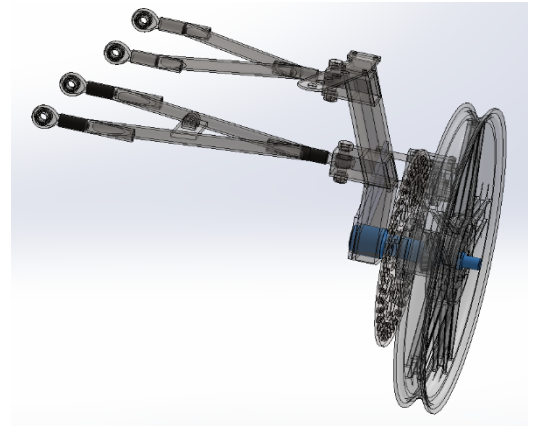


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MAE 156B: Individual Component Analysis

For this assignment, the component being evaluated is the spindle, a fixed round shaft holding the wheel-hub assembly, allowing it to rotate (see Figure 1, right, highlighted in blue).



I began by speaking to our sponsor, Ray, to understand functional requirements and potential sources for obtaining the spindle. The wheel-hub assembly is mounted on the spindle using bearings, to reduce the friction. The spindle must support vertical loads when the wheel hits bumps or dips. Spindles available on the market are typically connected to a knuckle, which is the kingpin and spindle combined. However, given the car's unique nature of high underbody clearance and low mass, we would need a bare spindle sourced.

After discussion with Ray and the team, the functional requirements for the spindle are given below:

- Spindle must arrive bare and not be fixed onto an upright or kingpin
- The spindle should be stiff
- The spindle must allow free rotation of the wheel about the axis
- Spindle must be able to support bump loads of at least 2g.

Some secondary considerations:

- The weight of the spindle should be kept at a minimum.
- The spindle should be stepped at the rear (i.e. extend past the thickest section with a smaller diameter), so that it is easier to weld on the kingpin
- The tapered bearings are already purchased, so matching the diameters would reduce cost
- Using the same material as the kingpin (4130 Chromoly Steel) will be preferable for welding

One option was to buy stock and CNC it in house. We could also buy a standard spindle off the shelf, or we can outsource the machining to a custom manufacturer and have the spindles made.

Originally, the spindle was to be manufactured, with a 1.25-inch diameter section for the inner bearing, and a 1-inch diameter section for the outer bearing. The bearings are already purchased, but the 1.75-inch diameter at the kingpin can be changed as the kingpin is yet to be fabricated. Prior FEA conducted demonstrated that when the loads were applied, a factor of safety of 3.85 was found.

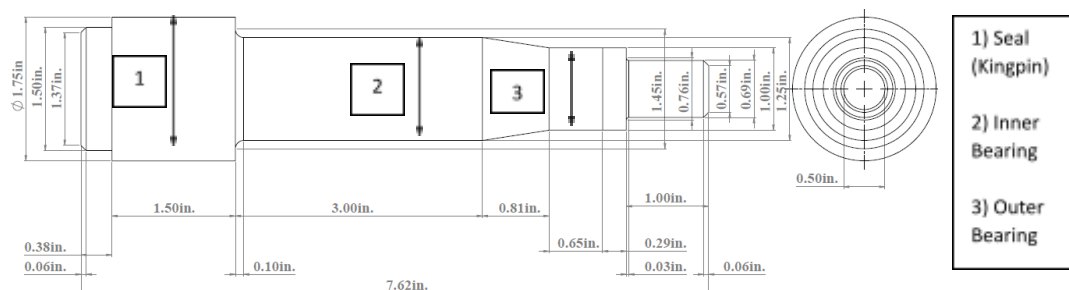


Figure 2: CAD Drawing of Spindle, courtesy of the Triton Solar Car Team

To find manufacturers of spindles, I consulted the Thomas Register to find companies that make spindles. An initial search with the keyword “spindle” returned 364 results, and many of these

spindles were not car spindles. A subcategory of “Axle spindle” only had 18 companies. One company, *GKN Wheels Armstrong*, had a catalogue for wheels and hubs, but not for spindles. Most other companies specialize in CNC lathe, rather than having a standard collection of spindles.

Ray suggested to look into dune buggies. A google search for “buggy spindle” returned several results, some that looked like what we were looking for. I found that bare spindles were mostly available in three sizes: “ball joint spindle”, “combo spindle”, and “King Kong Spindle”.

Spindle Type	Outer Bearing diameter (in)	Inner bearing diameter (in)	Seal diameter (in)
Ball Joint Spindle	0.689	1.142	1.575
Combo Spindle	1	1.25	1.75
King Kong Spindle	1.181	1.5	1.890

For the bare spindles, a Google search returned a few suppliers in California, all of which specialize in making parts for Off-Road Vehicles. However, all of them pretty much carried only the three sizes mentioned above, and all with the same material: 4130 Chromoly Steel.

Most of the websites had listed their source as *Latest Rage*, so I decided to call them. They are a distributor, and were not able to give much technical information, and instead referred me to vendors, including *Pacific Customs*, *Moore Parts Source*, and *Appletree Auto*.

Vendors of Spindles	Kartex	Pacific Customs	Nexgen Off Road	Appletree Auto	CNC from 1ft stock, 4130 Steel	CNC from 1ft stock, 6061 Al
Ball Joint	/	55.90	39.99	49.99	48.00	11.16
Combo	69.98	82.40	55.99	64.99	48.00	17.40
King Kong	79.98	55.99	59.99	/	50.88	18.72

Most of the vendors mentioned that the spindles were made locally at a machine shop, or they declined to state. 4130 Chromoly was the only material carried, and the other materials were either out of stock, or the vendors were unaware of them. Using the loading conditions and models provided by the Solar Car team, the different spindles were tested under the given loading conditions in FEA, with 4130 Chromoly Steel and 6061 Aluminium as two common metals, and FoS were computed.

Spindle	FoS, 4130 Steel	FoS, 6061 Al	Mass, 4130 Steel (g)	Mass, 6061 Al (g)
Ball Joint	3.26	1.96	624.99	215.42
Combo	3.85	2.31	823.60	283.87
King Kong	4.41	2.68	1062.43	366.19

Using aluminium will result in significant weight reduction, lower cost, but results in a lower FoS.

Sourcing Options	Pros	Cons
In-house manufacture	Low cost, can customize size and material for lower weight	Lower tolerance, high chance of making mistakes with tolerancing
Purchase	Low-medium cost, fast lead time, high availability, standard and easily replaceable	No customizability, real dimensions may differ from model
Outsourced manufacture	Able to get high tolerances, can customize size and material	Expensive (\$340 per part from <i>Hubs</i> , \$291 from Xometry)

Manufacturing the spindles in-house is the cheapest and would allow us to use Aluminium for weight reduction, but may result in poor tolerances and increases the potential for error, and would require a different method of attaching to the kingpin as opposed to direct welding. Outsourced manufacture gives better tolerances, but will be expensive and would have long lead times. Spindles are already commercially available for vehicle part replacement at low cost, so it will be best to just purchase

them. While the Ball Joint is cheaper and lighter, new bearings will be needed, and the kingpin and hub will need completely new designs, so the original (Combo) would be the best moving forward.

Keywords – Axle Spindle, Buggy Spindle, Ball Joint Spindle, Combo Spindle, King Kong Spindle

Phone Calls – Bill, *Moore Parts Source*, 714-666-6688. Other vendors (no contacts made): *Latest Rage*, *Kartek*, *Pacific Customs*.

Metal stock source: *Stock Car Steel and Aluminium*

<https://stockcarsteel.com/products/4130/4130-chrome-moly/4130-chrome-moly-round-bar.html>

CNC Instant Quote: *Hubs* <https://www.hubs.com/>, *Xometry* <https://www.xometry.com/quoting/home/>