ELECTRICAL MOTION CONTROL RETRACTABLE ROOF

Summary

Moog was contacted by SCX Special Projects, Sheffield to help develop and install a retractable roof over the Centre Court at Wimbledon. The original concept envisaged a hydraulic solution. However, following a design review with Moog, an electric solution was subsequently developed and since 2009, has helped ensure uninterrupted play during all weather for tennis fans worldwide.

Background

Even non tennis fans will know that the image of the Wimbledon Championships can be spoiled by the realities of British weather so uninterrupted play became a big priority not just for the fans, but for the world media.

The architects wanted a roof occupying minimal space in the open position, allow maximum sunlight access to the grass and ensure the same level of ventilation was afforded to the space.

Moog engineers, in discussion with the design teams, concluded that noise, oil seepage and vibration from many hydraulic power units meant electric actuation was the answer. Moog's solution met both technical and architectural requirements.

Project Success Factors

The following criteria played an important role in the selection process for this assignment.

- Create a control architecture for the actuated elements of a moving roof on the Centre Court at Wimbledon.
- A motion control challenge working securely, quietly, speedily, safely and accurately completed by the 2009 Championships where it would be under the scrutiny of the entire world.
- Collaborate efficiently with the other contractors at design phase and onsite throughout test and implementation.
- Provide Engineering and service support for the lifetime of the roof.
- Build in technological flexibility to meet future operational requirements.

The Technological Challenge

The challenge was to provide the motion control for a retractable roof on a building dating from 1922, enabling over 1,000 tones of steel to move safely above 15,000 spectators, effectively with 'one push of the button'.

The Moog Solution

The new roof works like a folding fabric concertina – with metal ribs or "trusses" supporting a translucent industrial fabric. The trusses are supported by the end arms and set into precise motion by electric actuators, which form a structural yet moveable part of the roof. The accuracy of movement has to be virtually pin point at both ends of the trusses.

Each bay is captivated on either side by a steel truss (10 trusses in total) spanning the 77m (253ft) wide court with approximately 5,200m2 (55,972 sq ft) of fabric keeping the rain out and allowing the light in. The ends of each truss are supported by a wheeled carriage or "bogie", which moves along a track positioned on the 'fixed' roof of the Centre Court. The roof takes eight minutes to close.

Moog supplied the high-performance electric control system comprising electric actuators, servomotors, servo drives and closed-loop controllers. Additionally, Moog worked with a partner to deliver the supervisory and data acquisition (SCADA) system.

A total of 148 axes of control were supplied by Moog, as well as the 40 control cabinets mounted on the roof trusses and main control desk housed within the Centre Court control room.

Modes of Operation

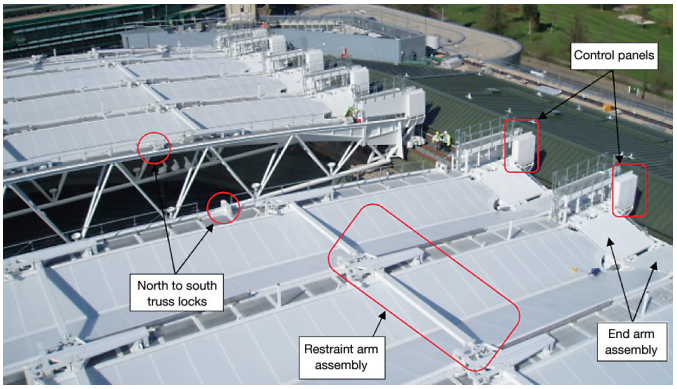
1. Move to Park Position

Both sections are stored at the North end of the Centre Court enabling maximum sunlight to reach the grass.

2. Move to Championship Mode

The south roof sections move down to the south and attaches to the fixed roof.

3. Deploy/Close the Roof



The roof deploys one truss at a time on both the north and south sections. The truss is deployed by the bogies and the end arm assemblies. The end arm assemblies look like giant inverted hinges, which open up from a very deep, narrow "V" into a wide, shallow "V".

During the movement the point of the V moves up and the ends move out, pushing the top of the deploying truss away from its neighbour. This movement is controlled using four end-arm actuators on each side. Each actuator is capable of pushing and pulling with a force equivalent to 35 tonnes (38 US tonnes) at its rod end. The actuators are connected to the end arm assembly so that there is a large mechanical advantage.

The positions of all the end arm actuators are controlled in closed-loop position control using its own in-built absolute encoder. All eight actuators are synchronised by the MSC controllers. However, as the end arm assembly deploys the mechanical advantage and lever ratio change; the MSC compensates for this change by using a look-up table to check the current actuator position against a linear deployment position. This check is important because not only does the MSC have to keep the end arm actuators synchronised, it also has to position the bogie directly below the top of the truss to keep the truss in a vertical position.

Across the centre of each roof section are four restraint-arm assemblies, each with its own actuator. These help maintain the shape of the truss across the length and help ensure that the trusses meet square when the north and south sections are fully deployed. These actuators also work through a non-linear linkage and they too have to be synchronized with the end arms and bogies.

Once a truss is deployed the restraint arms and end arms are locked and the next truss deploys. While the next truss deploys, a torque is sent to the bogie motors on the already deployed truss so that it moves in unison. In this way, when the last truss is deploying, the actuators and motors on that truss uses roughly the same forces as the first truss deploying on its own.

4. Roof Deployed

The roof retracts in a similar fashion to the deployment.

5. Sunshade Mode

Originally designed to keep off the rain, the roof has been upgraded to remove shadow lines. Since this upgrade, the roof has been used more for sun shading than to keep out the rain!

Benefits of the Moog System

The roof has been designed to work securely, quietly, speedily, safely and accurately. It demonstrates the partnership approach Moog brings to complex situations where many contractors are involved, and whilst it ensured that the finest technology was employed, the heritage of the venue was preserved. The collaboration has since been reinforced by the signing of the five-year support agreement.

Moog sends engineers to Wimbledon on a regular basis to test the roof and software, and are in attendance for the entire Wimbledon championship, having access to a full range of spares which can be called upon within two hours during a championship.

FURTHER INFORMATION

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