KART BACK AXLES…A PERSPECTIVE

Anyone involved in karting for any period of time has seen many changes…..tyres, engines, rules, classes and back axles.

Back axles and the logic behind the development has certainly led to some justified confusion and maybe even unnecessary commercialism.

Way back, there were 25 mm (one inch) solids leading to tubular 30, 35, 40 and 50 mm versions and now, an intermediate 45 mm.

Some karts that were "were impossible to drive" on a 40 mm axle are now are "gems" on 50 mm. Is this true? What can be the difference? Is a 50 mm axle inherently better than a 40 mm? Is chrome moly better than mild steel?

Before we go into looking at different axles, we must consider the functions of the axle and how it might respond under operational conditions.

Basic functions:

- Support the weight of the back of the kart
- Transmit engine torque
- Transmit braking torque
- Accept cornering loads

Basic responses:

- Flex under weight to give negative camber to back wheels
- Flex under acceleration to give "toe in" of back wheels
- Flex under braking to give "toe out" of back wheels
- Twist during cornering

Flex is a key word here. We could have said bend, but that could imply that the axle might permanently bend…undesirable. By flex, we mean that the axle will return to its straight shape after the load has been removed. This being the case, the axle is considered to be acting as a spring operating within its elastic limit.

Springs are compared by their spring rate. An automotive coil spring has a much higher spring rate than a kart carburettor throttle return spring.

Going back to axles, logic tells us that the only difference between the 50 mm and 40 mm axles is the spring rate. There is a slight difference in weight, but this is very small in the big picture of pass and fail. The spring rate is the big variable.

It must be stated that the following analysis is a fairly basic engineering analysis or perspective, and that the reality might be different.

From the Basic responses indicated above, it can be seen the spring rate can take two forms…bending and torsional. As the two are essentially related in a kart back axle application, we only need to consider one and the other will follow the same characteristic, so for the following analysis, only bending will be considered.

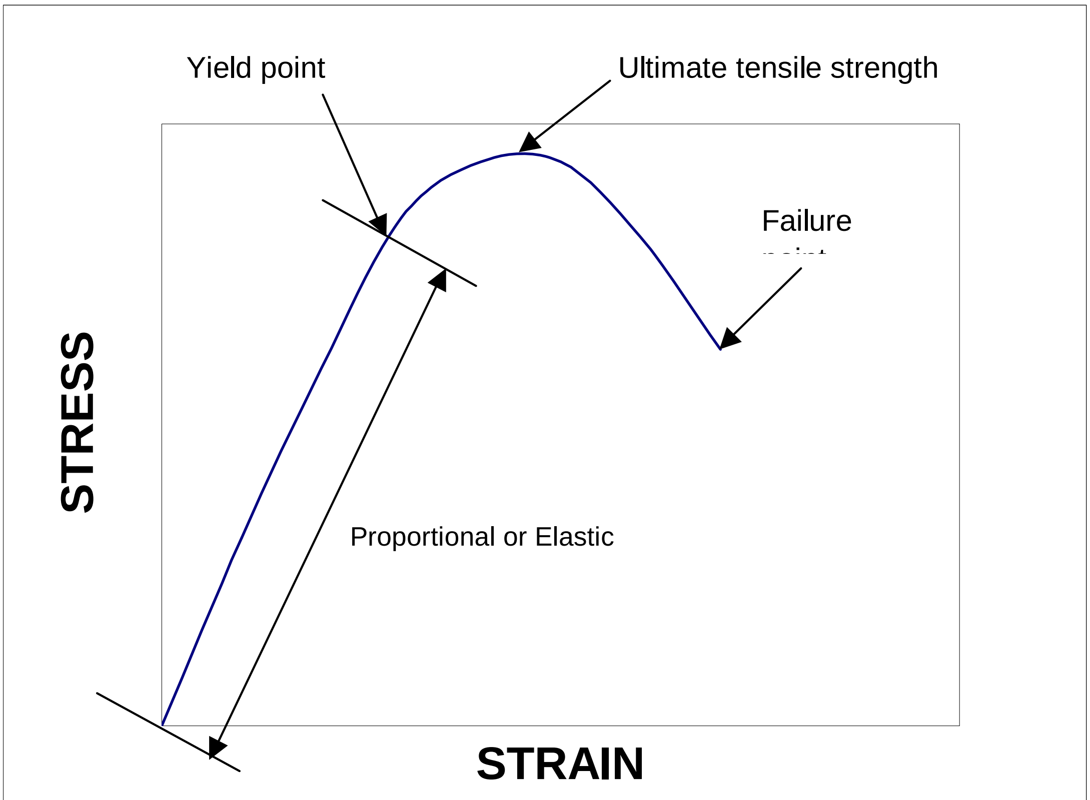
To compare axles we, fortunately or unfortunately, need to go to some engineering basics, Stress and Strain and then Section Modulus:

1. STRESS & STRAIN

Stress. (force per unit area). If we hung a 50 kg weight on a 10 mm * 10 mm square section length of material, it will see 50 kg per 100 sq mm. Taking gravity into account, where 1 kg is equivalent to 9.81 Newtons, the stress is 4.9 N/mm^2.or 4.9 Mpa. In reality this stress level would be considered as extremely low, and steels typically have an ultimate tensile strength of anywhere between 400 to 1300 N/mm^2 (or 400 to 1300 Mpa). The strength of materials is typically done using a tensile test instrument which applies an accurate and increasing force and also simultaneously records the elongation of the specimen under test. This leads us to the other term.

Strain. (percentage elongation). Whilst undergoing the tensile test, the amount of elongation per unit length is recorded and this can simply be converted to a percentage.

After a tensile test, the stress and strain measurements are plotted, with a typical characteristic for steel as shown below.



TYPICAL STRESS vs STRAIN CURVE OF STEEL

What can be seen from this is that there is a proportional zone of the stress/strain curve where the material acts as a simple elastic spring. It can receive a limited amount of stress (up to the Yield point) and it will deflect and return to its initial shape or length. Beyond the Yield point, the steel will withstand an increasing level of stress until it reaches its Ultimate Tensile Strength. Shortly after this point, the material will fail.

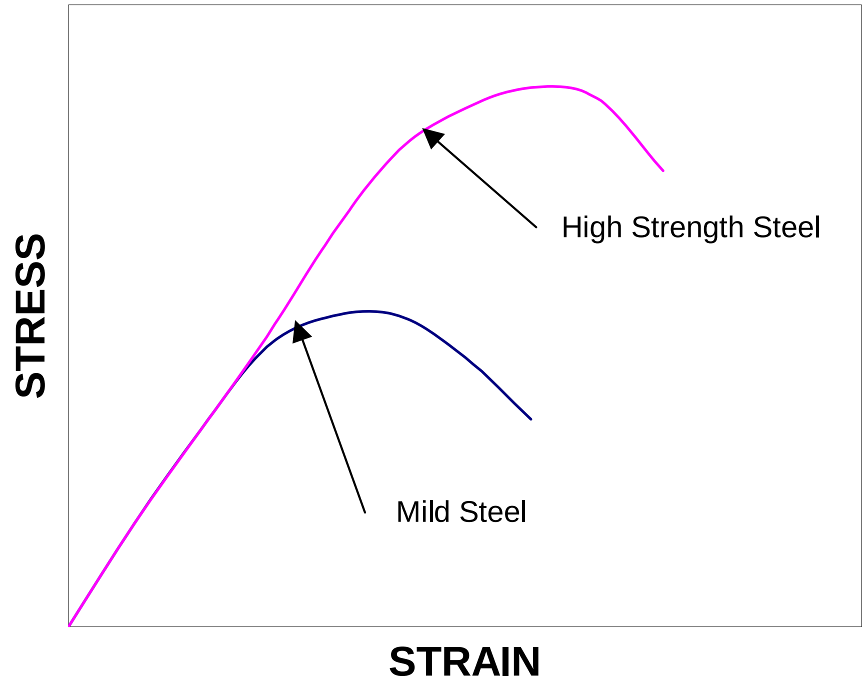
Given that we want our axle to not bend under practical loading (cornering forces including a slight nudge into the guy next to you), the axle size (diameter and thickness) <u>must</u> be chosen to operate in the proportional section.

Going back to the stress/strain curve, there are two interesting facts.

The first and the big one, is that the slope of the proportional section of the curve for ALL STEEL IS THE SAME. This in engineering terms is referred to as Modulus of Elasticity (Youngs Modulus) and for steels is usually quoted as 200 Mpa. The simple reality is, that you can have a length of mild steel and a length of chrome molybdenum steel, both of the same size, and they will be both stretch (or bend) by the same amount under a given force (in this case, a force not exceeding the Yield point of the mild steel).

The second fact is that the mild steel will eventually suffer permanent deflection and failure well before the chrome moly steel.

The following graph shows this:



STRESS vs STRAIN COMPARISON

From this it can be said that if your mild steel axle didn't fail (ie permanently bend), then there is absolutely no reason to use chrome moly or other expensive exotic steels.

Are you a believer so far?

Common question: "Some steels are much harder than other, doesn't this count and aren't they stronger and stiffer". Yes they are stronger and will withstand a higher ultimate stress before failure, but the deflection, whether it be in bending or twist, will be the same for all in the proportional phase.

2. SECTION MODULUS.

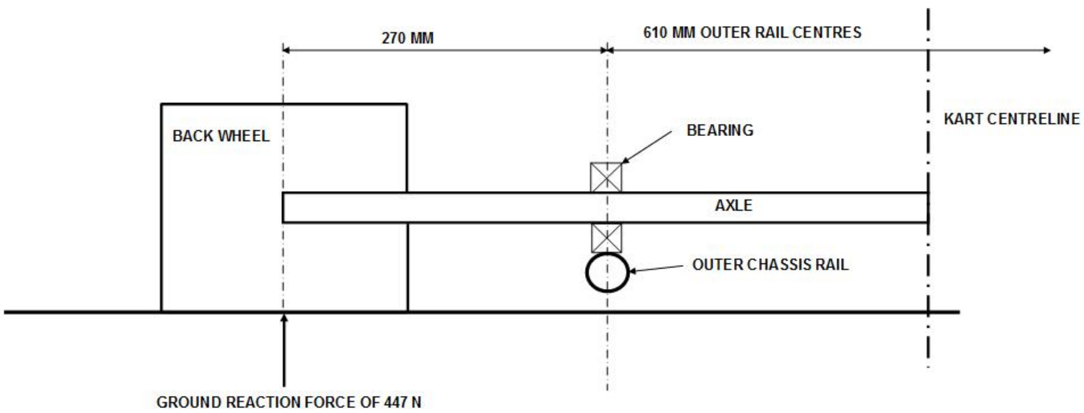
A very important engineering requirement is to be able to characterize the cross section of a part of a structure or machine to establish if it is strong enough in terms of failure or deflection. We all know that it is easier to bend a ruler when it is flat than when it is on its edge. This tells us simplistically that a deeper cross section is stronger than a wide cross section. From applied mechanics, each cross section can be analysed for its shape and a number can be calculated for the shape and size of the cross section. This is called the Moment of Inertia, for which the larger the number the stronger the structure. For round tubing, the formula to calculate the Moment of Inertia (I) is :

$$= 0.049(D^4 – d^4)$$ where: D = the outside diameter in mm
d = the inside diameter in mm.

For a 35 mm axle of 3 mm wall thickness, the value of I would be 38,875 mm^4.

In engineering design, it is essential to know and use Young's Modulus (E) and the Moment of Inertia (I). In conjunction with the known load, we can calculate the stress on the material and also how far it will bend. If the calculated stress is too high, the design must be modified to bring this within acceptable limits and/or factor of safety.

Let's consider the static loading on a back axle of a kart. In this case we'll use a Western Australian Sportsman Heavy class weight of 160 kg with an ARC watercooled engine. Assuming that it has a 57% rear weight bias, than the load on the rear wheels is 91.2 kg and if the loading is equal, each wheel will see 45.6 kg (447 Newtons). The chassis has its outer frame rails (and bearings) at 610 mm centres and the track is 1150 mm.



From the above situation, we can compare the stress in the axles and the deflection at the wheel. In doing this, we must acknowledge the following assumptions for simplicity:

- The axle extends to the centre of the wheel
- The length of the rear hub is not taken into account
- The sprocket carrier is ignored
- The axle is essentially rigidly clamped inboard of the bearing
- It is a static loading

Going back to basics, it is very rare that an axle will permanently bend in service. If it does it will either be due to an accident or, in the case of very thin wall axles, kinking to due overtightening of the grub screws?? So, on the basis that the axle runs true, the only way that the axle could affect the kart handling is the actual deflection or flex of the axle under the fairly complex series of loads it undergoes during cornering. This deflection can influence the overall chassis deflection and importantly can alter both the camber and wheel alignment (rear wheel steering) of the two rear wheels plus the road contact pressure of each of the two wheels. These factors will influence how the kart handles in a given situation.

With reference to the loading on the axle, we can use the following formula to calculate deflection (S) at the end of the axle, which will be the deflection of the wheel.

S = (L * F) /(3 * E * I) where:
L = load in Newtons
F = applied force
E = Young's Modulus
I = Moment of inertia

The following table shows the deflection of a range of axle sizes and wall thicknesses. Also included is the change of camber of the wheel from its vertical position at zero load.

Outside diameter	**Wall thickness**	**Moment of Inertia**	**Deflection at wheel**	**Camber change**	**Weight of 1000 mm axle**
mm	mm	mm^4	mm	deg	kg
50	1.5	67146	0.66	0.139	1.81
50	2.0	86855	0.51	0.107	2.38
50	2.5	105319	0.42	0.089	2.95
50	3.0	122593	0.36	0.076	3.50
50	3.5	138729	0.32	0.067	4.04
50	4.0	153777	0.29	0.061	4.57
45	1.5	48458	0.91	0.193	1.62
45	2.0	62468	0.70	0.149	2.13
45	2.5	75491	0.58	0.124	2.64
45	3.0	87572	0.50	0.107	3.13
45	3.5	98759	0.45	0.095	3.60
45	4.0	109097	0.40	0.086	4.07
40	1.5	33606	1.31	0.278	1.43
40	2.0	43139	1.02	0.216	1.89
40	2.5	51909	0.85	0.180	2.33
40	3.0	59960	0.73	0.156	2.75
40	3.5	67330	0.65	0.139	3.17
40	4.0	74060	0.59	0.126	3.57
35	1.5	22150	1.99	0.421	1.25
35	2.0	28278	1.56	0.330	1.64
35	2.5	33841	1.30	0.276	2.02
35	3.0	38874	1.13	0.240	2.38
35	3.5	43412	1.01	0.215	2.74
35	4.0	47490	0.93	0.197	3.08
30	1.5	13649	3.22	0.684	1.06
30	2.0	17298	2.54	0.540	1.39
30	2.5	20549	2.14	0.454	1.71
30	3.0	23433	1.88	0.398	2.01
30	3.5	25978	1.69	0.359	2.30
30	4.0	28211	1.56	0.331	2.58
25	Solid	19141	2.30	0.488	5.30

The significant number in the above table is the Moment of Inertia. If it is the same for two different axle types, then the deflection will be the same. A few examples of this are:

- a ∅50 mm * 1.5 wall axle is approximately the same as a ∅40 * 3.5
- a ∅40 mm * 2.0 wall axle is approximately the same as a ∅35 * 3.5

Which one is the best? Like many things with karting there is no clearcut answer, but the following may be considered:

1. If weight was critical, then the larger axle might be regarded as the one to use as it is lighter. Offsetting this is the greater tendency for the thinner wall axles to kink (permanently). Because of this and if weight wasn't an issue, then the smaller size axle might be considered the one to use.

2. If your mild steel axle wasn't failing, there would be no benefit to going to a stronger material.

3. The above argument and comparison indicates that ALL axles of the same diameter and wall thickness will act the same (ie, your mild steel axle will be exactly the same as a chrome moly axle). The sole reason for the use for stronger materials is to gain a greater resistance against permanent deflection (bending).

I am sure that the last two points will be argued against by many, but after all this is just a perspective and it must be repeated that many assumptions have been made.

Happy flexing

Ken Seeber

STRIKE PRODUCTS

(NOTE: This article was published in Kart Magazine in 2003)