Development of a high molecular weight EP(D)M for engine mounts

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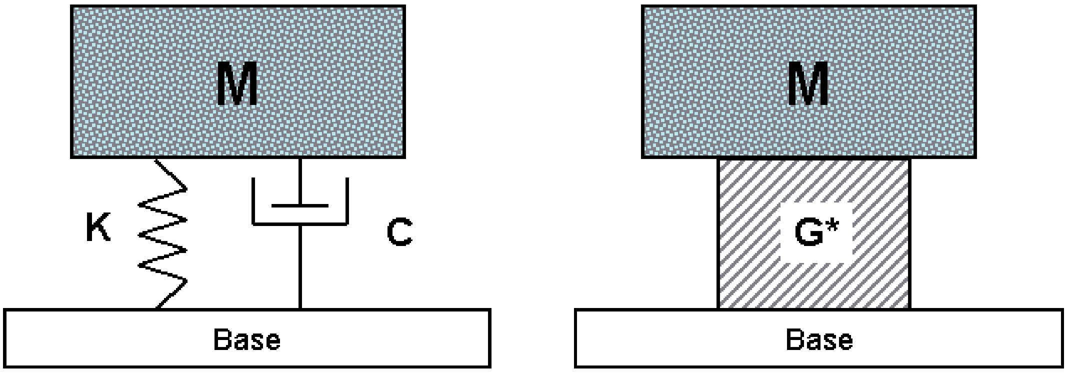
In nowadays vehicles the engine mounts are subjected to increased temperatures due to a lower availability of empty spaces in the hood. Therefore the automotive industry is looking for alternative materials for substitution of NR. Polimeri Europa developed at lab scale a high molecular weight EPDM that shows good vibration isolation, mechanical and ageing properties

Damped linear single degree of freedom model



Conventional single degree of freedom damped system

Elastomeric equivalent of the conventional system

Typical engine mount requirements

- High static load capacity (the weight of the engine) with low creep
- A static-dynamic performance to avoid the engine being shaked by starting and braking ($K'_N/K_S \approx 1$)

- **High damping at low frequencies and high amplitudes:** it must be able to control the response of the power unit to uneven road surfaces and shock excitation

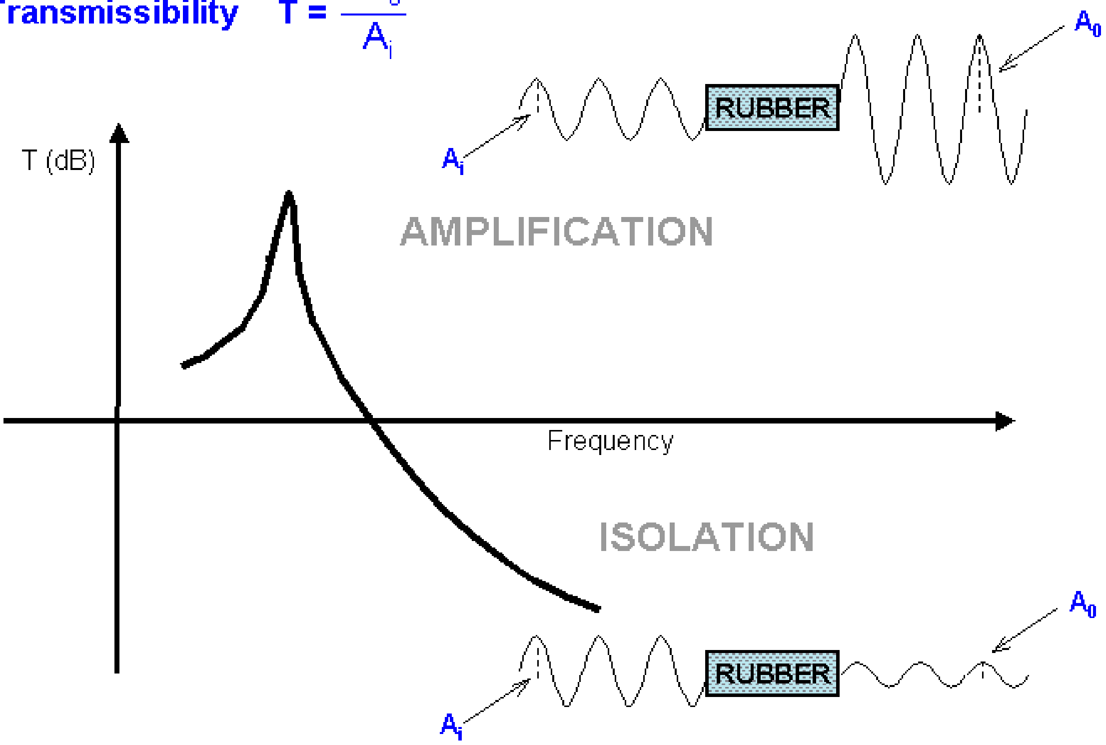
- **Low stiffness at high frequencies and low amplitudes:** the power unit is the main source of noise and vibration and should be acoustically decoupled from the vehicle body structure and the mounting system should provide adequate isolation of the inherent mechanical vibration of the power unit

- **Dynamic performance independent of temperature between -30 °C to 120 °C:** in the hood the elastomeric parts are subjected to high temperatures owing to a lower availability of empty spaces

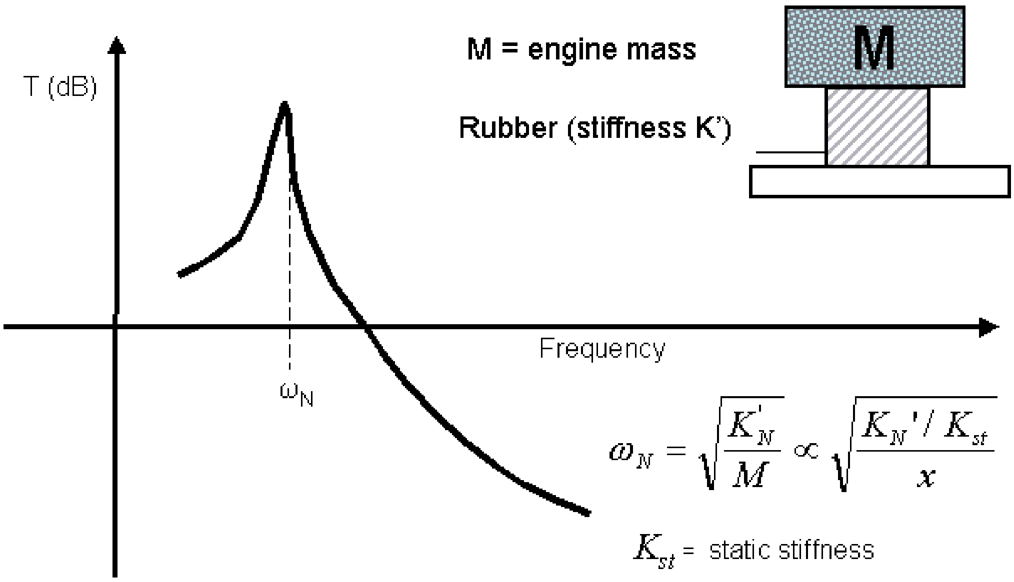
- **Low permanent set at high temperature and no effects of ageing on performance for many years**

- **Fatigue performance**

Transmissibility $T = \frac{A_0}{A_i}$



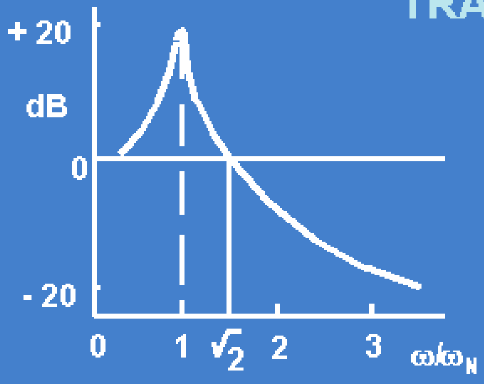
Transmissibility $T = \frac{A_0}{A_i}$



$$\omega_N = \sqrt{\frac{K_N'}{M}} \propto \sqrt{\frac{K_N'/K_{st}}{x}}$$

K_{st} = static stiffness
X = static deflection

TRANSMISSIBILITY



$$T^2 = \frac{1 + \tan^2\delta}{(1 - \omega^2 K'_N / \omega_N^2 K')^2 + \tan^2\delta}$$

a) $\omega = \omega_N$: $T = (1 + \tan^2\delta / \tan^2\delta)^{0.5}$, T decreases if tan δ increases.

b) $\omega >> \omega_N$: $T \approx (\omega_N^2/K'_N)(K'/\omega^2)(1+\tan^2\delta)^{0.5}$

so K' has to be low and increase only slowly with ω and tan δ very low

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From the equation $\omega_N = \sqrt{\frac{K'_N}{M}} \propto \sqrt{\frac{K_N' / K_{st}}{x}}$

given M and ω_N it is possible to evaluate K'_N and K_{st} and therefore a range of hardness:

45 ÷ 50 Shore A.

REQUIRED PERFORMANCE FOR CURED RUBBER COMPOUND:

Hardness 45 ÷ 50 Shore A

Good mechanical properties

To ensure optimal vibration isolation (very low transmissibility):

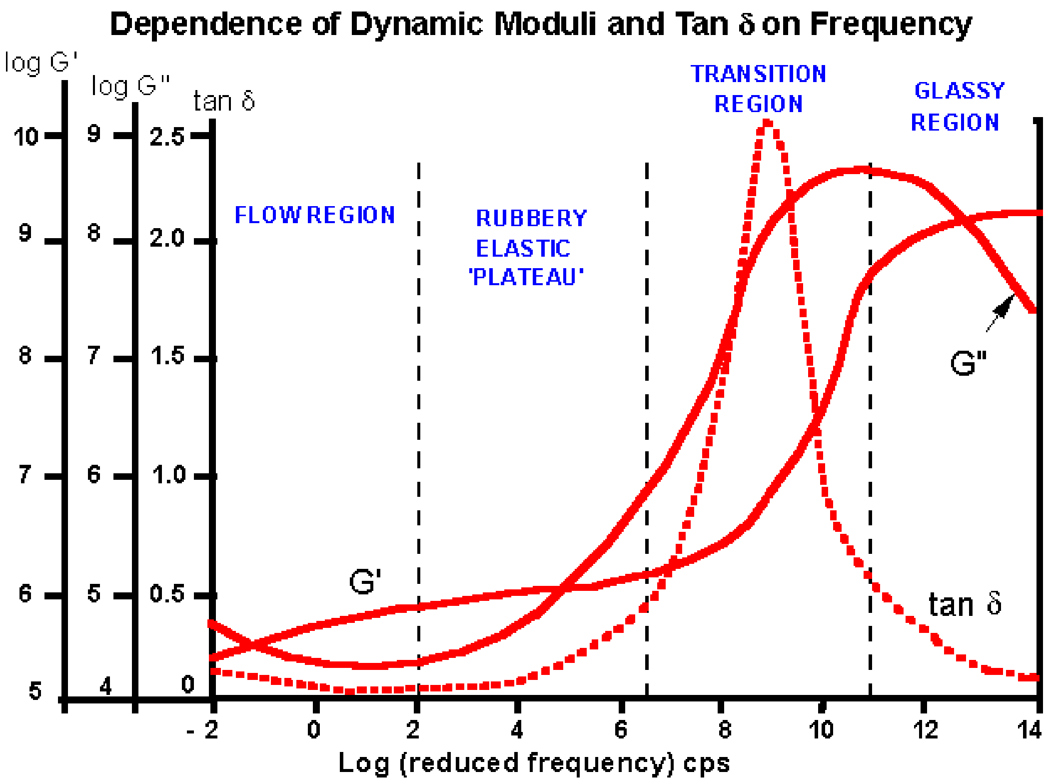
1) Low dynamic to static stiffness ratio
2) Very low damping (above natural frequency)

Oustanding ageing properties

To meet all these requirements, we developed:

a) A proper EPDM structure

b) An optimized formulation



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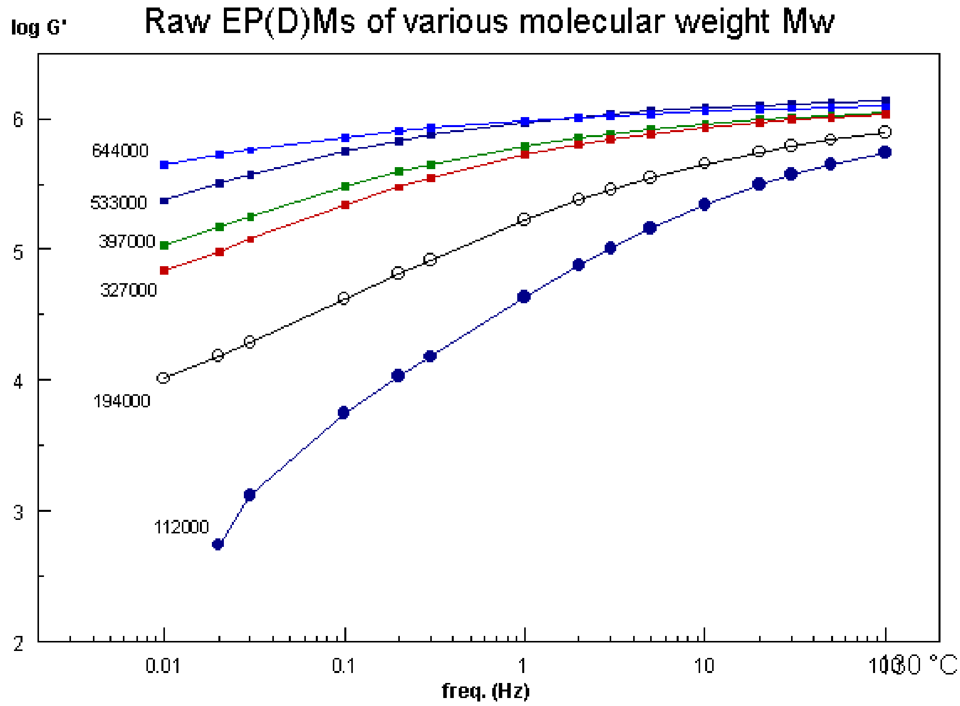
High Mw → low modulus vs frequency slope → low T



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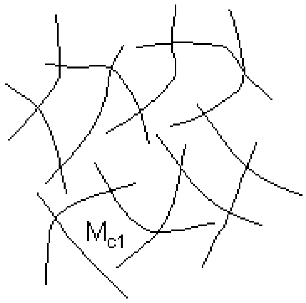
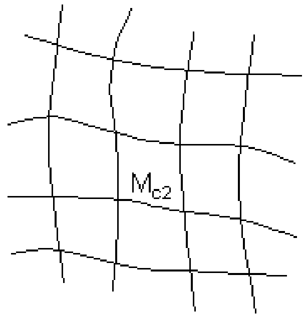
High Mw → tan δ very low → low T

M_{w1} $\qquad$ $M_{w2} > M_{w1}$ ($M_{w2} \sim 2\,M_{w1}$)



For the same ν: $M_{c2} = M_{c1}$



14 chains, 28 d-ends and 14 crosslink points

8 chains, 16 d-ends and 16 crosslink points

Flory: $\nu_e = \nu\left(1 - \frac{2M_c}{Mw}\right)$ $\qquad$ $M_{w2} > M_{w1} \rightarrow \nu_{e2} > \nu_{e1}$

less dangling ends → lower tan δ

EP(D)M structure

Oil extended terpolymer ~ 40 % $\qquad$ ML 125 °C > 56

% C3 ~ 32 (amorphous, balance between low ethylene and mechanical properties)

High ENB = 7-8 % (high crosslinking density)

Mw ≥ 500000

Mw/Mn ≤ 2.2 (narrow MWD means uniform crosslinking density, well distributed ENB)

EP(D)M optimized formulation

1) Processability of high Mw → polymer oil extension

2) Hardness 45 ÷ 50 Shore A → low carbon black loading

3) Low K' and tan δ → low surface area black

4) Injection moulding article → sulphur curing system

Central composite experimental plan:

3 variables (total carbon black loading, FEF/SRF, oil)

20 compounds

↓

Optimized (FEF based) compound

	EP(D)M	Target
Hardness (Shore A)	50	45 ÷ 50
T.S. (MPa)	15	> 18
E.B. (%)	460	> 400
Tear Resistance (N/mm) (DIN 53507 A)	6.4	> 7
Compression Set (%) (ASTM D395) 22 h, 100 °C	15	< 30
Compression Set (%) (ASTM D395) 22 h, 125 °C	32.5	< 42
K'_{150}/K_{st} (CUNA NC 953)	1.6	< 1.8
Tan δ (15 Hz) (CUNA NC 953)	0.105	< 0.1
Tan δ (150 Hz) (CUNA NC 953)	0.095	< 0.15

CONCLUSION

1. Polimeri Europa developed on a lab scale a promising high Mw EP(D)M ideal for engine mount application.

2. An optimized sulphur based formulation was studied and tested giving acceptable mechanical and dynamic properties and outstanding aging properties.