travel exceeds limits.

Recipe

Bell size and characteristic recipe selection from the touch screen HMI:

Item	Value
Bell selection:	Up to 30 different bell weights and characteristics selectable from the HMI.
Recipe name:	Custom bell names for each selectable bell from the recipe system.
Recipe save:	Save the current working parameters to the selected bell recipe entry.
Recipe load:	Load the selected bell recipe to the current working parameters.
Parameter entry:	28 Different parameters for each bell with data entry from the HMI
Typical bell parameters:	Includes bell / clapper mass, centre of mass, inertia, clapper pivot offset, set angle, friction, stay stiffness, rope wheel radius, rope pulley radius etc.

Ringer performance

Bell ringing performance can be measured to improve rope handling technique and reduce energy requirements from the bell ringer. HMI gauges of rope power and efficiency allow the effect of differing rope handling techniques to be immediately evaluated by the bell ringer while ringing takes place. The following table shows aggregate statistics provided to measure ringing performance.

Item	Value
Measurement modes:	Four different measurement modes selectable from the HMI: • Continuous overall average. • Continuous per rope pull • Fixed bell cycle average • Fixed bell cycle per rope pull HMI entry of the number of bell cycles to measure using Fixed modes.
Statistics reset:	On demand using a HMI button or auto reset on start-up.
Stay contact displays:	Number of stay contacts at handstroke and backstroke while ringing.
Peak rope force displays:	Peak forces for rope motion while arresting and driving for both handstroke and backstroke positions.
Ringing power displays:	Net power into the bell and total power from the ringer for both handstroke and backstroke. Overall net and total power.
Ringing efficiency displays:	Handstroke, backstroke and overall ringing efficiency.
Ringing efficiency gauges:	Net, total power and overall efficiency gauges.

Calibration and Reference

The following table shows system calibration and referencing setup functions used during BellSim commissioning and maintenance.

Item	Value
System referencing:	Set-up of the rope and traverse carriage to the reference positions. Single button referencing when rope and traverse at the reference positions.
Load cell calibration:	Tare and range of the rope loadcell based on known rope loading.
Rope position limits:	Setup of the rope position extreme limits which activate emergency stop
Traverse position limits:	Setup of the rope traverse absolute limits which activate emergency stop.
Traverse reverse:	Set-up of the traverse reverse function to handle long parking distances.

Windows App

A Windows based computer application is designed to enhance the basic touch screen HMI. The app will run on the same computer used to operate AbelSim and when dual monitor screens are available, both applications can be viewed simultaneously. The windows app uses a high speed data link directly with the BellSim controller so that all displays operate at high speed. The following features are offered but more will follow according to future development activities:

Item	Value
Trends and charts:	Trend plots of useful variables such as rope force, rope position, bell angle, ringing efficiency etc. Trends can be configured to start and stop with operation of BellSim.
Rope force gauge:	Large bar style gauge indicating the current rope force.
Efficiency gauges:	Large gauges indicating ringing power and efficiency.
Settings and parameters:	Entry pages to allow device setup with associated help texts for each parameter. Also allows bell recipe parameters to be entered.

Technical

The following table shows the main BellSim technical details:

Item	Value
Maximum rope pull:	95kgf Torque limited via servo drive with overload trip.
Maximum rope speed:	6mps.
User interface:	Touch screen HMI
Bell strike signal:	Isolated +/-12V suitable for the popular AbelSim ringing simulator.
Supply type:	230VAC single phase.
Supply current rating:	13A.
Dimensions:	828W x 735H x 846D[(a)]
Approximate weight:	120kg.
Peak carriage lateral force[(b)]:	100N based on the sliding carriage weight of 55kg
Peak rope drum torque[(c)]:	<150Nm on the device frame about the drum axis at maximum rope pull
Standards and approvals:	Generally constructed using UKCA or CE certified equipment. Electrical equipment designed to BS EN60204-1

Note (a): With rope traverse sliding carriage at the fully rear position. Sliding carriage width is 485mm.
Note (b): Horizontal force on the device frame due to motion of the sliding carriage.
Note (c): Twisting force on the device frame due to the servo motor and gearbox at maximum rope pull.

Maintenance and Service

BellSim is designed and manufactured using standard off the shelf industrial automation equipment. All programmable equipment is configured using manufacturer supplied software tools or manually using the supplied equipment user interfaces.

All equipment documentation will be supplied as a package together with a comprehensive user manual.

The use of standard control equipment will allow BellSim to be serviced and maintained by any competent industrial automation engineer.

To further aid fault finding and maintenance, a remote access system is available as an option to allow control system diagnostics and small software changes over a standard internet connection which will minimise time consuming visits to site.