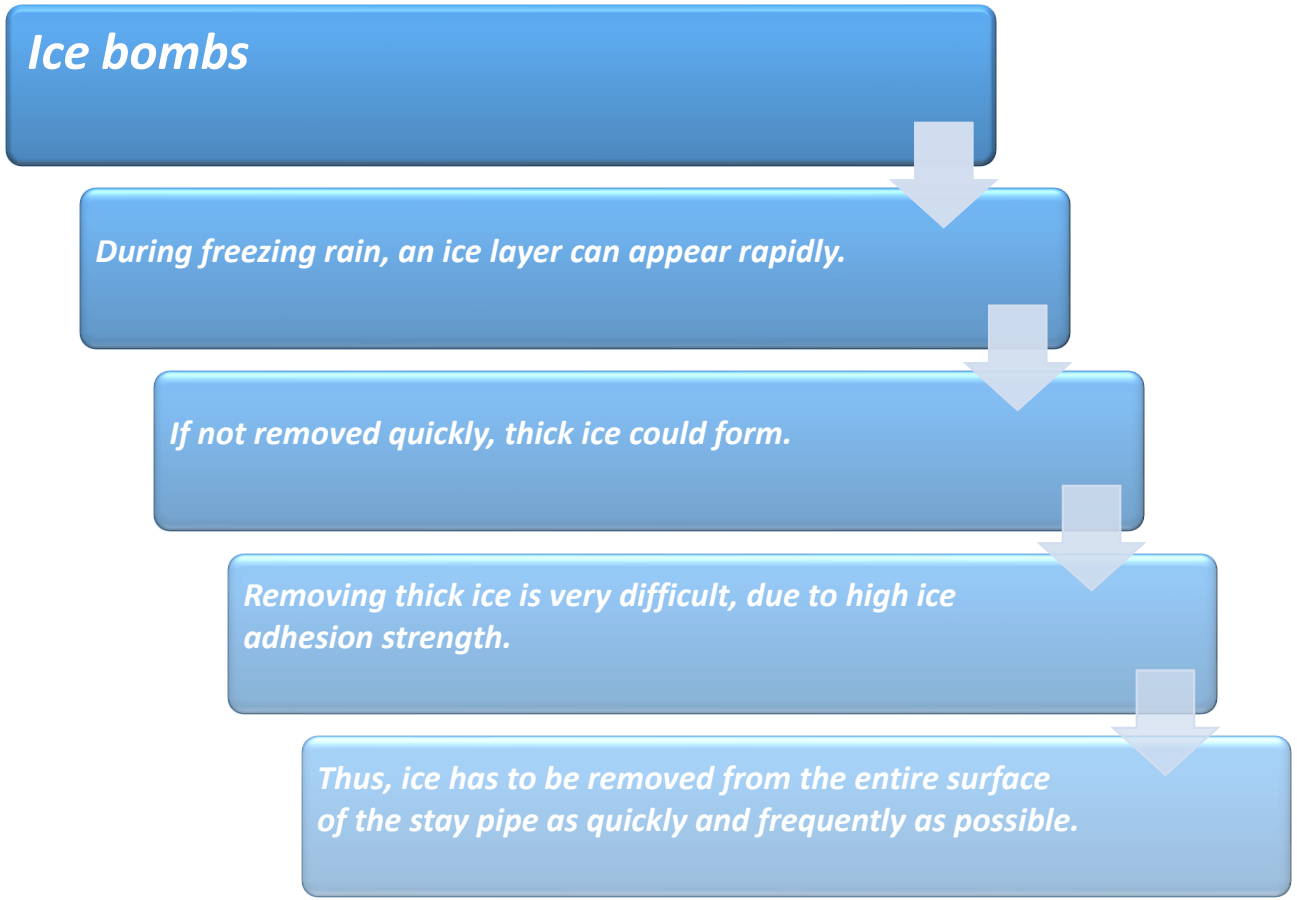
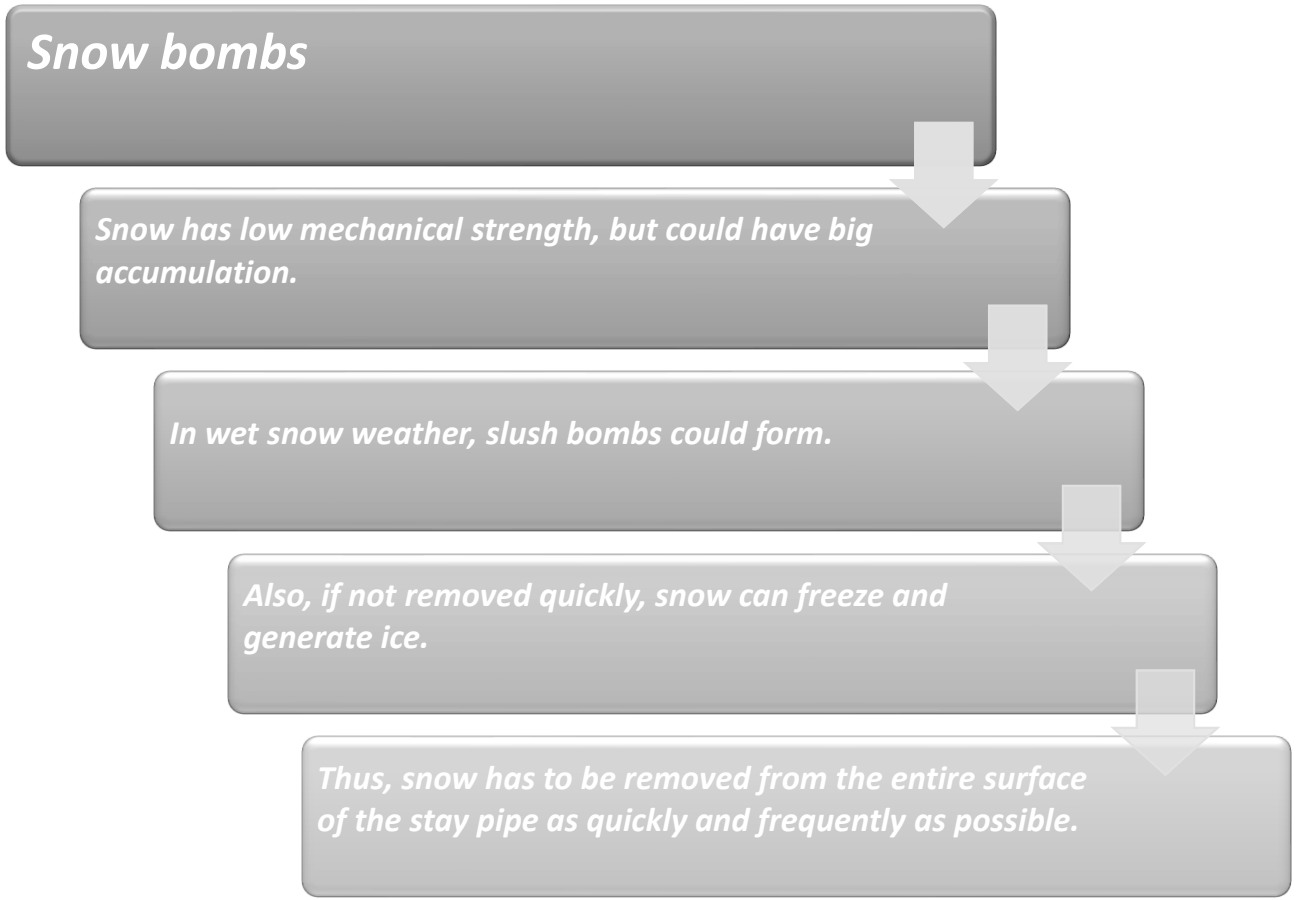
SCRAPER MESH DE-ICING SYSTEM FOR BRIDGE STAY CABLES

TOPOMACHINES

Ice bombs


Ice bombs
During freezing rain, an ice layer can appear rapidly.
If not removed quickly, thick ice could form.
Removing thick ice is very difficult, due to high ice adhesion strength.
Thus, ice has to be removed from the entire surface of the stay pipe as quickly and frequently as possible.

Snow bombs


Snow bombs
Snow has low mechanical strength, but could have big accumulation.
In wet snow weather, slush bombs could form.
Also, if not removed quickly, snow can freeze and generate ice.
Thus, snow has to be removed from the entire surface of the stay pipe as quickly and frequently as possible.

Challenges of bridge stay cable de-icing

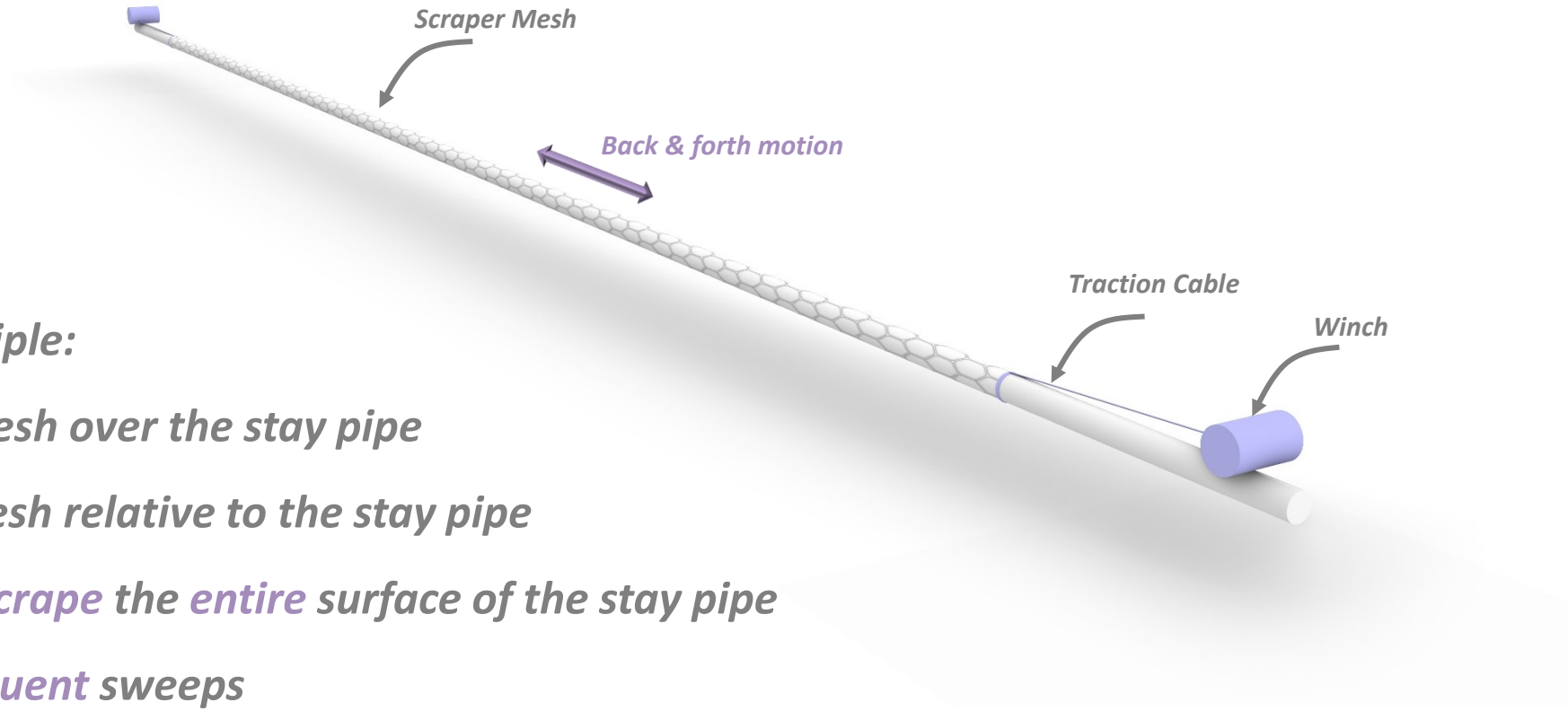
- *The surface to de-ice is huge, equivalent to several football fields;*
- *Weather conditions during de-icing could be extreme: freezing temperatures, strong winds, freezing rain, snow…;*
- *Ice needs to be prevented from accreting, or otherwise be shed very quickly;*
- *Although ice is brittle, its adhesion to the underlying surface could be very strong;*
- *The stay pipe itself is relatively fragile;*
- *Aerodynamic performance of the stay pipes/stay cables needs to be preserved;*
- *Wet snow / slush bombs need to be addressed too;*
- *The bridge shall remain open during de-icing operations.*

Proposed solutions so far

Solution	Description	Shortcomings
Cable collars	Heavy collars are launched sequentially and impact/detach ice while moving down the stay pipe	Expensive and risky manual operations / Risk of falling object / Damage induced in the stay pipe
Heating elements	Heat energy is used to melt ice interface and detach ice	Huge amount of energy needed
Ice retaining texture	Protruding ribs or strakes are used to concentrate ice accretion and control its shedding	Performance / Large pieces of ice can fall / Wind drag issue?
Electro-thermal pulse	Skin system providing heat shock at ice interface	Fragile / Sensitive to lightning
Robotic sweeper	Autonomous device moving up and down and scraping or breaking ice doing so	Reliability / Damage induced in the stay pipe / Sensitive to lightning
Vibrating elements	Fix or moving vibrating elements	Reliability / Maintainability / Damage induced in the stay pipe / Performance with thin ice
Ultrasonic system	Ultrasonic vibration device	Performance / Sensitive to lightning
De-icing fluid	Liquid deicers sprayed over the ice	Difficulty to spray the entire stay pipe surface / Amount of de-icing fluids / Environmental concern
Icephobic coating	Icephobic or hydrophobic coating is used to prevent ice adhesion	Overall performance / Performance over time / Durability
Mechanical scraping	Moving elements scrape the ice from the surface	Ice adhesion needs to be overcome

Our innovation: Scraper Mesh System

Patented (Europe + China)



Working principle:

- *Position a mesh over the stay pipe*
- *Move the mesh relative to the stay pipe*
- *Sweep and scrape the entire surface of the stay pipe*
- *Perform frequent sweeps*

Scraper Mesh System main features

- *Tensile system: very effective for force transmission all along the stay pipe.*
- *Distributed system: covers the entire stay pipe surface.*
- *Interface system: ideally positioned at ice/snow interface with the stay pipe.*
- *Active system: moves relative to the stay pipe surface.*
- *Controllable system: speed, force and frequency of motion are adjustable according to snow and icing conditions.*
- *Complementary functions: additional functions could be built-in (please see further below).*

Scraper Mesh System action

The Scraper Mesh System:

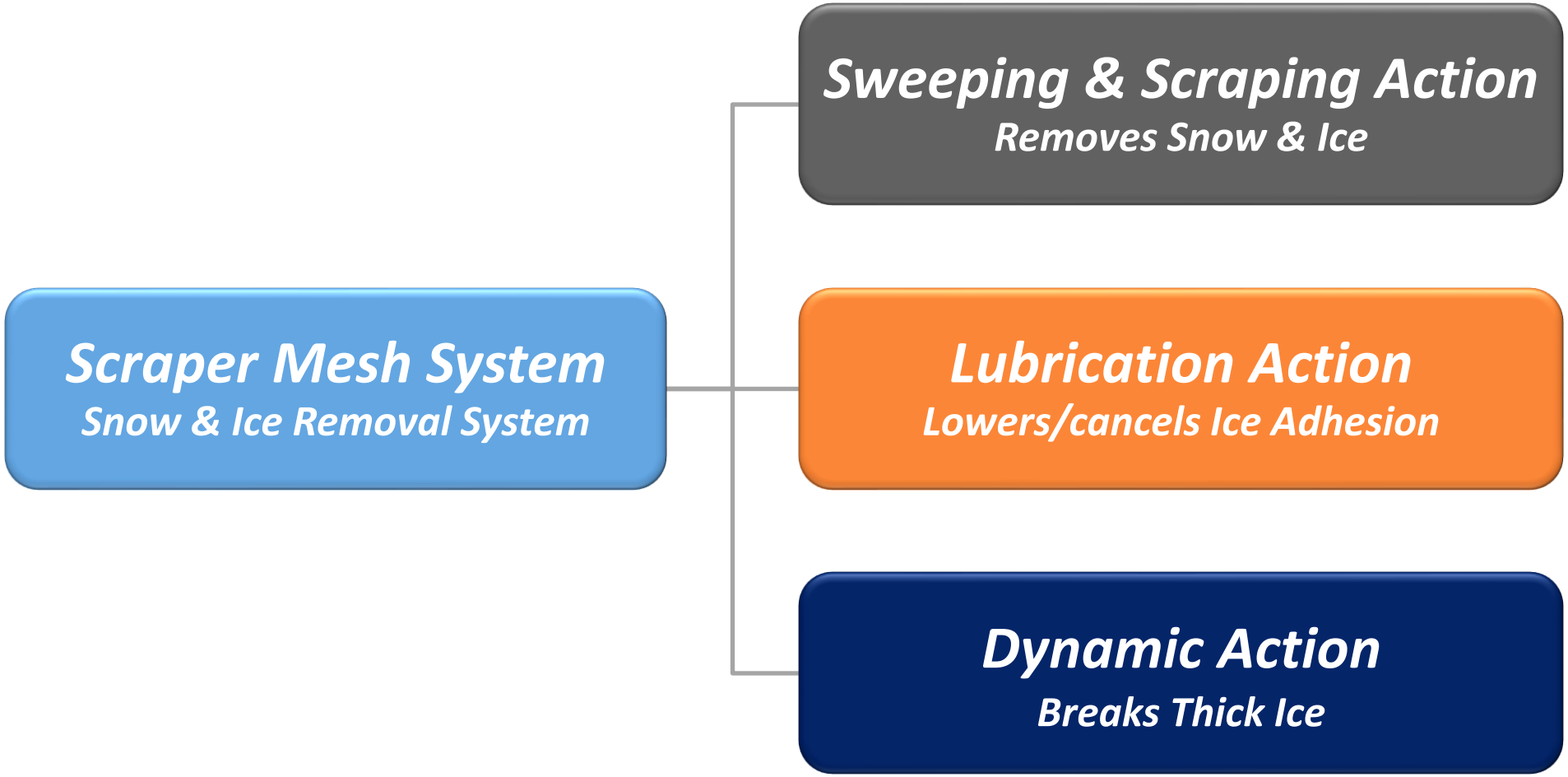
- ***Makes it possible to treat the entire stay pipe surface instantly;***
- ***Immediate action, as it is already positioned over the stay pipe surface;***
- ***Ideally positioned at ice/snow interface with the stay pipe;***
- ***Removes snow by mechanical sweeping action;***
- ***Removes ice with repetitive scraping action;***
- ***Breaks and removes thick ice using dynamic impulse forces.***

Problem of ice adhesion

- *For a stay pipe made of HDPE, the breaking shear stress of ice could exceed 1 MPa.*
- *Any mechanical action to detach ice at freezing temperature can damage the stay pipe:*
  - *Large forces would be exerted onto the stay pipe*
  - *Progressive deterioration of the stay pipe surface occurs when ice detaches*
  - *Mechanical damage → Generation of through-thickness micro- or macro-cracks*

Any damage induced in the stay pipe can affect the integrity of the stay cable in the long term.

Scraper Mesh System complementary functions



Lubrication action

Lowers/cancels ice adhesion at ice/stay pipe interface, by supplying lubricant material all over the stay pipe surface:

- ***A flexible pipe circuit of low diameter is integrated into the Scraper Mesh, conveying lubricant fluid all over the Scraper Mesh extent;***
- ***Scraper Mesh rings are used as lubricant reservoir and also as lubricant paintbrush;***
- ***Lubricant is injected into the flexible pipe and stores inside the rings;***
- ***Due to the pressure exerted in the lubricant, valves open and lubricant is poured onto the stay pipe surface;***
- ***Scraper Mesh back and forth motion spreads the lubricant uniformly over the stay pipe surface, creating a lubricant film.***

Complementary Lubrication System

- *The Scraper Mesh includes a fluid circuit to convey lubricant material;*
- *Small diameter flexible pipes are used;*
- *Small lubricant tanks need to be installed, preferably at the top end of the stay cable;*
- *Heating of the lubricant might be necessary;*
- *Pumps are used to inject the lubricant into the Scraper Mesh fluid circuit.*

Some typical figures for a 500 m long, ∅250 mm stay pipe :

- *The surface to de-ice would be of the order of 400 m²;*
- *The amount of lubricant which is required for each de-icing cycle would be around 4 liters (0.01 mm thick lubricant film);*
- *The lubricant could be plant oil or natural material such as clay or graphite;*
- *Lubricant consumption will be very low.*

Scraper Mesh System: Typical specifications

- *Scraper Mesh System*
  - *Mesh cell length = 15D to 25D (D is stay pipe diameter)*
  - *Traction ropes = ∅2 mm steel wire rope, with plastic coating*
  - *Scraper rings = Steel, mass 1kg, includes mechanical and flexible pipe connectors*
  - *Scraper mesh mass (est. for ∅250 stay pipe) = 50 kg per 100 m stay pipe*
  - *Electrical winch (actuator) = 1 metric Ton load capacity, mass 20kg*
  - *Dynamic impact system = located at both ends of the stay pipe, mass 10 kg.*
- *Lubrication System*
  - *Armored flexible pipe integrated into the Scraper Mesh*
  - *Lubricant tank = 10 liters.*

Scraper Mesh System: Normal Operation Mode

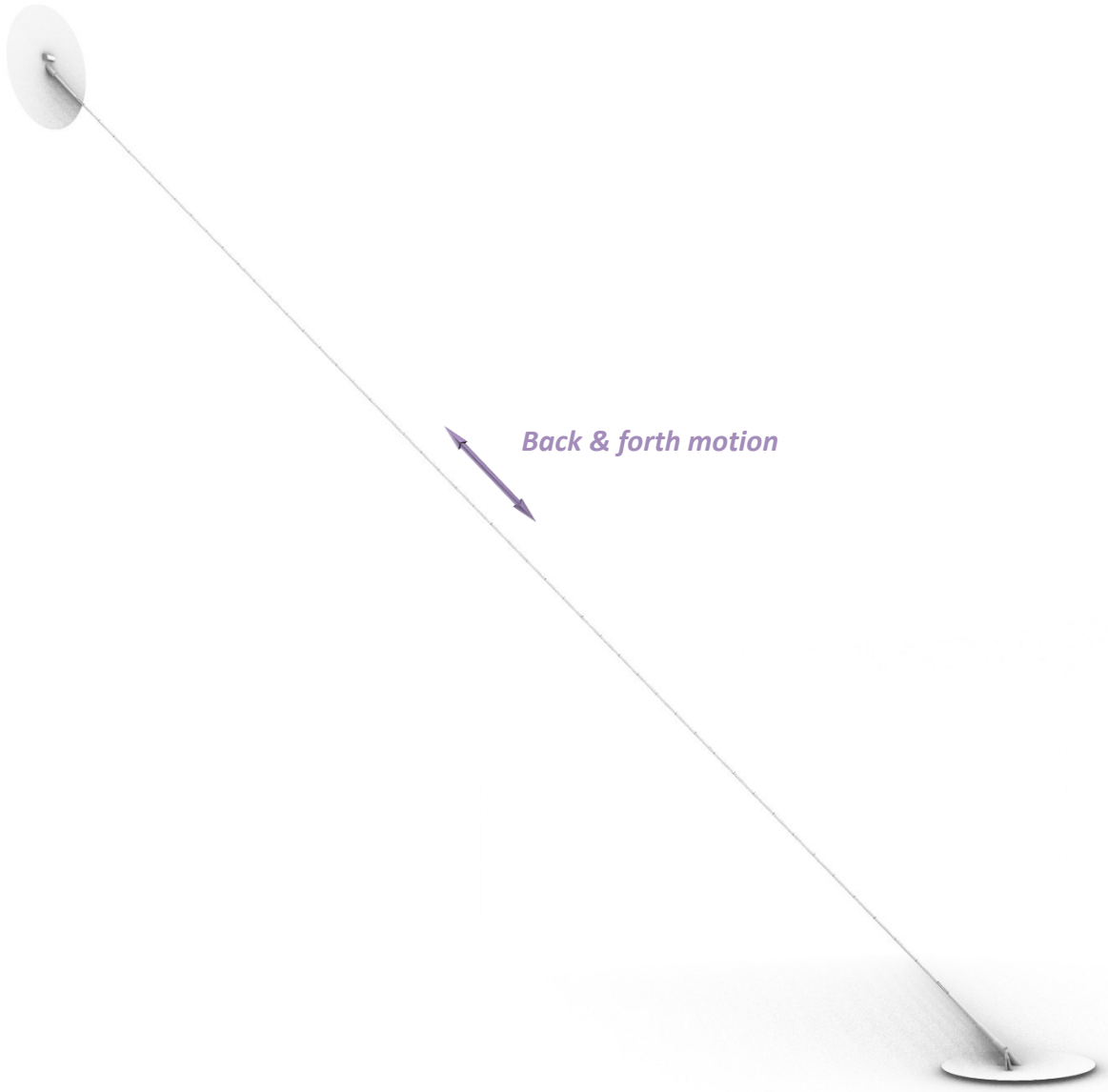
Normal Operation sequence of the Scraper Mesh System is as follows:

- ***Sensors automatically detect snow / ice conditions and provide the information to the Central Control System;***
- ***Scraper Mesh System is activated:***
  - ***Lubricant is injected into the fluid circuit integrated into the Scraper Mesh;***
  - ***Scraper Mesh back & forth motion is ordered (e.g., one sweep cycle = 2 minutes)***
  - ***Scraper Mesh motion is paused (e.g., pause = 10 minutes);***
  - ***Continuous back and forth motion could be ordered in the event of heavy snow or severe icing conditions;***
- ***The Scraper Mesh System is therefore able to remove snow and ice from the surface of the stay pipe (preventive action).***

Scraper Mesh System: Accidental Operation Mode

Thick ice accidental situation corresponds to when the Scraper Mesh System has not been able to operate on time and a thick layer of ice is formed over the stay pipe. In that case:

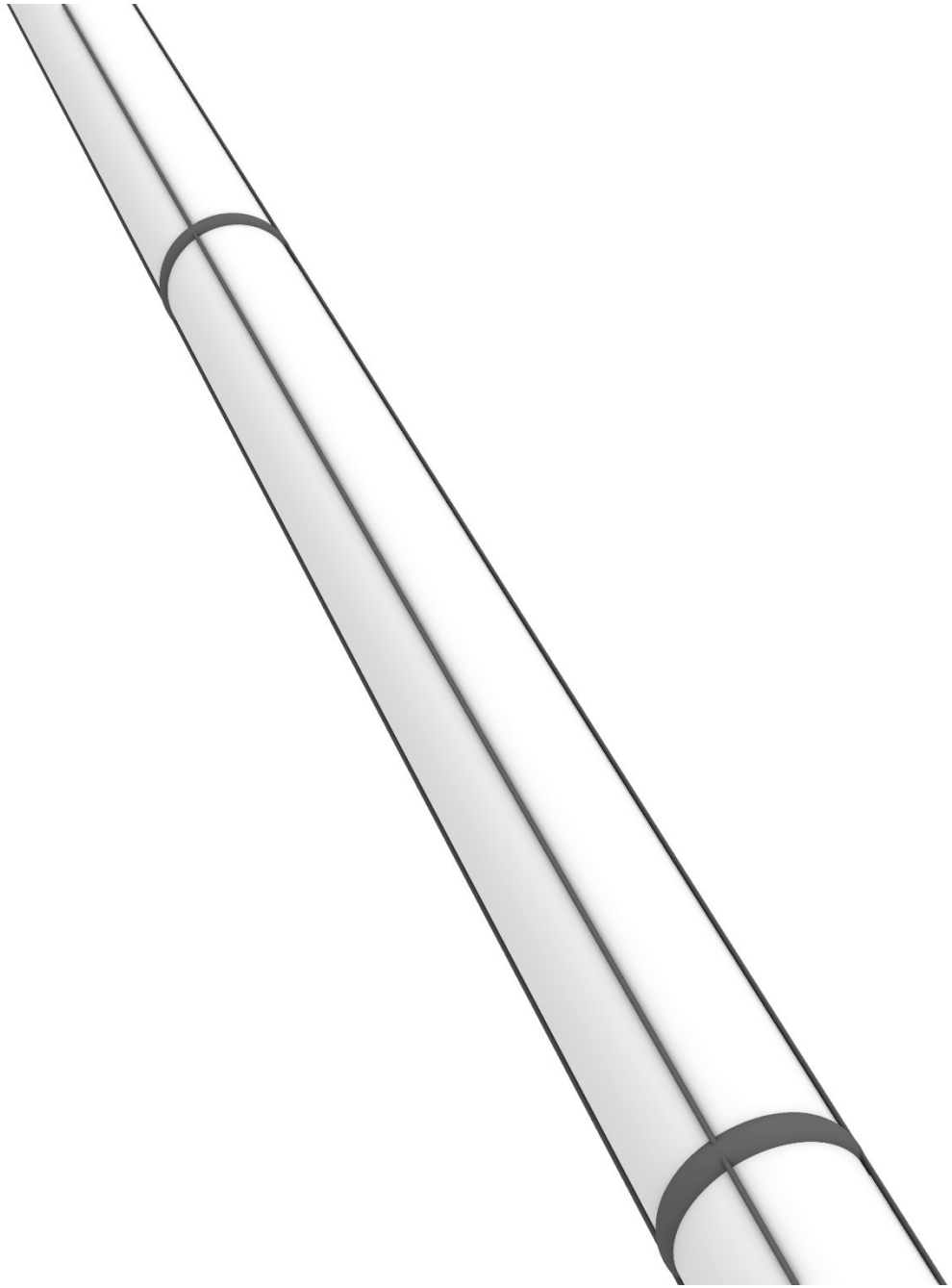
- *Hot lubricant or deicing fluid is injected into the fluid network of the Scraper Mesh;*
- *Scraper Mesh motion is ordered:*
  - *If traction force is too high, additional fluid is injected;*
  - *When motion is detected and traction force is within the normal range, fluid injection is halted;*
- *Scraper Mesh System "dynamic mode" is activated:*
  - *Dynamic impact device generates vibration impulse waves in the Scraper Mesh;*
  - *The vibration impulse waves break down the ice layer whatever its thickness;*
- *The Scraper Mesh System is therefore able to break and shed thick ice from the surface of the stay pipe (curative action).*

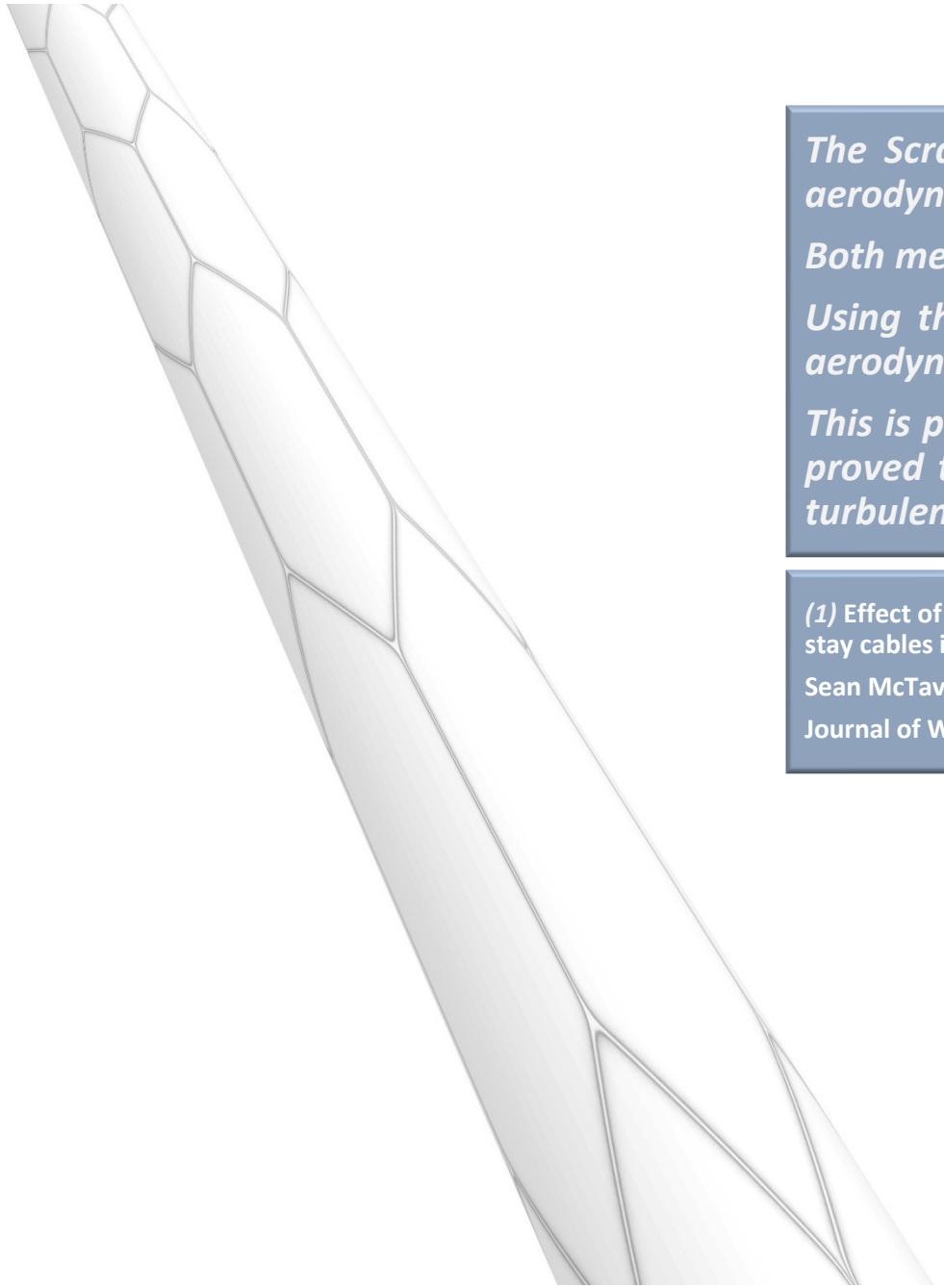

Back & forth motion











The Scraper Mesh design can be adapted to obtain enhanced aerodynamic performance.

Both mesh geometry and strand cross section could be adapted.

Using the right combination, it should be possible to minimize aerodynamic effects both in laminar and turbulent wind.

This is put forward considering the fact that helical strakes have proved to be most effective regarding drag reduction and wind turbulent flow response(1).

(1) **Effect of cable surface characteristics and flow turbulence on the aerodynamic behaviour of stay cables in dry conditions.**

Sean McTavish, Annick D'Auteuil, Arash Raeesi

Journal of Wind Engineering and Industrial Aerodynamics, Volume 207, 2020, Article 104414

Scraper Mesh System unique features

- *Fully automatic, high performance system*
- *High-end, yet based on standard, available technologies*
- *Reactive, already present over the entire stay pipe surface during snow and ice episodes*
- *Effective, being located at the ice-snow/stay pipe interface*
- *Quick, quasi continuous removal of snow and ice (preventive action)*
- *Cost-effective, robust and reliable*
- *Extremely low energy consumption*
- *Eco-friendly (nature-friendly lubricant material is used)*
- *Easy installation, operation and maintenance*
- *Does not damage the stay pipe, thanks to its plastic-coated strands and rings*
- *Could have favorable aerodynamic effect regarding drag and rain-wind induced response*
- *Could be made almost invisible, or otherwise decorative (e.g., biological mesh geometry)*

The way forward

- *Scraper Mesh System:*
  - *Fine tuning and validation of the mechanical design*
- *Lubrication System:*
  - *Preliminary design*
  - *Optimization of the coaction with the Scraper Mesh*
- *Wind tunnel testing:*
  - *Fine tuning and validation of the aerodynamic design*
- *Prototype testing (laboratory)*
- *Detailed design*
- *Prototype testing (in situ)*
- *Full-scale implementation*

www.topomachines.com

contact@topomachines.com