Redesigning a Smart Lock for Use in a Storage Park

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Many people are familiar with padlocks. These locks, typically made out of metal and opened with a key, can be used in an outdoor environment. The same cannot be said for smart lock. Smart locks are electronic locks that generally do not require a key but can for example be opened using a passcode. They are connected to servers, which provides benefits over traditional locks. However, smart locks are not normally used in an outdoor environment, which is also the case for the specific smart lock that was redesigned for this assignment. It is unfit for an outdoor environment mainly due to it not being waterproof and unable to withstand low temperatures.
This project aimed to redesign the smart lock to make it suitable for an outdoor storage park by implementing waterproofing and improving the thermal properties of the lock, while also considering the mechanical strength. To do so, three objectives were formulated and completed: analysis of the smart lock to be redesigned and other available smart locks, determining if the steel in a storage park influences the signal strength of the lock, and establishing if a redesign of the lock can improve on its thermal and mechanical properties.

Literature research resulted in the identification of several strategies for waterproofing electronics, such as using adhesive seals, waterproof membranes and gaskets. When it comes to having electronics function well in cold climates, not much research has been done on areas that are directly applicable to the smart lock. Some items, such as the use of heaters, can be implemented, however. There are also more general approaches that can be used, such as using different batteries or implementing insulation. Using heaters does reduce the lifespan of the battery of the lock, which is undesirable as the batteries cannot be replaced. This leaves battery replacement and insulation as the possible options. Battery replacement alone is not enough as the motor used to open the lock itself is sensitive to low temperatures. This was also evident from the experimental investigation done into the thermal response of the lock, which showed that the lock stops functioning properly when its internal temperature reaches approximately 2.4 ˚C. This measurement was also confirmed through a mathematical model which was used to further investigate the thermal properties of the lock. The manufacturer of the smart lock is working on redesigning the motor to solve this issue. If this turns out to be feasible, battery replacement can be used as a supplement to make a lock that can withstand cold climates. Insulation, on the other hand, is something that would be useful in more moderate climates. Insulation ensures that the lock does not get too cold to function for an extended period of time, but eventually a temperature equilibrium will be reached. At that point, the lock will no longer work. However, in places with more moderate climates having a lock that can withstand shorter periods of frost, e.g. night frost only, can be a useable option.

Moving forward with these two concepts, the battery replacement and insulation, in addition to the waterproofing, optimisations needed to be made. Based on this, for the waterproofing, the use of O-rings, adhesive seals and a membrane is proposed. For the battery replacement, batteries are suggested that should function at temperatures as low as -40 ˚C. These batteries have different dimensions than the one currently in use in the smart lock, and two of them are required rather than the current single battery. This requires the case of the lock to be altered to fit the batteries. The method that allows for the easiest manufacturing, and thus lowest cost, is simply elongating the case enough to fit the batteries. Lastly, there is the insulation of the lock's case. This aspect requires a good balance between mechanical strength and thermal properties. Air was chosen for the insulating material as it would not decrease the recyclability of the lock, but simply leaving a hollow section of air between two walls would not be strong enough. Therefore a rib structure is suggested. The mechanical strength of this structure was optimised through the use of simulations. The thermal properties were analysed through calculations and the mathematical model that was also used to investigate the thermal properties of the original lock design. This showed that while the use of insulation should keep the lock at an operational temperature for several hours (dependent on the outside temperature), it is unlikely to do so for an entire night of freezing temperatures.

The redesigns resulting from this project are two versions of the lock that could be used in different climates. One version with a redesigned motor as proposed by the manufacturer and less temperature-sensitive batteries for cold climates, and an insulted version for more moderate climates. Both versions use the same components for waterproofing. Future research on this project can focus on testing the concepts to determine if the waterproof design is indeed waterproof and if the proposed versions work well in their intended climates.