

Materials and Manufacturing: Redesign Product

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Scooter X Go Kart Analysis and Redesign

Introduction

The brief I have received is to re-engineer and design the Scooter X Go Kart as a light exploration vehicle suitable for Mars. There are numerous considerations to be made when redesigning for such a radical change in working environment, most notably propulsion and safety.

Typical Use & Work Environment

The current use of the Scooter X Go Kart is as a general consumer leisure product. It is designed for fast, smooth surfaces. It is two-wheel drive, has a basic tubular steel chassis and 163cc 4 stroke engine. Whilst this is simplistic and easy to repair, it lacks power and as a result struggles when travelling on inclines even when the rider is only half of the Karts maximum capacity of 250lbs. The clutch is also relatively weak, resulting in strain when not on flat, even surfaces (The Pro Rider, 2017). This is one element that require alteration if the product is to be usable on the Martian surface.

The chassis essentially acts as a load bearing structure to support the rider and running gear, with little extra protection or styling. Whilst purely functional, it is not an ugly product, but not very aesthetically pleasing either; rugged would be its best descriptor. The only rust protection and aesthetic quality of the chassis is the black gloss paint that covers its surface (Jones, 2013).

The wheels and tyres are very robust and tough, with tall sidewalls and deep, widely spaced tread, perfect for driving on a wide range of surfaces. Whilst the overall diameter would not be enough for extreme rock crawling, they are sturdy enough to be used on a variety of harsh and difficult terrain. They are also relatively simple to repair and replace, as they are of a standard size and fit, so alternative parts are also readily available.

Materials & Production Methods

- Chassis – Tubular Steel (Extruded, Bent)
- Tyres – Compound Rubber (Milled, Compressed & Vulcanised) (Dunlop, 2015)
- Running Gear – Aluminium (Die Cast)
- Seat – Polypropylene (Injection Moulded)
- Engine – Cast Iron (Sand Casted)

New Working Conditions & Design Considerations

The working environment of the redesigned product would be on the surface of Mars. This is much more demanding than the original product's typical environment and, as such, requires many design considerations to be taken. For example, Mars has a much thinner atmosphere and much finer dust, so a conventional internal combustion engine (ICE) would not be a viable option. Not only would there not be enough oxygen in the atmosphere for it to operate without heavy modification (Heywood, 2018), but the dust in the Martian atmosphere is fine enough to pass through normal air filters and slowly destroy the cylinder walls of the engine. An electric motor and battery pack would arguably be the most sensible solution as they could be recharged using solar power or using the generator of the landing craft and / or Mars base. The electric motor would not have to be particularly powerful, as the gravity on Mars is approximately three times weaker than Earth's. This coupled with the fact that the old engine only produced 6.5 Horse Power (The Pro Rider, 2017), means that an electric motor would be sufficient to propel the product and its user. Small electric moped motors produce around 5.4 Horse Power and cost only around USD\$100 per unit. Each buggy could utilise two of these motors (one per rear wheel or one per axle) and achieve a range of around 80km on a single charge with a relatively compact lithium ion battery pack (Mi & Masrur, 2017).

A further design consideration is that the lack of front suspension would not be practical for use on the uneven Martian surface. The lack of front suspension would cause the front end of the Go Kart to jump and crash violently on rougher terrain, potentially leading to mechanical failure. Added shock absorbers and springs would allow for a comfortable ride along the uneven surfaces of Mars (Bastow, 2004).

New Design & Manufacture Methods

The new design provides a usable powertrain for extra-terrestrial atmospheres which is better equipped to traverse uneven terrain and provide rollover protection (NASA, 2017). Despite all of these additive factors, its chassis is lighter (and more rigid) thanks to the carbon cage structure (Corner Balance, 2018). The carbon cage would have to be hand layered in sections, using a mix of woven and uni-directional weave, over inflatable bladders. These bladders would have the rough shape of the desired part and would be wrapped in multiple layers of carbon fibre (Oakley Design, 2019) (Burrill & Zurschmeide 2012). The carbon covered bladder would then be placed in a steel mould which, in turn, would be put into a press. This would incrementally compress the mould whilst the bladder inflated, ensuring that the part would perfectly take the shape of the mould (How it's Made, 2015). It would also be heated to ensure that the resin that seals the carbon layers together is evenly distributed. The parts would then be left to cool before being taken from the mould and placed in an oven to cure at 90 degrees centigrade. The surface of the parts would then be sanded, and the bladders removed. The parts are then built on a jig, ensuring accuracy and consistency and are held together using aerospace strength adhesive (Global Cycling Network, 2018). The finished cage is then ready for surface finishing, in this case requiring only sanding and coating with protective varnish and lacquer, as a cosmetically attractive painted surface is not required for its working environment and would increase the cost of the vehicle.

The running gear, seat and motor would then be bolted on using the same locations as the original product, in order to minimise repackaging and re-engineer as little as possible, thus retaining ease of maintenance, a key requirement for its new working environment: if a part were to break or detach it must be easily repairable and with as few and tools as possible. All bolts on the Kart will be either 10 or 15mm depending on the stress they are under (e.g. engine and suspension mounts would be 15). As a result, only one tool and two attachments would need to be carried with the vehicle and could even be stowed in a small concealed case on the chassis.

The additional two shock absorbers and springs at the front would help to raise its ride height and the Scooter X Go Karts' ability to traverse rough and challenging terrain. The springs would be attached to the chassis and wheel hubs in order to get the strongest connection and lowest amount of additional engineering for a good setup.

Suitability & Advantages

The carbon chassis has several advantages and is much more suitable for travel outside Earth. It is much lighter: requiring less fuel to leave the atmosphere and it is much stronger and more rigid, allowing it to be used in harsher terrain and protect its user. The change from an ICE to an electric motor and battery pack would also make the vehicle much more suitable for Mars, as electric motors can operate in a total lack of oxygen, whilst ICE cannot operate effectively in low oxygen environments (Read & Lewis, 2004).

The addition of front suspension would facilitate movement over the tough Martian terrain (Carr, 2018) much more comfortably and reliably than the previous solid axle setup, also helping the Kart to carry heavier loads, such as research equipment over rough ground (Bastow, 2004), eliminating the need for larger vehicles for smaller reconnaissance and research missions. Similarly, it ensures increased safety if the driver were to navigate a steep ledge then the suspension, coupled with the lower gravity, would cushion injury and prevent major mechanical damage.

Cost Justification

Whilst the cost of the product would increase dramatically with the modifications I have made, the Go Karts would still be an extremely cost-effective option for light manned exploration of the Martian surface. Space exploration business and organisations such as Space X, Virgin Galactic or NASA would benefit from purchasing several light exploration vehicles that are pre-designed and built. They would not have to research and develop their own light Mars manned rovers, saving money, time, resources and creating a standard product with universal parts and ease of repair.

Summary

Overall, the product has undergone a significant number of design adaptations. Whilst some of these have been rather radical, the product is still recognisable. It uses some of its original parts and is visually very

similar. However, the changes made to the product now allow it to be operable not only in a different working environment, but on another planet. It is much stronger, safer and lighter, all of which are imperative in its new product lifecycle. Thanks to modern technology, the old carbon chassis can now even be recycled to make forged carbon fibre. This reduces the lifetime running cost as old parts can be recycled, including the metal and plastic components. Additionally, the battery packs can be reconditioned, meaning that the environmental impact of the product has been drastically improved as a result of its zero carbon emissions. The only consumable product would be the tyres and even their life cycle may likely be increased due to the lower gravity, as they would be under less strain.

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Scooter X Sport Go-Kart: Analysis

Manufacture methods:

1. Extruded Steel
2. Diecast Aluminium
3. Sand Casting
4. Milled & Vulcanised Rubber
5. Injection moulded
6. Bent, Welded & Bolted

Materials:

- Tubular Steel
- Aluminium
- Cast Iron
- Compound Rubber
- Polypropylene Plastic

Pros:

- Lightweight
- Fast
- Simple controls
- Low number of components

Cons:

- Poor off-road ability
- Struggles on steep slopes
- ICE will not operate on Mars
- Lack of rollover or crash protection

1. Extruded Steel (Tubular Steel - Chassis):

Heated steel is pushed through a die that controls the size and shape of the tubes. Different inserts can be used to control the inner diameter to change the weight and strength of the final product.

2. Die Cast Aluminium (Steering arms, brake levers, etc):

Molten aluminium is forced into a negative mould cavity to create the desired part. It is left to cool before the part is removed and any over mould is sanded off. The part is then ready to be finished further or used as is.

3. Sand Casting (Cast Iron Engine block and head):

Sand casting requires a shape to be encased in sand which is then compacted. The original object is then removed leaving a negative mould of the original. Molten iron is then poured into the mould to create the product. The product is left to cool then dug out of the sand.

4. Milled & Vulcanised Rubber (Tyre):

The rubber for tyres is made from a blend of 30 different rubbers and compounds. The rubber is cooled and then cut into strips that are used later to form the main structure of the tyre. The metal band, tread and textile elements are placed in the curing machine where it is compressed and vulcanised.

5. Injection Moulding (Polypropylene Plastic):

The injection moulding process is used to manufacture large quantities of plastic products. It uses large steel mould tools. The tool has two halves that when pressed together create a negative of the desired product. This cavity is then injected with the chosen plastic at a high pressure. The part cures for a few seconds before the tool separates and the final product is removed.

6. Bending, Welding & Bolting (Chassis and Fasteners):

The tubular steel of the chassis is shaped in a tube bender and then welded together in sections. MIG welding is a process where a solid wire electrode is fed through a welding gun, in a similar manner to that of a glue gun. However, MIG (Metal Inert Gas) welding also pushes a shielding gas from the welding gun to prevent the join or materials being joined from getting contaminated or oxidising quickly. The different chassis sections then have items such as the seat, engine and running gear bolted to them using nuts and pre drilled holes to ensure correct positioning and ease of construction.



Scooter X Sport Go-Kart: Comparison

Original Manufacture Methods:

- Extruded Steel
- Diecast Aluminium
- Sand Casting
- Milled & Vulcanised Rubber
- Injection moulded
- Bent, Welded & Bolted

Original Materials:

- Tubular Steel
- Aluminium
- Cast Iron
- Compound Rubber
- Polypropylene Plastic

New Manufacture Methods:

- Carbon Layering
- Oven Curing
- Diecast Aluminium
- Milled & Vulcanised Rubber
- Injection moulded
- Bolted Assembly

New Materials:

- Carbon Fibre Composite
- Aluminium
- Compound Rubber
- Polypropylene Plastic

Old



1. The old chassis construction of tubular steel was heavy and did not offer a significant level of protection.
2. The original internal combustion engine and clutch were not suitable for the Martian environment.

3. The lack of front suspension in the original design posed a problem for exploring Mars due to the rough terrain and resulting instability of the vehicle in its original form.

New



1. The new one-piece carbon fibre chassis offers a lighter, more rigid construction with much more protective structure in case of a rollover.
2. The new direct drive electric motor is able to operate in any atmospheric conditions and will be much more effective at providing power in uneven conditions.
3. The addition of front suspension allows the new design to be able to traverse the Martian surface without hinderance and in much greater comfort.

In summary, the revised design is a much more viable option. This is a result of its lighter weight, ease of maintenance and high drivability.