Lecture T4 –The Controlled-Friction Track for Gravity Race Cars (US 8,708,245 B2)

INTRODUCTION

The invention described herein comprises an improved track which increases the speed of a gravity-driven racing car. Firstly, a low-friction material on the central guide strip reduces the frictional drag when contacted by a car's wheels. Secondly, a micro-grooved (serrated) wheel rolling surface increases the friction for lateral movement of the car wheels through a fingerprint effect, thus straightening the trajectory of the path to the finish line. Thirdly, this effect, reducing the amount of sideways movement towards the central guide strip, also reduces the velocity and thus the amount of sliding friction associated with guide strip bumping. Fourthly, the micro-grooved surface also reduces the contact area between the wheel and the track surface causing a reduction in rolling friction. These four effects and their associated measurements will be discussed below. By 1decreasing the amount of track interaction with the car, the finish times will be more representative of the car itself. This means the race competition will be more fair, approaching a race on a perfect track.

MEASURING SLIDING FRICTION

Sliding friction is very simple to measure. Object 1 is caused to move across the surface a second stationary object 2 when a force is applied to cause the sliding. If the downward force on 1object 1 is *Fp* and the horizontal force to cause sliding of object 2 is *Fs* the coefficient of friction is the ratio of slide force *Fs* to the perpendicular weight force *Fp*. So the coefficient of sliding friction (COF), sometimes called μ, is

$$\text{COF} = \frac{F_s}{F_p} \qquad (1)$$

Actually, to get object 1 to move from rest, the force *Fs* must be slightly larger than the force required to keep the object sliding at a constant velocity. This slightly larger force gives the coefficient of what is called static friction and the somewhat smaller force gives the commonly used sliding COF. However, it is common to use the static value for COF since it is almost always a good approximation. Remember, the equation (1) does not contain how much apparent contact area is shared between the 2 objects. This fact, which goes against common sense, is explained in detail in Lecture 2. **Table 1** lists the measured COF. Note the calipers in **Figure 1** showed (zoom in for better view) 0.35 in as the distance the tension spring stretched before movement started (then objects put back in initial positions for photo). The spring constant, called *k*, has already been measured as 5 grams (g) to cause a stretching of 1 in, so k = 5 g/in and COF = $\frac{5 \, x \, 0.35}{36.3}$ = 0.048.

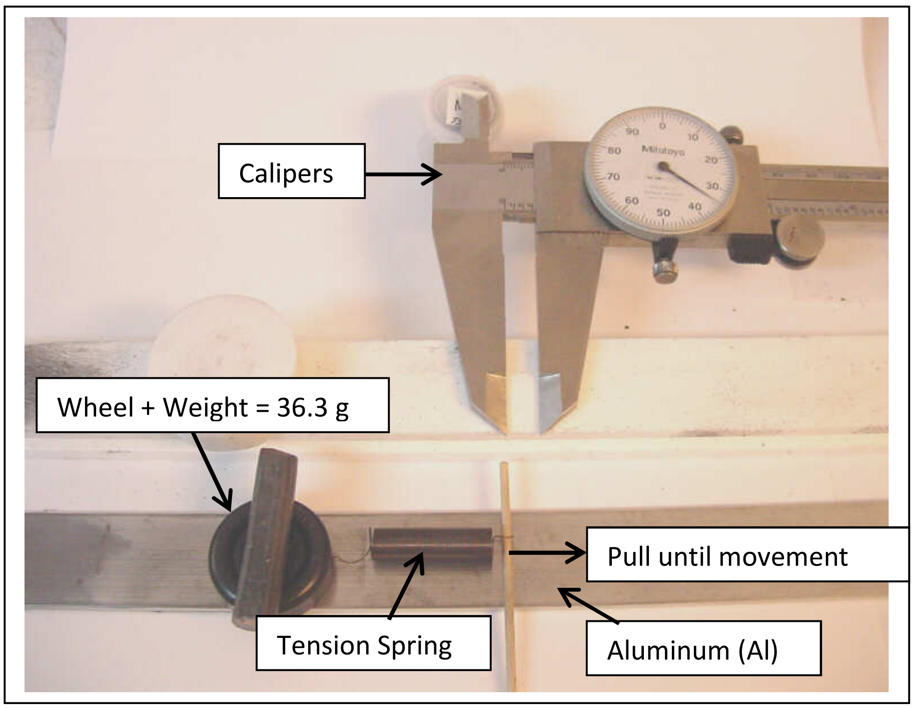

Figure 1 – Measuring the Coefficient of Sliding Friction (COF)

From **Table 1** we see that High Density Polyethylene (HDPE) is very low friction, even slightly better than Teflon®. This caused it to be chosen for reducing the frictional drag when a polystyrene (PS) wheel rubs the central guide strip. The PS wheel rubbing on bare smooth Al has a COF of 0.34 so this drag has been reduced to 0.039 or almost 90% less friction.

COEFFICIENT OFSLIDING FRICTION (COF)					
	Surface 1 Wheel	Surface 2 Track		Direction	COF
				DownTrack or CrossTrack	
Row	All Smooth	Mat'l	Type		
1	PS	HDPE	Smooth	Both	0.039
2	PS	Teflon®	Smooth	Both	0.040
3	PS	PS	Smooth	Both	0.31
4	PS	PE	Smooth	Both	0.34
5	PS	Al	Smooth	Both	0.34
6	PS	Al	Grooved	Cross	1.25

Table 1 – Showing the Coefficient of Sliding Friction (COF) for a polystyrene (PS) wheel against several surfaces.

Figure 2 shows how a 1/8 inch diameter HDPE insert can be pressure fit into a channel in the central guide strip of an aluminum racing lane.

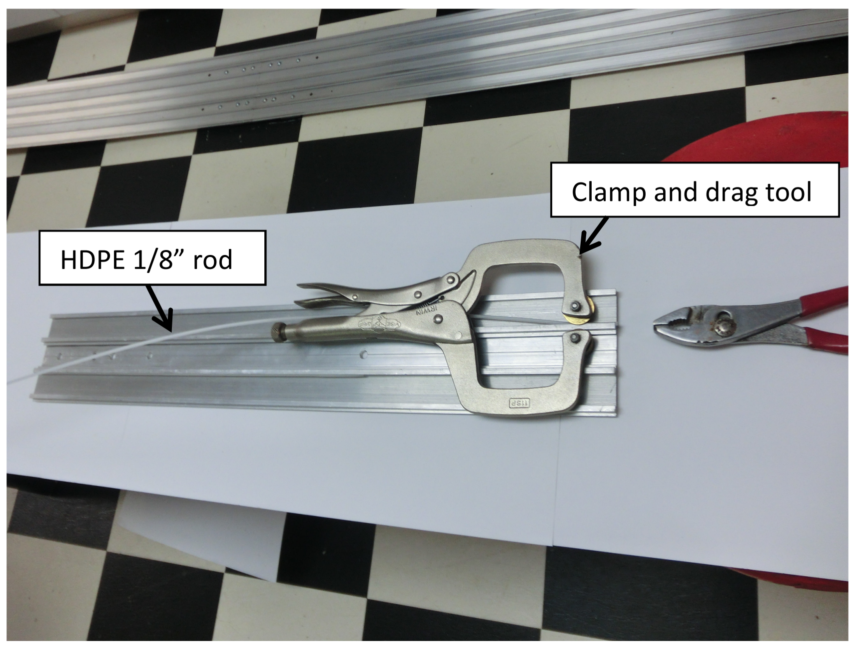

Figure 2 – Showing HDPE welding rod being inserted into channels on the central guide strip of a 2 ft long lane piece used for testing. The main 2 lane track is in the top background.

THE FINGERPRINT EFFECT

Suppose one licks the tips of the index and middle fingers to remove body oils, and then drags the two fingertips directly towards the chest with modest downward pressure on top of a fresh sheet of paper. Usually a vibration will be felt accompanied by a "squeak" as the fingertips move in the elbow direction. Next, move the fingertips left and right and less resistance will be felt. One theory has that the fingertip ridges themselves, aligned perpendicular to the motion, increase the ability to grasp objects, such as fruits, thereby providing an evolutionary survival advantage. And grooves on ladder steps are arranged perpendicular to motion to better resist the incipient slipping of the foot. So why not put small "micro" ridges parallel to the direction of travel on the running surface of a pinewood derby racetrack? This would resist any tendency for slippage left or right and allow the car to maintain the shortest trajectory towards the finish line. Sort of a built in automatic "rail riding" technique without the rubbing friction drag of an aluminum guide rail surface (COF = 0.34). Also, the HDPE guide strip insert just discussed would be needed less frequently as car wheels would tend to stay in the center of the running surface.

As shown in **Figure 3,** an extrusion profile with micro-ridges produced an aluminum lane with a serrated running surface. The extrusion also produced a channel for inserting standard size aluminum bar stock 0.0625″ (1/16) thick. The normal height of the guide rail above the running surface is 0.250″ (1/4) so the guide rail height is arranged to be 0.031″ (1/32) higher than 0.250″ when running on the serrated surface and this amount lower than 0.250 when running on the smooth flat surface. Also in **Figure 3 o**ne can see the ends of the HDPE rod inserted as a low friction bumper on the guide strip.

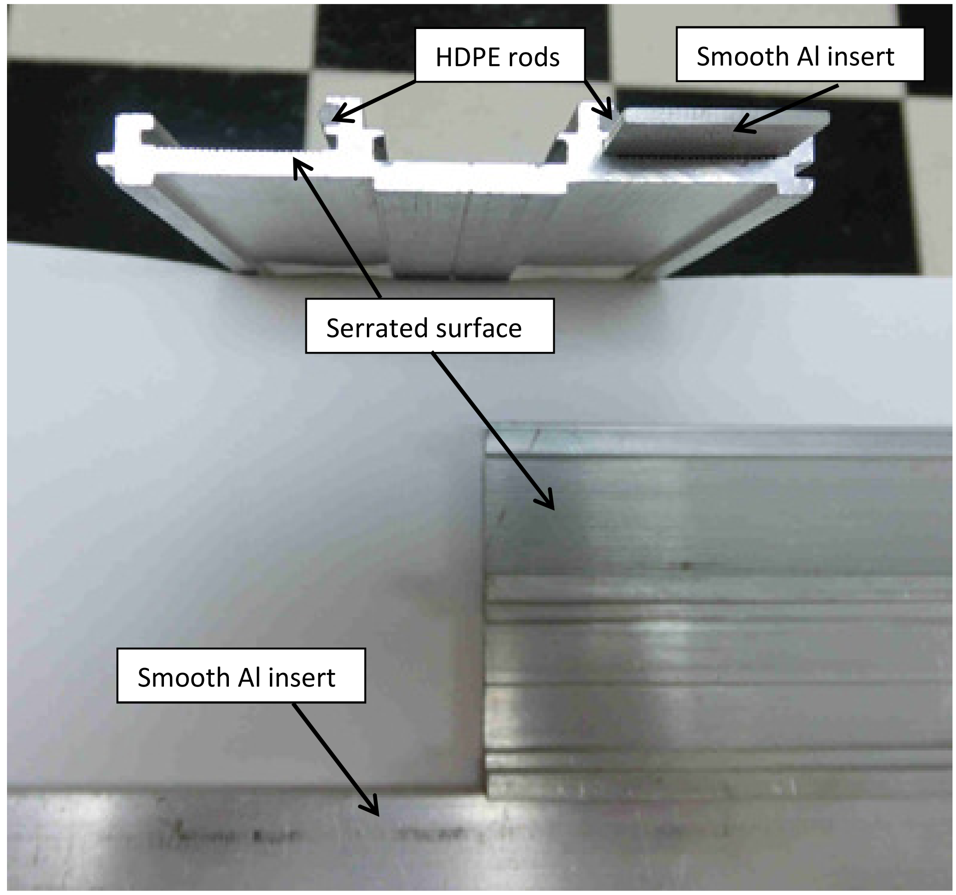

Figure 3 – Showing the micro-grooved or “serrated” running surface of the track with the option of converting to the prior art smooth aluminum surface with standard 1/16” x 1” x 8 ft inserts

Figure 4 shows the setup for measuring the cross-track COF on either the serrated surface or the smooth aluminum surface. The smooth surface showed the **Table 1** value of 0.34 but the serrated micro-grooved surface showed a value about 4 times larger at 1.25. So this is the mechanical version of the fingerprint effect and in the following lecture the actual performance of cars on this track will be tested. It is expected that if it requires 4 times more force to cause the weighted rear end of a car to swing side-to-side, then it should certainly undergo fewer excursions to bump the guide strip. Again, if one wishes to race on standard aluminum, or if one wants to try other surfaces like formica, simply insert strips of the desired material.

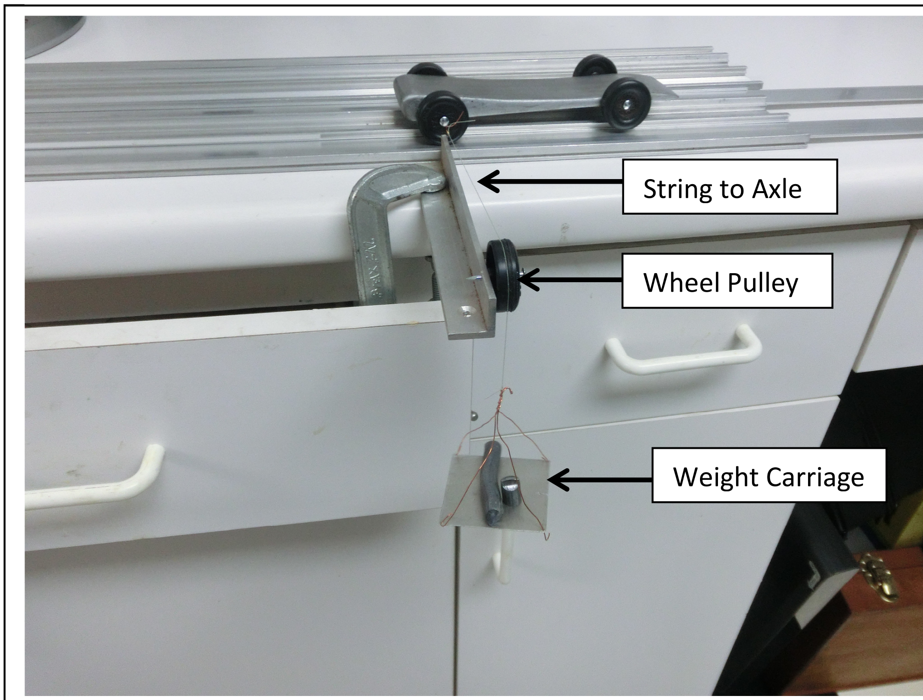

Figure 4 – Measuring the force required to cause cross-track sliding on the serrated and/or the smooth running surface

ROLLING FRICTION

Lecture 6 discusses rolling friction as graphed in **Figure 5**. **Figure 4** provides a model to help visualize rolling friction. The magnified sections of wheel and track show that as the wheel rolls to the left (no sliding in *x* or *y* direction) it compresses track material, and/or wheel material as well, depending on relative hardness. Later, as the wheel contact leaves this area, the bonds formed from compression must be broken, leading to tensile forces as the wheel surface leaves the track. These are the perpendicular "make and break" forces in the *z* direction only. Some of the energy required to compress material may be stored as potential energy (like compressing a coil spring) that can be recovered as a "push" upwards on the wheel as it rolls forward. However, all of these molecular motions generate heat, which shows up as an inability to recover all the mechanical work expended, just like sliding friction. Generally, the harder a material, the less rolling friction it will have. Regarding glass vs. aluminum, tempered glass is two to three times harder (and smoother) which accounts for less rolling friction on such surfaces.

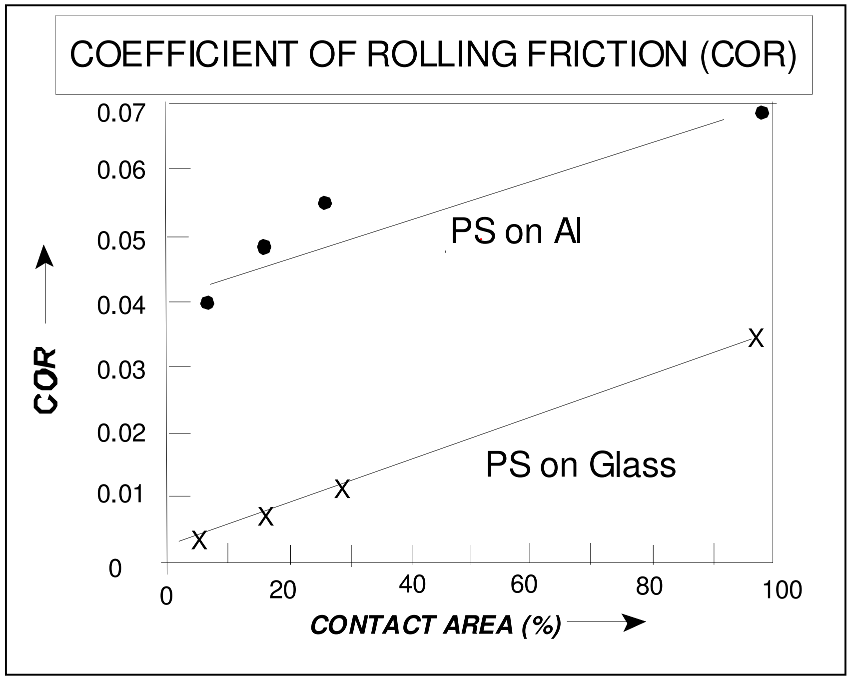

Figure 5 – Coefficient of rolling friction as described in Lecture 6.

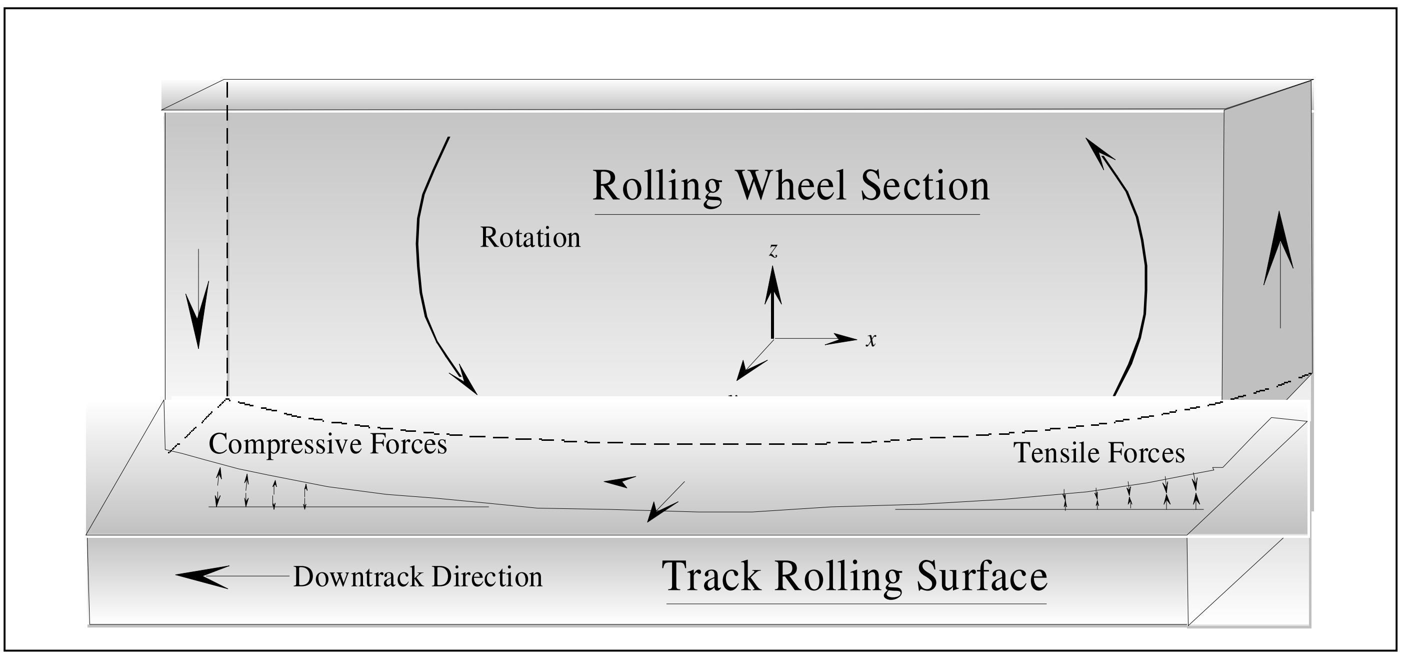

Figure 6 – Source of rolling friction as described in Lecture 6.

Ordinary sliding friction is caused by movement from tangential *x*, *y* forces opposite the sliding direction but rolling friction is really not this type. Sliding friction is not dependent on apparent contact area, see **Lecture 2**, but rolling friction is— more like an atomic Velcro® effect of making/breaking. So another benefit of the serrated rolling surface is to reduce the contact area to just a few percent, effectively eliminating rolling friction.

G-STOPPER

We have just seen how the Friction Controlled Track could increase car speeds. But stopping a car safely after it passes the finish detectors has always been a problem. The cars that start from a 4 ft height can pass the finish line at 16 ft/sec or 11 mph. The best prior art had to offer was the inclined central guide strip at the end of the horizontal run. This stopping method dates back to the early days of wooden race tracks but the principle is the same. Occasionally, and unfortunately, someone's prized creation would be launched through the air and be broken. Literally dozens of hours work by a parent and a child would be wasted. The fastest cars slide farthest up the inclined plane, and the speed we are adding in the friction-controlled track adds to the risk.

Figure 7 introduces the G-Stopper, a sliding carriage with a block of memory foam inserted. The lower part of the carriage slides in the lower central channel of the guide strip. The entire lane in front of the G-stopper is not shown for clarity but the direction of car travel would be into the photo. The memory foam absorbs the kinetic energy of motion of the car wthout rebound. Also the friction of the foam block bottom edges rubbing against the top of the guide rails reduce carriage travel. This slow motion **video** shows the G-Stopper in operation. Notice the smooth uniform deceleration exactly opposite the forward motion. Just slide the carriage back to its original position when car is retrieved.

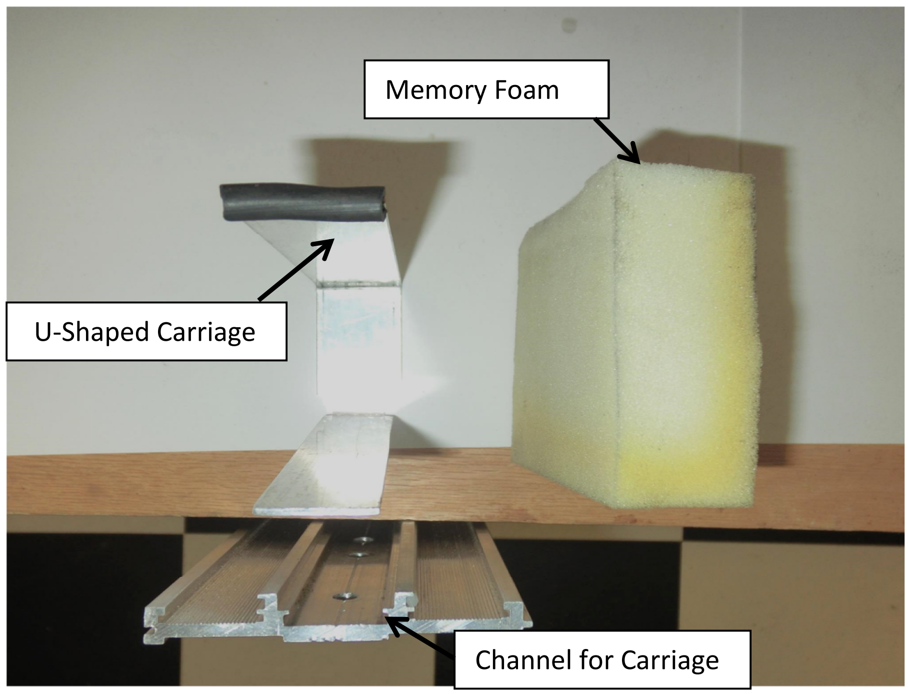

Figure 7 – The G-Stopper uses a sliding carriage carrying a block of memory foam.