POSSIBILITY OF MANUFACTURING OF RACE POLYURETHANE BUSHINGS USING RAPID PROTOTYPING AND PROTOTYPE MOLDS

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Abstract
This contribution deals about possibility of manufacturing using rapid prototyping and prototype silicone forms. Rapid prototyping process allows to manufacture prototype parts from various materials, what allows to create prototype forms for prototype molds from thermoplastic and thermoset material. Aim of this research was to obtain new knowledge of preparing prototype parts using rapid prototyping and prototype silicone molds. The parts – bushings of lower control arm and rear camber arm of trailing arm suspension were designed due the dimensions of arms and simulated to maximum calculated stress. After positive result, bushing prototypes were manufactured on Rapid Prototyping machine and stainless steel inserts and wraps on CNC lathe. Prototype form was manufactured from 2-part silicone using prototype inserts. Whole bushings were than tested on race track on track-day vehicle EK9, group Street Modified.

Key words: polyurethane bushings, rapid prototyping, race suspension, prototype moulds

INTRODUCTION
Rubber has traditionally been used for automotive suspension bushes. It has the advantages of low cost, is easy to work with, it can be used for a wide variety of applications and is able to provide a level of insulation between steel components. However, it has some significant disadvantages:

- rubber is vulnerable to abrasion,
- rubber will deteriorate when exposed to ultra-violet light and water,
- rubber will deteriorate when exposed to chemicals such as oil, petrol, salt, antifreeze, and other solvents and airborne contaminants.

All this causes the rubber to start to lose its elasticity and as importantly its resilience. In time rubber will lose the shape it was designed to be. The car’s suspension components start to move to a position different from the ideal, with a loss of handling precision and predictability and accelerated wear of other components and tyres.

In contrast, polyurethanes, especially those manufactured using cold pour/thermo setting processes, can be resistant to all of these problems and retain its original shape. The result is a suspension bush which will last a lot longer than rubber – and will perform consistently throughout its life.

Trailing-arm suspension
The trailing arm system is literally that - a shaped suspension arm is joined at the front to the chassis, allowing the rear to swing up and down. Pairs of these become twin-trailing-arm systems and work on exactly the same principle as the double wishbones in the systems described above. The difference is that instead of the arms sticking out from the side of the chassis, they travel back parallel to it.

Polyurethane as the material for bushings
Polyurethane is a term used to describe a wide ranging family of elastomers (any compound exhibiting the characteristics of natural rubber; stretchy and elastic). Depending on the formulation, urethane has a higher load-bearing capacity, greater tear strength, better compression set, greater abrasion resistance, tolerant to greases, oils and ozone and allows for more unique designs.
Rubber is the sap of trees found mostly in tropical climates. The sap is altered by mixtures of carbon (why it’s black) and mineral oils and various fillers. Polyurethane is completely chemical or man-made. Because rubber is a biodegradable product it is affected by ozone and will over time dry rot and degrade, while urethane will keep going and going.

There are many advantages to using PU for bushings:

- polyurethane can be made quite a bit firmer than rubber,
- polyurethane has a high resistance to oil contamination and doesn’t deteriorate quickly like rubber does when it comes in contact with oil.

Polyurethane engine mounts, transmission mounts and suspension bushings also reduce chatter, missed shifts or harsh shifting and improve overall throttle response. In extreme cases, worn rubber bushings can allow enough movement in the power train or suspension to cause serious damage to other critical and expensive parts and worn suspension bushings can lead to serious alignment and handling issues.

Polyurethane is an ideal material for performance suspension bushings, engine and transmission mounts. Rubber mounts and suspension bushings are still commonly used by vehicle manufacturers as they do provide a good compromise between comfort and durability, but in many applications, especially where performance is concerned polyurethane is a superior choice that improves performance as well as longevity.

Increased horsepower, larger wheel and tire packages, stiffer performance shocks and lowered suspension mixed with grit and grime push rubber bushings beyond design limits. Polyurethane bushings are firm enough to control movement and maintain alignment in sway bars, control arms, and other stressed suspension and engine components with much less harshness or resonance associated with solid metal or nylon bushings.

Most all urethane bushings and mounts are manufactured from a two part liquid cast system. It basically constitutes a polyol or prepolymer and a curative. Much like epoxy, when the two are mixed together, they begin to harden and form a solid material. This mixture is poured into molds where it forms the bushing, mount or pad when it turns a hard solid. Other ways include injection of melted urethane pellets. This is accomplished much like plastic injection molding where the pellets are melted and forced through a small opening into a closed mold cavity. Another way is to cast a solid round bar and then machine it to the desired shape.

The original rubber bushing or mount was fairly soft which helped to attenuate noise and vibration that is generated by the tires and road surface. Increasing the hardness of the bushing either with harder rubber, urethane or even bronze, will allow more transmission of noise and vibration. Some manufacturers formulate the hardness and design to reduce this effect. A softer urethane bushing allows the vehicle to perform better without the harshness, even over the same hardness rubber piece.

**Simulation and manufacturing process**

Our goal was to simulate and manufacture prototype polyurethane bushings for race day track car Honda Civic EK9. Whole original rubber bushing was examined, measured and new polyurethane race bushing was designed in CAD SW Solidworks 2012, shown on Fig.2.

![Fig.2 Design of prototype polyurethane bushings](image)

Next step was to explode the complete bushing to regular parts – PU filling, steel core and wrap. Whole part with added material properties was simulating at SolidWorks 2012 Simulation to detect the utility of prototype bushings. Bushing were loaded to force 2350N, as the maximum force measured at the top mount of rear trailing arm connected to chassis with adjustable rear camber arm by Saikuro. Maximum calculated von Mises stress stress was 2465826.8 Nm², what was far below the maximum strength of material $40 \times 10^6$Nm². Elastic modulus of selected material is $2409999872$ Nm² and Poissons ratio 0.3897. Distribution of von Mises stress is displayed on Fig. 3.

![Fig. 3 Distribution of von Mises stress](image)

URES Displacement of simulated prototype bushing is shown on Fig.4, where maximum calculated displacement URES was calculated to 4.214e-003.
After these tests and simulations prototype was considered as feasible for manufacturing and track use. BJB F-90 A/B red polyurethane with hardness 90 ShA.

Steel core and wrap were manufactured on CNC lathe GILDEMEISTER N.E.F.CT20 from 17400 stainless steel, shown on Fig 5.

Inner PU fill was manufactured by rapid prototyping on DIMENSION SST 3D Printer from ABS material. Model from STL format was processed at Catalyst software, 242 layers of 0.224mm were generated showed on Fig.6.

Manufactured prototype was brushed with P1200 wet sandpaper and sprayed with filler to obtain better finished surface and wet polished. Finished part is showed on Fig. 7. Center rods were made on lathe from Aluminum.

Whole form was than imbed with ShinEtsu KE-17 Silicone. After the silicone cured over 24hours, tho mold was taken out of acrylic, cutted to 3 parts and removed the pins and plastic master. After that, whole prototype form was completed together with stainless steel inserts manufactured before. Splitted form with inserts is shown on Fig. 9.

After completion of forms, the inner cavity was filled with two part BJB F-90 A/B red polyurethane. After 6 hours the mold was opened and prototype bushing was picked out. Whole part is shown on Fig.10 and Fig.11. Whole part was put
to laboratory oven with 60°C for 12 hours to obtain final properties and gates were cut off.

For more precise handling and firmer control on project vehicle, installing polyurethane bushings can make an enormous difference because they help to maintain the right alignment of caster, camber and toe, even on rough or uneven pavement. Polyurethane bushings can be used in a wide variety of suspension components and also in mounts for the body, engine and transmission.

Another advantage of polyurethane bushings is that they're virtually impervious to oil and other road contaminants. These units will not crush down or wear out like rubber bushings, and are designed to be free-floating, rotating 360 degrees, so the suspension can articulate fully without binding. In contrast, rubber bushings are often bonded to a metal shell and sleeve, and function with a twisting action that, when pushed to its limit, binds up instead of rotating freely like urethane units. Rubber bushings can even induce wheel hop from the spring-like action of the rubber twisting back and forth.

CONCLUSION

Rapid prototyping is one of favorite option for manufacturing prototypes and prototype inserts for polyurethane casting forms for its cost, effectiveness and accuracy. With this option, prototype race bushings for track-day car were manufactured from 90A red polyurethane. Installed bushings were driven about 80km on track and about 1500km on classic road and still have no cranks or other faults. Whole car is much stiffer and cornering at high speed improved. Car is now a bit more oversteer, but with use of ITR anti roll bars and semi-slick tires is behavior neutral. Time at track day on Slovakia ring improved to time 3:08:720 at track variant N4, what is more than 5 second better than best time of this car. Next possible improvement using rapid prototyping and rapid tooling can possible be manufacturing of camber arms and control arms from strengthened aluminum alloy on CNC mill for obtaining less weight and better traction.

References


This paper is the result of the project implementation: Technological and design aspects of extrusion and injection moulding of thermoplastic polymer composites and nanocomposites (PIRSES-GA-2010-269177) supported by The international project realized in range of Seventh Frame Program of European Union (FP7), Marie Curie Actions, PEOPLE, International Research Staff Exchange Scheme (IRSES).