the use	
Vehicle	**application**
In General	all systems
combustion engine	fuel system
	turbo system

	Exhaust Gas Generation system
	exhaust particle filter system
	Exhaust brake system
	engine coolant
chassis	hydraulic brake system

e of fluoropolymers in automotive s

fitment trend and key technical drivers
.increasing durability by reducing total CO2 footprint of vehicle .increasing fitment of PHEV where packing is becoming smaller due 2 drivetrains (ICE and electrical) . Increasing fitment rate of full BEV wheree no ICE / cumbustion engine is present
.decreasing permeation legislations of HC fuel molecules .increasing (aggressive) bio fuel content. .increasing temperture due tighter vehicle packaging (hybrids) , more turbo and direct inject technology . Lower extractables materials for for hybrid vehicles
.increasing fitment (40 % to 85 %) due better fuel ecocnomics driven by tighter CO2 emision legislations .increasing operating temperatures due tighter packaging

high fitment (50-80 %) due low NOX emission legislations
100 % of diesel and increasing for gasoline
90 % fitment on trucks
100 % for all combustion engines (ICE) , but trend to lighter materials to save weight due CO2 emisison legislations
increasing fitment rate of flexible hose element near by hydraulic brake cylinder due tolerance stackup driven by tigher packaging and shorter brakedistance legislations

systems and the disadvantages of alter

fluid transfer lines made out of fluoropolymer (FP) materials
FP properties : PTFE . applicable : PTFE : -200 C / + 260 C, .virtually inert to all chemicals known .uneffected by light, UV and oxidation .resistence to aging and weather condition .ultra purity, no extractables .no surface fouling and discolouration .non-flammable, UL94V0 .lightweight .superior flex life , 18 Million cycles .ultra low fuel permeation .lowest coefficient of friction of any solid material known , non sticking, selfcleaning . no aging and unlimited shelflife . preformable . resistance to any solvent known .very good electrical properties and high resistivity
.inner coating of ETFE for fuel transfer hoses and tubes .inner liner for fuel transfer jumper lines chassis to engine
inner liner of FP for oil lubrication- and water coolant transfer lines

.inner liner of FP for pressure sensor lines to detect clocked heat exchanger .inner liner of FP for actuation lines for bypass valves
.inner liner of FP for pressure sensor lines to detect clocked particle filters .inner liner FP for fuel injection to burn / clean filters
.inner liner of FP for actuation lines to activate brake valve
.inner liner of FP for water coolant transfer lines in situations of long life additives in coolant and high operating temperature of 130 C . Inner liner of FP for oil coolant transfer lines and high operating temperatures of 150 - 170 C
.inner liner of FP for hydraulic oil transfer brake lines

native materials/technologies
specific key material /design requirements
. Lower CO_2 footprint for manufacturing of the components . Lower CO_2 footprint of used materials in the components . Lower weight to save fuel / reduce CO_2 in the components . Increase lifetime components to match lifetime vehicle to reduce CO_2 by spareparts . Increased safety for driver and human being
.low to zero HC permeation to meet legislations .high chemical resistence with biofuels (B30/B100/E20/E85/M15/CNG)and to corrosion .higher operating temperatures upto 140 C .low to zero extractables , high purity to avoid injector blockages, spcaially with hybrids . Low burnthrough/ fire resistence to gurantuee safety/ avoid fire .high resistence to noise distribution (from DI pumps) and vibration to meet noise legislations . Flexible hose element to absorb tolerance stack up due downsizing, jumping between engine -chassis and cracking during crash
.high operating temperatures up to 260 C for oil lines (turbo itself upto 850 C) .flexible hose element to absorb tolerance stack up due downsizing .high resistence to vibration and movement to avoid cracking line and fire .good cleanliness / purity to avoid oil channel blockages and fire .outer diameter hose/tube to enable downsizing and CO_2 reduction

.chemical resistence to exhaust gas and corrosion . High operating temperatures up to 260 C . High resistence to vibration and movement to avoid cracking of line and fire . Flexible hose segment to absorb tolerance stack up due to downsizing and packaging . very low volumetric expansion to keep good control on the NOx emmisison
.chemical resistence to exhaust gas and corrosion . High operating temperatures up to 260 C . High resistence to vibration and movement to avoid cracking of line .low to zero extractables , high purity to avoid nozzle injectro blockage .Low burnthrough/ fire resistence to gurantuee safety/ avoid fire . Flexible hose segment to absorb tolerance stack up due downsizing and movements between the modules .low to zero HC permeation to meet legislations .high chemical resistence with biofuels (B30/B100/E20/E85/M15/CNG)and to corrosion
. High operating temperatures up to 260 C . High resistence to vibration and movement to avoid cracking of line . Flexible hose segment to absorb tolerance stack up due downsizing and movements between the modules
.good chemical resistence agaist long life additives in the coolant medium .hydrolyses resistence at relative high temperatures upto 120 Cfor water coolant medium .high operating temperatures upto 150 - 170 C for oil lines .flexibility to absorb tolerance stack up between the various modules
. Very low volumetric expansion for good response time and powerful brake .high flex-life > 150.000 - 300.000 cycles .meeting impulse requirements .resistence against water absorption / penetration to avoid contamintion and slow braking response .flexibility to absorb tolerance satck up between the system modules and chassis vibration . additional for two-wheelers resistence to UV, weathering and road conditions

steel (stainless steel smooth or corrugated)
. Not flexible, ie safety risk . No purity, risk not meeting legislations . Heavier (+60 %) , more CO_2 emission . Low flex life, ie safety risk
. Steel is possible for under chassis and on engine itself but will pass more noise form pump and more weight on vehicle . ie more CO_2 . Is not prefarable is will crack with crash, thus safety issue . not possible as jumper line will crack due realtive big movement between engine and chassis
. risk of cracks due engine/turbo vibration and mounting issues under tension and causing fire, specially on larger engines like for trucks and buses. . Add's more weight, ie more CO_2

. is possible for the sensor lines, needs redesings and validation 5-6 years .not possible for the actuation lines but risk of cracks due engine/turbo vibration and mounting issues under tension and causing fire, specially on larger engines like for trucks and buses; this requires redesign of engine platform , which takes about > 7 years for OEM . . Add's more weight, ie more CO_2 . possible are electronic actuated valves which eliminate the actuation lines , but then the elctronic must be cooled , ie need for coolant lines , which gives same material issue as in previous point mentioened , thus not possible
. potentially possible for the sensor lines , this requires some redesign of engine platform , which can take 2-3 years for OEM . . Add's more weight, ie more CO_2 .Not possible for the fuel injection line risk for cracks (causing fire) due movement between exhaust injector nozzle and fuel dosenunit ; complete redesign will takes 7 years for next engine platform
. Not possible due risk of cracks due engine/exhaust vibration and movements ,specially on larger engines like for trucks and buses. . Add's more weight, ie more CO_2
. Possible but risk of cracks due engine/exhaust vibration and movements ,specially on larger engines like for trucks and buses. . Add's more weight, ie more CO_2
90 % of the hydraulic is made out of steel , but a flexible jumper line is needed to absorb tolerance stack ups, else risk for cracks and is safety critical system

alternatives and disadvan
rubber
. Lower operating temperature (only upto 180 C) , safety risk . Soft, slow response time , safety risk . Low purity, risk not meeting emission legislations .Lower permeation resistence , risk not meeting legislations .low electrical resistivity (risk only in case of Fuel Cells) , .Lower chemical resistence , risk of safety .Larger, higher OD/ID and weight (+25 %) , more CO2 emission
. not possible due not meeting HC permeation requirements in combinations with biofuels . Problems and risk with cleanliness/ purity , ie blocking injectors . Having higher CO2 footprint as material , but also due higher weight . Having larger OD diameter for same fuel flow , thus gives packaging issues
. Hindering downsizing of engines due packaging issues (due larger OD) and/or in combination with capable of operating temperatures upto 180 C .hydrolysis aging issues for the coolant lines in case of downsized engines / hybrids vehicles

. Not possible , it will hindering the downsizing of engines due packaging issues and/or in combination with not meeting the operating temperatures as rubber only goes upto 180 C; the exhaust gases are upto 700 C and the environment of the bypass valves on the EGR easily can see upto 250 C , hot oil leaking will cause fire .possible are electronic actuated valves which eliminate the actuation lines , but then the elctronic must be cooled , ie need for coolant lines , which gives same material issue as in previous point mentioened, thus not possible
. Possible for sensor line .Not possible for the fuel injection ,rubber will not meet the operating temperature as rubber only goes to 180 C
.Not possible , rubber will not meet the operating temperature as rubber only goes to 180 C
.possible for water coolant . Not possible for most oil coolant lines as rubber just goes up to 180 which does not give enough safety margin
. Not possible as rubber is too soft , the volumetric expansion is to low , which leads to slower response times,, thus longer braking way

tages against Fluoropolymers
Silicon
. Lower operating temperature (only upto 220 C) , safety risk . Soft, slow response time , safety risk .Lower permeation resistence , risk not meeting legislations .Lower chemical resistence (hydrolyses aging) , risk of safety .Larger, higher OD/ID and weight (+ 25 %) , more CO2 emission
.way too expensive . To soft to meet burstpressures, packging and crach requirements, thus safety problem as is fuel transfer lines
.too expensive .possible for oil lines for some engines as capability silicon only upto 220 C .not possible for turbo coolant lines due hydrolysis issues at higher temperatures

.too expensive .possible for some engines as capability silicon only upto 220 C , . not possible because of low volumetric expansion , ie no good control / response time on valve , thus no meeting emission reuirements . possible are electronic actuated valves which eliminate the actuation lines , but then the elctronic must be cooled , ie need for coolant lines , which gives same material issue as in previous point mentioened , ie not possible
.possible for sensor lines , .Not possible for the fuel injection , Silicon not will meet the operating temperature as silicon only goes to 220 C
. Possible but silicon only goes upto 220 C , so redesigns on engines are needed , however brakepower on trucks are safery critical , so extensive validation needed, > 3 year
possible , but far too expensive
. Not possible as Silicon is too soft , the volumetric expansion is to low , which leads to slower response times, thus longer braking way

Other polymer plastics
. Lower operating temperature (almost all upto 140 C) , safety risk . The one with the highest operating temperature capabilities are PPS and PEEK wih respectively upto 180 C and 240 C , but these are very rigid, thus not flexible as hose , showing very low elongation @ break (< 50 %), thus safety risk . Lower burnthrough / melt , safety risk .lower impulse , safety risk . Lower aging resistence , safety risk
. possible as today also Nylon Multilayer materials are used . but depending on the OEM these Nylon multlayer materials are not meeting the burnthrough and fire resistence / safety, this is specially the case for cars produced in EU for export EU . . Nylon Multilayers are not compatible with all biofuel @ high operating temperature and permeations requirements , which is specially the case for cars produced in EU for export EU
. No other plastic will meet the operating temperature respectively they having a softening and melting point below or to close to 240 - 250 C .

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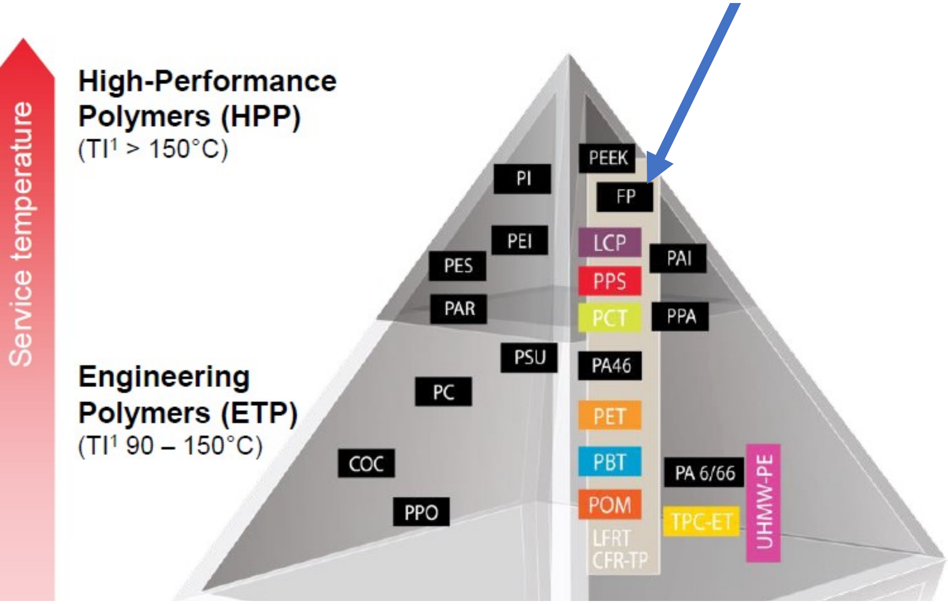
PPS or PPA aref for <u>some</u> oil line applications possible , but are less flexible , they do age, become stiffer ,   needs redesigns ,

. For several vehicles and 2-wheelers is possible , but low-mid performance brake systems , else other polymer plastics are not meeting or not having enough safety margins related to impulse tests and flex life



LCP – Vectra®/Zenite®

PPS – Fortron®

PCT – Thermx®

PET – Impet®

PBT – Celanex®

PBT Alloy – Vandar®

TPC-ET – Riteflex®

POM – Hostaform®/Celcon®

UHMW-PE – GUR®

Long Fiber and Continuous Fiber Reinforced Thermoplastics*

LFRT – Celstran®, Factor®