**Drivetrain**

Due to the highly interdependent nature of the motor and the transmission, these components were considered in tandem. The wheels constitute the final drive output, and as such affect the parameters of the motor, requiring them to be similarly considered in conjunction with the rest of the drive train.

PERFORMANCE CALCULATIONS

The following equations denote the required performance characteristics of the motors, based on the technical specification and board parameters. As discussed in the feasibility report, rolling resistance incurred is approximately 4.6N – this is negligible compared to the other forces the board is subjected to and has thus been neglected in further calculations.

The decision process for selecting the motor type isThe was determined to be: such inpossess,due to nothavingares

The requisite power output from the motors is 5000W [eqn. 9] – supplying this level of mechanical power with a single motor is unfeasible due to the size of such a motor, indicating that a dual motor system is more practical.,will between the motor and drive wheels

MOTOR CHOICE

Based on the required parameters, a 6374 motor (63mm diameter, 74mm length) as such motors are typically provide the above characteristics. Specifically, a pair of Torque Boards 6374 190KV motors were selected, each deliveringW3.57Nm of torque9.T curven-and high starting torque is required. As this starting torque will be less than the quoted peak torque, this motor was chosen as it is able to provide the 3.15Nm required at starting and not only at peak operating point. ,ing

**TRANSMISSION**

SUMMARY

Power to the wheels of the skateboard will be delivered using a high torque rubber belt transmitting the power from a brushless DC motor to the wheels.

MOTOR CONFIGURATION AND TRANSMISSION CHOICE

The decision to not use a motor attached from the truck directly to the wheels (direct drive), or a motor built into the wheels (hub motor), is summarised in the decision matrix xx. Both of these methods were dismissed, as they would severely limit the size and thus performance of the motors that could be implemented, leaving the board incapable of traversing the 15% gradients inherent in the user case. This problem is compound by the lack of room for gearing that could provide the required torque. Hub motors were deemed particularly unsuitable due to their poor heat dissipation, which would become a major problem given the high-power output required.

To enable a gear ratio and allow for the relocation of the motor to allow for a larger, more powerful motor a belt drive is most suitable, similarly summarised in matrix xx where it can be seen that due to its reduced noise, maintenance frequency and cost as well as better manufacturability that a belt drive is a more suitable than using a chain.

It was decided to use a high torque belt as can be seen in the profile xx, which allows for transmission of a large amounts of power xx, as well as high torque at a typical xx% efficiency as quoted by the manufacturer xx. This style of belt is resistant to holding its shape after being held in a particular position, during storage, which would otherwise cause vibrations through the board. The flexibility from having teeth also helps negate this effect. Having teeth eliminates slip, which not only increases the efficiency but also reduces the heating of the pulleys. This is further decreased by the surface area of the teeth allowing for better heat transfer from a pulley to the belt and from the belt to air. The materials for the belt need to be able to withstand UV light so as not to degrade as the belt will be exposed to sunlight for prolonged periods of time. The chosen belt consists of a chloroprene compound combined with fibreglass tensile cords: chloroprene provides resistance to heating and a high shear tooth resistance, with the fibreglass cords allowing the belt to withstand the required torque without either snapping or stretching and thus reducing transmission efficiency. Additionally, the teeth are coated in a nylon covering, enhancing the belts durability and wear resistance.

The most appropriate method for mounting the motors is to attach them to the trucks as this ensures that the motors stay in the same relative position to the wheels during skateboard steering and providing constant tension in the transmission belt.

RISK ASSESSMENT

In order to eliminate road gravel from becoming trapped between the belt and the pulley and potentially locking up a pulley a casing was designed to protect the drive system as seen in xx. The main considerations of this case were:

* To keep dirt and gravel out
* To enable easy disassembly to clean out the inside from small particles that could possibly enter- ideally without the need for any tools so the user can perform this operation when on a ride.
* To be lightweight and add limited parts and manufacturing cost to overall design.

This system was designed in SOLIDWORKS xx and during initial manufacturing will be 3D printed using xx ABS xx ASA xx plastic due its high durability, impact resistance and (UV protection). If the production volume is increase at a future date the manufacturing of this part could be transitioned to be injection moulding alongside the production of the main battery and Vesc casing.

**WHEELS**

The wheels of the board constitute a vital component of the drive system, as they serve as the means of transferring power to the road and enabling motion. There are various factors here which can be optimised, such as power transfer maximisation for the driven wheels and running efficiency for the non-driven. The bearings have a significant effect upon the latter as they are key in the reduction of rolling resistance, making the choice of bearings a major design consideration. The final design consideration relating to the wheels concerns the connection between them and the power train. As a rear-wheel belt system was judged the most optimal, the task at this stage becomes determining the best manner of interfacing the belt with the rear wheels. Regarding the dimensions of the wheels, it was decided that as this design is a retrofit, the original wheel diameter of 70mm would be maintained. As this fall within the typical range for longboard wheels (60-100mm), this enables the torque values of the drive train to be compatible with a range of pre-existing boards.

WHEEL MATERIALS

The two sets of wheels (driven and non-driven) have significantly different roles: the driven set are required to propel the board, and as such must be of a material of sufficient traction to develop power at the road surface whilst being sufficiently resistant to abrasion to withstand extensive use without wearing out. In contrast, the non-driven wheels serve only to provide steering and low resistance to motion. Typical longboard wheels are made from polyurethane, which provides a μrolling in the range of 0.02-0.04 and a μstatic of 0.2. These values make polyurethane ideal for use in the non-driven wheels, with the small μrolling inducing low resistance with μstatic being large enough to provide enough traction for steering purposes. However, μstatic for polyurethane is insufficient to prevent slip should this material be used in the driven wheels. Rubber compounds provide a μstatic in the range 0.35-0.45, a significant improvement. However, natural rubber suffers from reduced abrasion resistance compared to polyurethane, thus synthetic rubbers are required: styrene butadiene (commonly used in car tyres) provided the ideal solution, enabling both the increased traction and wear-resistance required. Though this compound is more expensive than natural rubber, the wheels overall constitute a very small proportion of the overall material costs, thus the extra expenditure was deemed acceptable.

BEARINGS

Another essential consideration is the type of bearings to be used – the main criteria here are to maximise running efficiency by incurring as little rolling resistance as possible, whilst maintaining sufficient durability both in terms of long-term usage and resistance to sudden impacts. Three materials are widely used in skateboard bearings: steel, titanium and ceramic. Ceramics feature prominently in high-performance conventional skateboards due to their significant advantage in terms of rolling resistance over titanium and steel. This is due to such ceramics (most commonly Silicon Nitride) being about 640% harder than their metal counterparts, reducing deformation and thus energy loss. Additionally, silicon nitride has a high specific heat capacity (0.673kJ/kg), enabling continued performance at high speeds at which substantial heating is incurred. Ceramics also possess greater resistance to oxidation when exposed to moisture, allowing for long term durability without regular oiling. However, ceramics are prohibitively expensive, costing upwards of 360% more than steel and titanium. Additionally, ceramics are quite brittle materials, with yield and ultimate tensile strengths substantially lesser than metal bearings. The σUTS of 170MPa was deemed insufficient given the potential for high-speed impact that the board could suffer, making ceramics unsuited to the user case. In terms of rolling resistance, titanium (ASTM Grade 7) and steel (SAE52100) perform similarly, both exhibiting a Brinell Hardness of 200kg/mm2. SAE52100 has a slightly greater σUTS of 590MPa compared to 550MPa for titanium, which in combination with being the most affordable (£15/set) suggests that these would be the most advantageous material. However, with a heat capacity of only 0.475 kJ/kg, steel bearings are less suited to continued use at the high speeds the board will be capable of running at, and would require regular replacement due to the accelerated wear. Titanium however is more resilient to heating at 0.554 kJ/kg, resolving this issue, as well as being more resistant to oxidation. Though titanium is more costly at £25/set, this extra expenditure constitutes only a 1.1% increase in the overall cost of the board, indicating that titanium is the optimal choice as various design problems are resolved at minimal extra expense.

DRIVE TRAIN INTERFACE

The interface between the driving belt and the driven wheels is a major consideration within this design. As described above, a rear-wheel, belt-drive system was found to be optimal, and thus the design task became how to effectively connect the belt to the rear wheels. One option would have been to utilise an axle connecting both rear wheels, with the belts connected directly to this axle – this would have allowed for a simple integration of the belt with the driven wheels without the need to mount any components to the wheels directly. However, it would have required a radical redesign and implementation of non-standard trucks, as conventional designs that most boards are compatible with have both wheels mounted independently of each other, with no central axle. This problem was circumvented by opting to mount cogs directly to the rear wheels over which the toothed belt would run, additionally improving efficiency by removing any slip that may have occurred at the axle. Initially, a combination of mechanical and chemical fastenings was considered, such as screws combined with an adhesive. In keeping with common mechanical design practice, a factor of safety of at least 2 was deemed acceptable. Upon researching some of the market leaders in rubber-metal adhesives, it became clear that mechanical fixings would be unnecessary: the required tensile strength was estimated to be 0.15MPa, with all the adhesives considered being capable of such a load with wide factor of safety margins. With even the lowest costing adhesive achieving greater than 2 it was decided that the choice of adhesive could be based solely upon expense, as the higher FOS’ provided by the more costly glues (the highest at 141) were simply not required. The selected glue, Weicon GMK 2410 Rubber Metal Contact Adhesive, provides a factor of safety of 3.6 with the material cost running to less than 10 pence per wheel, meeting all design requirements for this component.

The finalised wheel design consists of two sets of wheels - the front wheels made of polyurethane to provide steering capability whilst keeping rolling resistance as low as possible, with the rear wheels of SBR rubber to provide the traction for power transfer whilst retaining long-term durability. The rear wheels will interface with the drive train via directly mounted cogs, attached adhesively with Weicon GMK 2410 glue. Both sets will run over titanium bearings, which provide the best compromise between running efficiency and resistance to wear, impact and heating.

**TRUCKS AND SUSPENSION**

Due to the need to mount motors to the trucks, it was clear that a new set of trucks would be required over the standard set that came in conjunction with the Mindless Longboard we were provided with as a prototype starting point. Initially, we considered designing our own custom trucks in-house in order to easily mount the motors whilst achieving the required load capacity and ground clearance. However, such a task would have taken up considerable resources and design time, and market research revealed that a wide array of commercially produced solutions was available – thus, it was decided to implement an off-shelf-solution and utilise the extra time and resources furthering the development of the more complex areas of the project. If the project were to be scaled up to mass-manufacturing, it would be worth reconsidering as designing and producing our own trucks could potentially reduce overheads and would also reduce our reliance on external partners, decreasing the risk of the overall business model. However, for this one-off prototype, the commercial solution remains the best option.

FINAL IMPLEMENTATION

After considerable market research, a set of trucks and motor mount from Torque Motors were selected. The trucks possess a track width of 218mm (314mm w/ axles) and are compatible with the corresponding V6 motor mount. This mount is suited for supporting two motors and has length of 63mm, enabling the use of the 6374 motors required by the drivetrain. The trucks have a light all-aluminium construction, giving them a mass of 0.55kg each (1.1kg front and rear) – this was considered acceptably small as it would constitute less than 1% of the specified rider’s bodyweight and thus have little affect on the board’s performance.

LIMITATIONS

One major drawback of this solution is that these trucks do not incorporate any form of suspension. Initially, we had deemed suspension to be a desirable component in order to improve ride quality; however, the majority of commercially available trucks on the market do not cater to this requirement, with those that do being additionally heavy, prohibitively expensive and requiring a high level of maintenance. Such suspension systems are commonly used in off-road and stunt-style skateboarding, which makes for an unrealistic comparison for our urban-based user case. As trying to incorporate this feature into the design would hinder not only the performance of the board due to the increased weight, but also reduce its marketability due to the extra expense, this limitation with regards to suspension was considered acceptable as the suspension was of lesser importance to satisfying the user case than other areas of the design that could benefit from the time and resources.