STABILIZER BARS – FLEXIBLE MOUNTING

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Summary

Stabilizer bars are mounted in motor vehicles by means of flexible bearings situated in the back part. The purpose of such bearings is to fasten the stabilizer bar and to link it with both the vehicle body and axis. The purpose of an additional bearing rigidity is to improve the stabilizer bar parameters, thus it increases the stabilizer bar performance when cornering. The article outlines methods widely used for mounting methods and strength calculations of stabilizer bar, FEM computations of the clamp and the flexible bearing of stabilizer bar L405VA. A proper construction and the selection of parameters influence the strength properties, the weight, durability and reliability as well as the selection of an appropriate production method. An improper preparation of Finite Element Method calculation models consequently leads to wrong results. It is particularly difficult to interpret the results and to find an error if we do not have a comparative calculation base (such as results of fatigue tests, analytical strength calculations). The article contains general instructions for construction of flexible mounting.

Keywords: stabilizer bar, flexible mounting, construction

1. Introduction

The mounting of a stabilizer bar consists in its simplest form in fastening its arms each to a suspension arm which for this purpose must be disposed principally in the lengthwise direction of a vehicle. In addition, per arm, two mostly rubber–cushioned clamps or, in case of rectangular arm rolling, two screw connections by means of simple punch holes are designed. Fig. 1a shows such versions for various axle structures. This type of connection, however, is only rarely used nowadays. Today, stabilizer bar suspensions in which the back is pivot – mounted at two points (Fig. 1b) of the vehicle body or the axle by means of rubber or plastic bushings and the arm ends are pin–jointed in various ways with the axle or the body are generally used. They are versatile and therefore can be found in by far most cases.

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The requirements for the back mounting of stabilizer bars are widely varied: On the one hand, considerable forces must be transmitted, on the other hand, it should preferably occur without secondary springing, the bearings must not cause noises or damage the stabilizer bar surface. Furthermore, the axial forces are to be taken up in the direction of the stabilizer bar back in order to prevent lateral shifting of the stabilizer bar [2, 3].

In principle, the following types of stabilizer bar mounting on the vehicle body are distinguished:

- clamped (force fit),
- adhesive (material bonding, pre-vulcanised elastomer elements),
- slide bearing (bushing),
- rolling bearing (e.g. groove ball bearing).

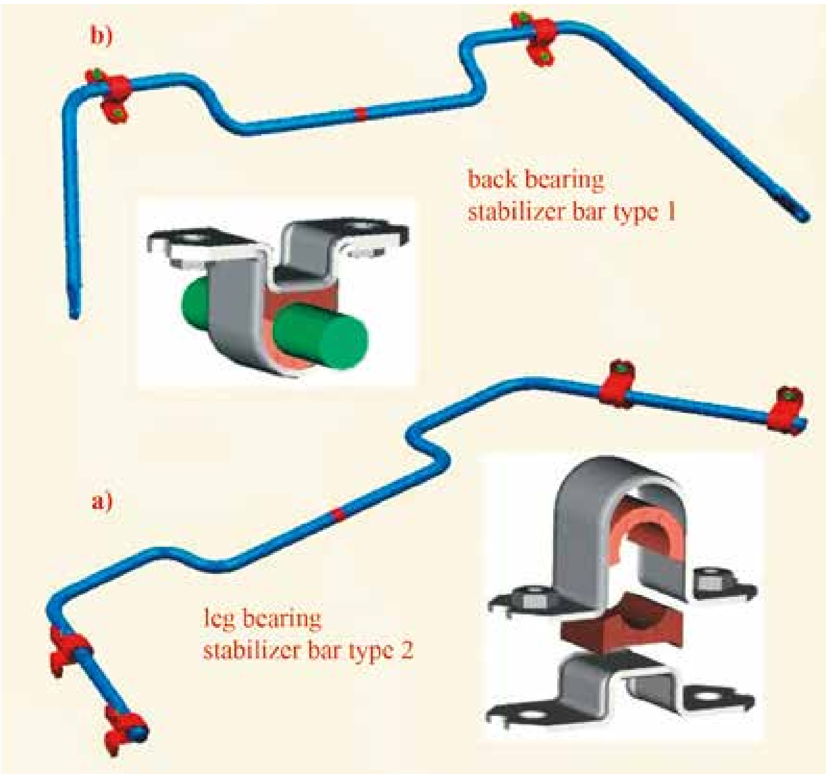

Fig. 1. Bearing arrangement of a stabilizer for a vehicle [2, 3, 9]

2. Back bearings

2.1 Back bearings – clamp bearings

Features:

- Bearings are, position-oriented, mounted under high pressure (force fit between rubber and stabilizer bar),
- No relative movement between stabilizer bar surface and back bearing. The twist of the stabilizer bar is taken up by deformation of the rubber only (secondary spring rate),
- Axial protection of the stabilizer bar by force fit,
- Penetration of dirt and moisture possible.

The secondary spring rate is determined by the applied rubber volume and its hardness. As a rule, the bearing is pretensioned to such extent that smaller rotations are taken up in the rubber only, while only greater rotations lead to slipping through. The axial displacements are prevented by the stabilizer bar running into the rubber bearing. In addition, the stabilizer bar bending begins already in the bearing [2, 3, 6, 9, 10] (Fig. 2).

2.2 Back bearings – adhesive bearings

Features:

- Rubber bonding process like in conventional vulcanization, but in a different order. Bonding of pre-vulcanized rubber to prepared metal part by „tempering",
- In contrast to the clamped rubber bearing (force fit), the connection between the stabilizer bar and the elastomer is realised by material bonding (Fig. 3),
- Bonding agent system like in conventional vulcanization,

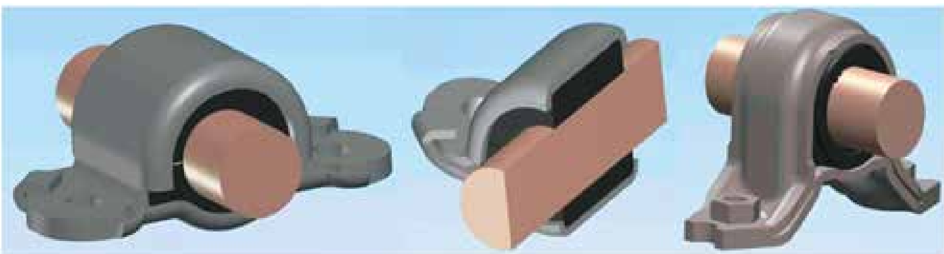

Fig. 2. Example of bearing for stabilizer bar – clamp bearings

- Bonding agent cross-linker acts on the remaining free valences in the already cross-linked elastomer,
- Quality of the rubber-metal bonding corresponds to the conventional process, i.e. the adhesion coefficients and fracture patterns are identical,
- Possible dynamic twisting of ± 25°,

- Secondary spring rate by elastic deformation of the rubber [2, 3, 6, 9, 10] (Fig. 4).

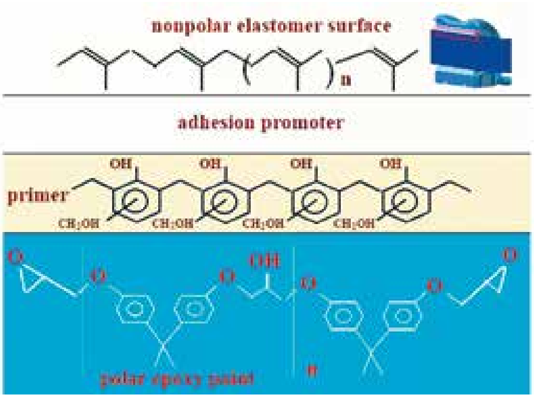

Fig. 3. Chemical process of bearing fastening (adhesive mounting) [9]

Fig. 4. a) Example of stabilizer bar mounting – adhesive mounting
b)Examples of flexible bearings used in adhesive mounting

Advantages:

- axial support without additional protection,
- improved durability (no wear by dirt due to material bonding),
- no squeaking noises.

Disadvantages:

- additional process step / cost,
- expensive servicing (replacement of bushings only with the stabilizer bar),
- expensive recycling process.

2.2.1 Bonding process – adhesive primer / adhesion promoter

For bonding the chemically incompatible reactants elastomer and epoxy paint, the cross-linking agents – primer and adhesion promoter – are necessary [2, 3, 6, 9].

Primer contains: phenolic resins, chlorinated natural rubber, zinc oxide, silicic acid, titanium dioxide. The structure of phenolic resin shows a great structure similarity to epoxy paint.

Adhesion promoter contains: chlorosulfonated polyethylene, chlorinated natural rubber, zinc oxide, silicic acid / stearic acid, carbon black, cross-linker (DNB = dinitrobenzene).

Reactions: cross-linking of chlorosulfonated polyethylene.

A further variant, which is increasingly used, is to permanently connect the rubber bearing with the stabilizer bar and optionally with the bearing clamp. The direct vulcanization of the rubber on the stabilizer bar is rarely used in order to do this. The machines must hold the entire stabilizer bar, which excludes the possibility of manufacturing many parts at the same time. Due to long vulcanization times of several minutes, a cost-effective manufacturing is inconceivable. The subsequent varnishing is also problematic due to the unavoidable joint with the rubber. A better solution is to apply the rubber bearing after varnishing the stabilizer bar and join with the clamp preferably in one operation. For this purpose, pre-vulcanized rubber bearings are required which with a defined pressure, which is preferably applied with the bearing clamp, are mounted in the correct position on the stabilizer bar. Subsequently, the bearing is completely vulcanized (Figs. 5 and 6).

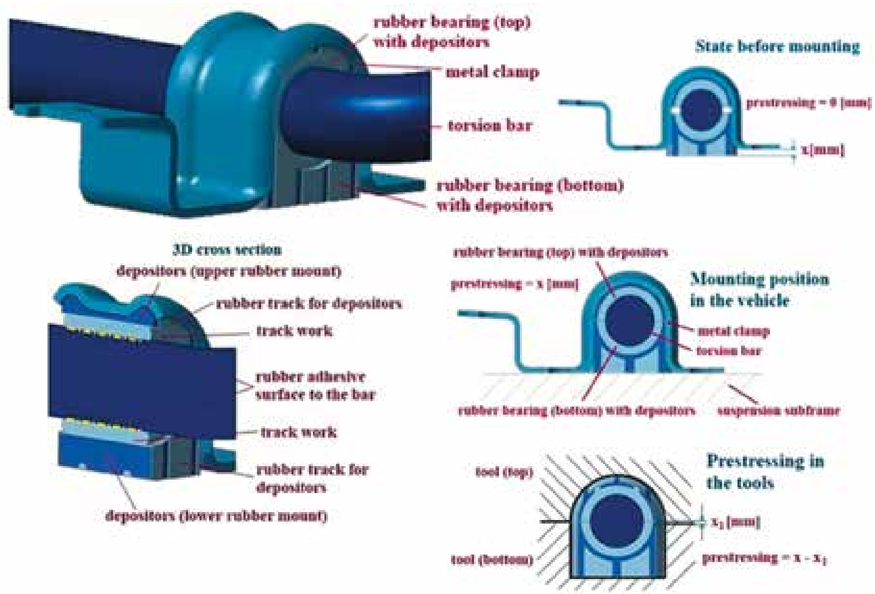

Fig. 5. Device for the vulcanization of flexible bearings (adhesive mounting, Figs. 3 and 4) [2, 3, 9]

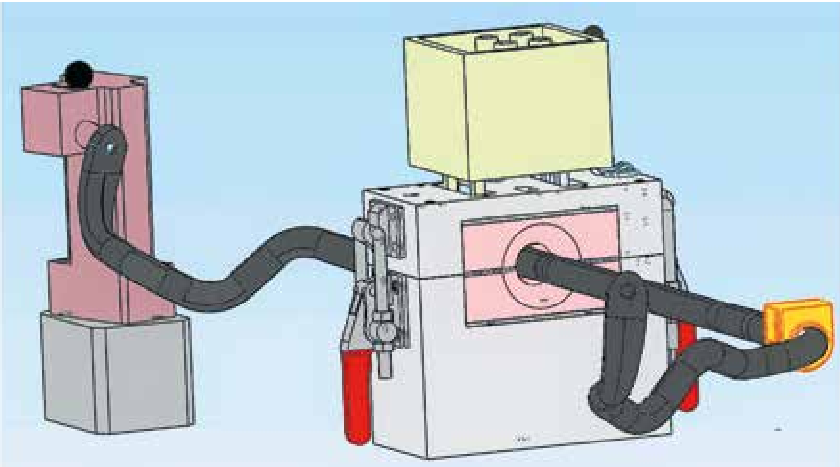

Fig. 6. Device for the vulcanization of flexible bearings (adhesive mounting, Figs. 3 and 4)

2.3 Back bearing – slide bearing (back bearing with plastic sleeve)

Features:

- The plastic sleeve is, position – oriented, injection moulded on the varnish. Then the rubber bearing and the clamp are mounted,
- Easily twistable, low-friction back bearing (no/low secondary spring rate),
- Axial protection by sleeves with stop collar,
- Water and dirt can penetrate between plastic sleeve and rubber,
- Formation of squeaking noises possible.

In combination with conventional rubber bearings, for lateral guidance injection moulded plastic rings or squeezed rings (Figs. 7, 8a – e) made of steel are used in order to ensure lateral guidance. Constructions in which an injection moulded plastic part meshes with a corresponding counterpart have not been used in series yet. In view of the fact that so high requirements must be put on the precision of such parts, a cost-effective manufacturing is impossible (Figs. 8f and g) [2, 3, 6, 9, 10].

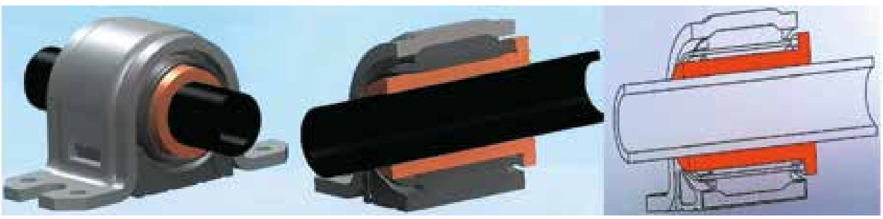

Fig. 7. Example of stabilizer bar mounting – slide bearing

2.4 Back bearing – rolling bearing

A bearing of a particularly high quality and price is the version with rolling bearings (Fig. 9). The rolling bearing is slid over a plastic sleeve injection moulded on the stabilizer bar. The outside diameter of the bearing is enclosed by a rubber layer. Then the entire element is bolted with the vehicle by means of a bearing bracket of cast aluminium [2, 3, 6, 9, 10].

Features:

- Frictionless bearing, minimisation of the breakaway torque due to rolling bearing (no secondary spring rate),
- Rubber helps ensuring the cardanic movement and the acoustic decoupling,

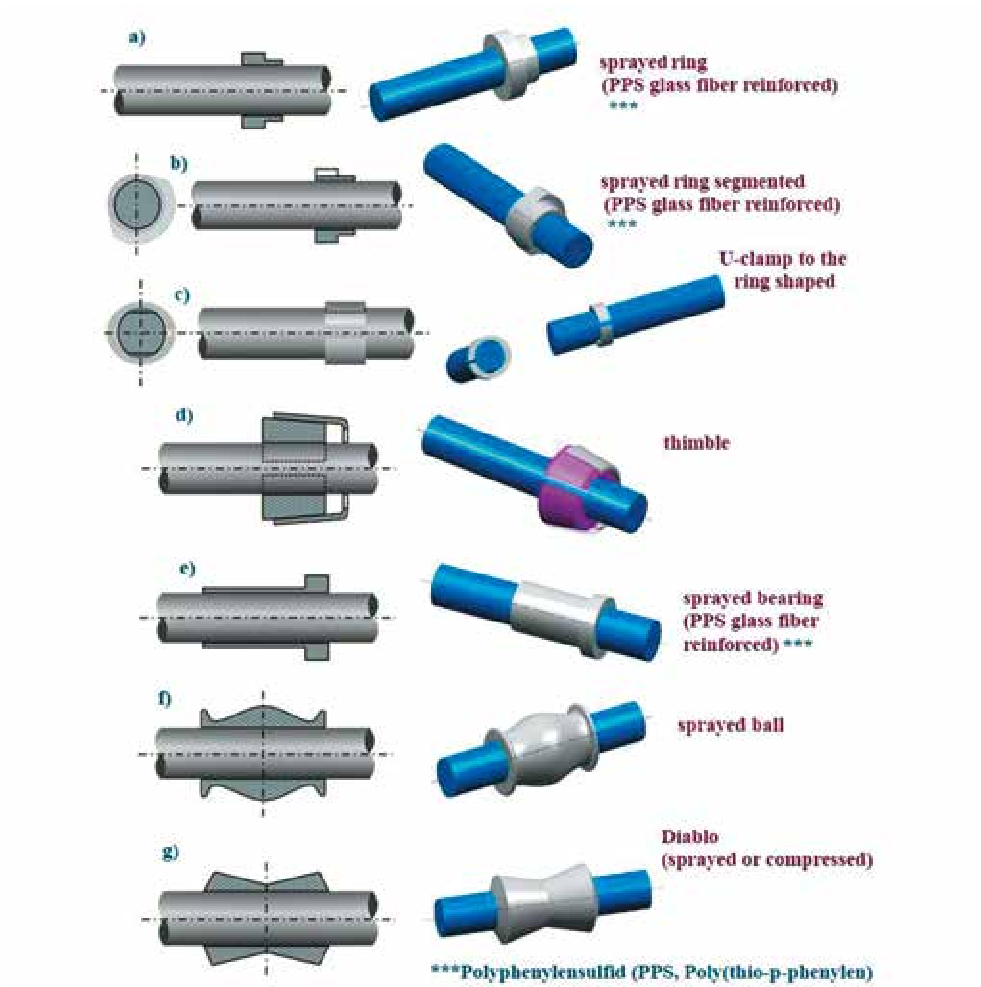

Fig. 8. Examples of fastening of bearing sleeves used in slide bearing (Fig. 7) [2, 3, 9]

- Axial protection through sleeves with stop collar,
- Water and dirt can penetrate between plastic sleeve and bearing.

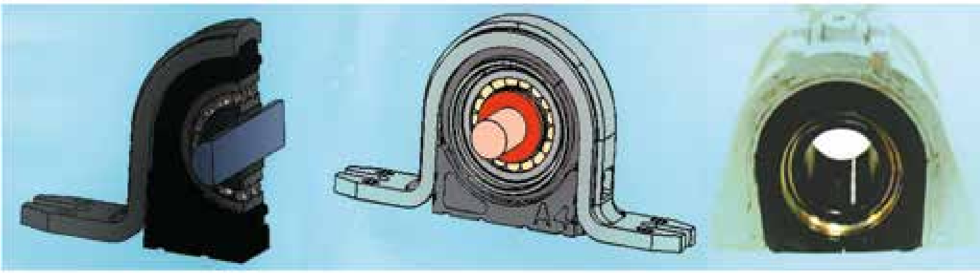

Fig. 9. Example of stabilizer bar mounting – ball bearing

2.5 Strength calculations with FEM

In case of the flexible mounting (back bearing – adhesive bearings), not only the deformation of the bearing but also the clamp deformation (stress concentration) must be taken into consideration (Fig. 11a) [1, 4, 11]. The meshes were built using the HyperMesh software (Figs. 10a and b) [12]. The bearing has a lateral slot (red line – Fig. 10a). This leads to irregular stress distribution und bearing deformation (Fig. 11 b).

The calculating stages of flexible bearing at the design stage – in prototype phase:

1. Strength computations of the flexible bearing (using FEM) at assumed loads or displacement ends of stabilizer bar and Shore hardness (data of car manufacturers) (Fig. 10 and 11d–g),
2. Strength computations of the bearing clamp, taking into account the assumptions of point 1 (Fig. 10 and 11a–c),
3. Determination of the surrogate stiffness of the elastic bearing and the total stiffness of stabilizer bar.

Subsequently the bearing with the clamps (prototypes) are tested on fatigue life (Fig. 14b and c). In addition measurements of the Shore hardness are carried out (Fig. 14a and d, Fig. 15). The computational models are subject to the basis of verification and validation. In the article are demonstrated calculations of elastic bearings L405A used in the car Land Rover. The elastic bearing under operating load (Table 1) did not undergo premature destruction. However, in the clamp of elastic bearing, are microcracks generated (Fig. 14 c) which conduct a premature failure. The Shore hardness measured after the process of fixing the bearing (Fig. 6) was within acceptable tolerance (Fig. 15).

Table 1. Computational parameters of the flexible bearings of stabilizer bar L405VA

tubular stabilizer bar	Ø31x5,5mm
computational deformation of stabilizer bar 2s	109,5mm
force acting on the bearing F_z	6285 N
Shore hardness of the elastic bearings	65±3
total stiffness/rate of the stabilizer bar	36,09 N/mm

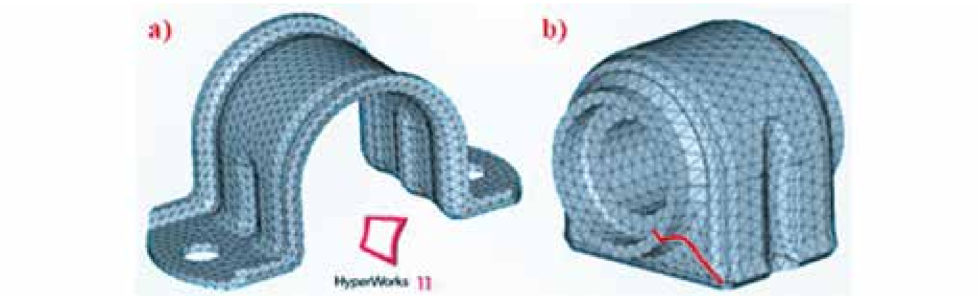

Fig. 10. Computational mesh FEM (HyperMesh) – clamps and flexible bearings of stabilizer bar L405VA

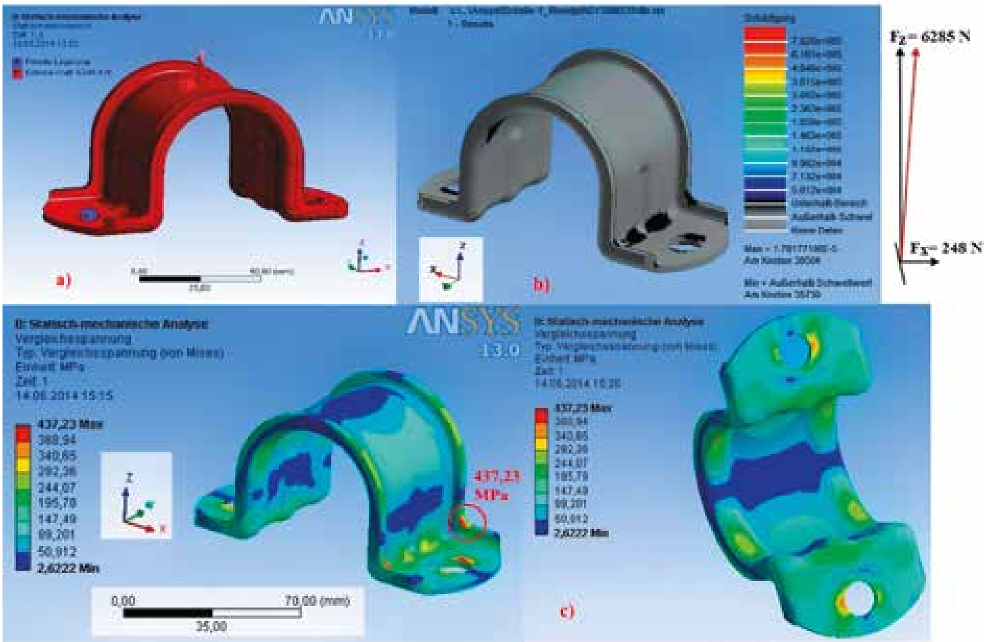

Fig. 11. Strength computations FEM of the clamp and flexible bearing of stabilizer bar L405VA

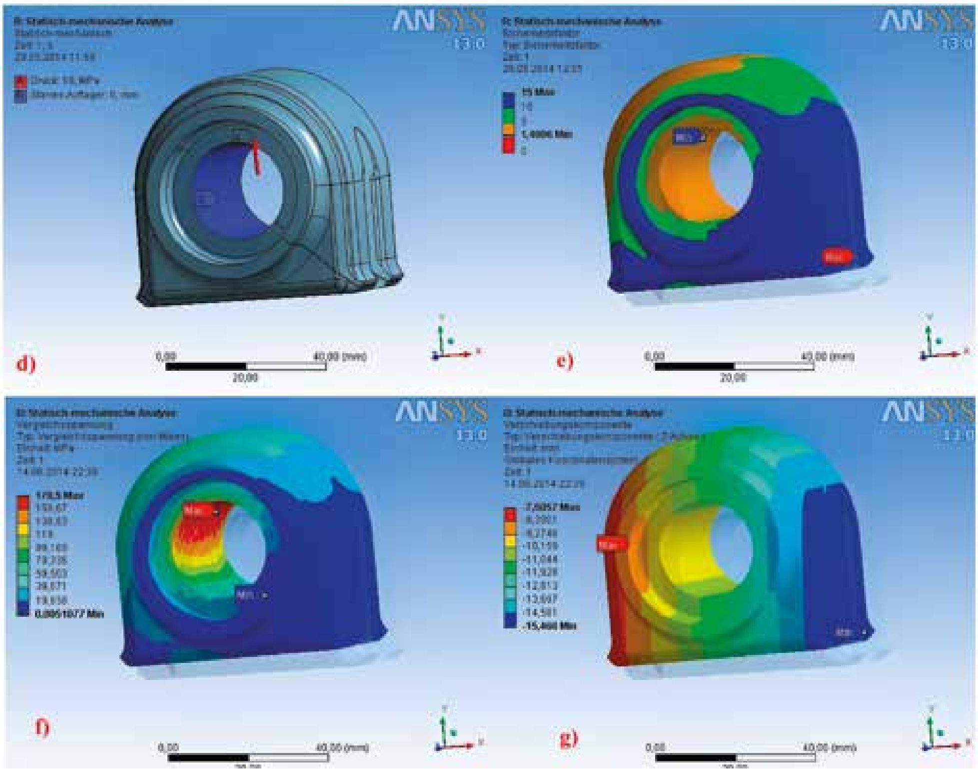

Fig. 11. Strength computations FEM of the clamp and flexible bearing of stabilizer bar L405VA, cont.

The strength calculations using FEM (Ansys and nCode) (Fig. 11) coincide with the results of fatigue tests conducted at ThyssenKrupp Federn & Stabilisatoren GmbH.

2.6 Spring rate

The characteristic of rubber springs, due to different moulding potentials, can be progressive, degressive, and in case of small spring travels also linear (Fig. 12a). In non-linear characteristics, progressive characteristic in which the spring rate increases more sharply and degressive characteristic with decreasing spring rate, i.e. the spring becomes softer with increasing load, can be distinguished. Springs with a progressive characteristic are preferred in automotive manufacturing.

Rubber is clearly softer in case of shear and torsional stresses than in case of tensile and compressive loads. As a result of the internal friction, the unloading characteristic is lower than the load characteristic (Fig. 12b). Relevant in dynamic loads of rubber-sprung vibrating systems is the so-called dynamic spring rate R_{dyn} which is greater than the static spring rate R. The ratio R_{dyn}/R depends on the Shore hardness (Table 2, Fig. 14a) [5, 8, 13].

Table 2. Material parameters for rubber springs – shear modulus G and dynamic spring rate R_{dyn}

shore hardness	shear modulus G [N/mm²]	R_{dyn}/R
45	0,5	1,2
55	0,75	1,4
65	1,1	1,9

$$shore\ A = 116{,}1 - \frac{1409}{shore\ D + 12{,}2} \tag{1}$$

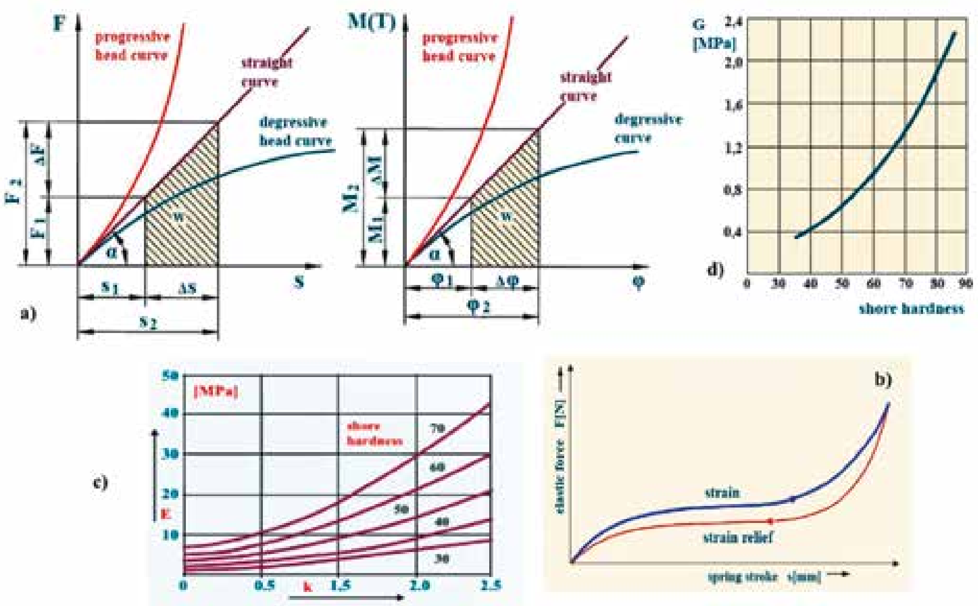

Fig. 12. a) Spring characteristics: force – displacement, moment – angle of twist [8]
b) Spring characteristics – rubber springs [8]
c) Elasticity modulus of rubber (dependent on k – form factor) [5, 8, 13]
d) Shear modulus (depending on Shore hardness) [5, 8, 13]

Hardness

As comparative measure for the hardness, according to *DIN* 53505 the Shore hardness A is used. The rubber grades used for spring elements have about 40 to 70 Shore units [5, 7, 8, 13].

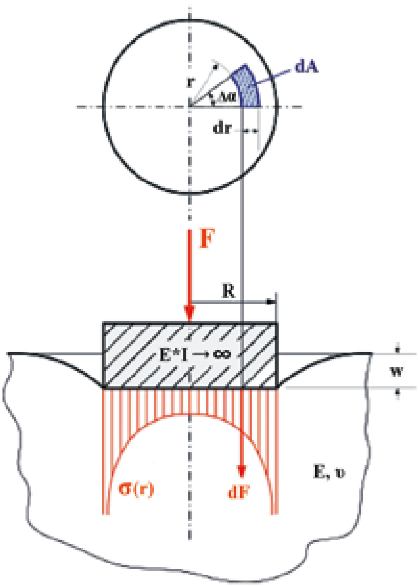

Fig. 13. Elastic half-space under load by a rigid punch [7]

A linear relationship exists between penetration depth and Shore hardness value like between penetration depth and spring force, which is expressed by the equations (Fig. 13):

$$F = c_1 + c_2 + S_{h_A} \qquad [\mathrm{N}] \qquad (2)$$

for spring force and

$$w = c_3(100 - S_{h_A}) \qquad [\mathrm{mm}] \qquad (3)$$

$$w = \frac{F}{2} * \frac{1 - \upsilon}{E} * \frac{1}{R} \qquad [\mathrm{mm}] \qquad (4)$$

for penetration depth. Using (2) and (3) in (4), a direct relationship between the elasticity modulus and the Shore hardness can be established in the following form:

$$E = \frac{1 - \upsilon^2}{2Rc_3} * \frac{c_1 + c_2 * S_{h_A}}{100 - S_{h_A}} \qquad [\mathrm{N/mm^2}] \qquad (5)$$

where: υ – Poisson's ratio, c_1 = 0,549 N, c_2 = 0,07516 N, c_3 =0,025 N (constant), S_{h_A}– Shore hardness

Shear modulus

The shear modulus G (Fig. 12d) is independent of the form. Thus it is a mere material parameter which increases with rising hardness (Table 1) [5, 8, 13].

Besides FEM strength calculations were performed Shore hardness measurement.

The results of Shore hardness measured on the stand shown in Fig. 14 lie within the tolerances of.

Elasticity modulus

In compressive load, the transverse elongation, in particular the hindrance to transverse elongation, has an effect on the elasticity modulus E. Thus the E modulus is dependent not only on the Shore hardness, but also on the form (Fig. 12c). This effect can be taken into account by a form factor k which is defined as the relation of loaded surface to free surface. For a cylindrical rubber spring with the diameter d and the height h [5, 8, 13]:

$$k = \frac{\pi d^2/4}{\pi dh} = \frac{d}{4h} \qquad (6)$$

Fig. 12c shows the dependence of the E modulus on the form factor and on the Shore hardness.

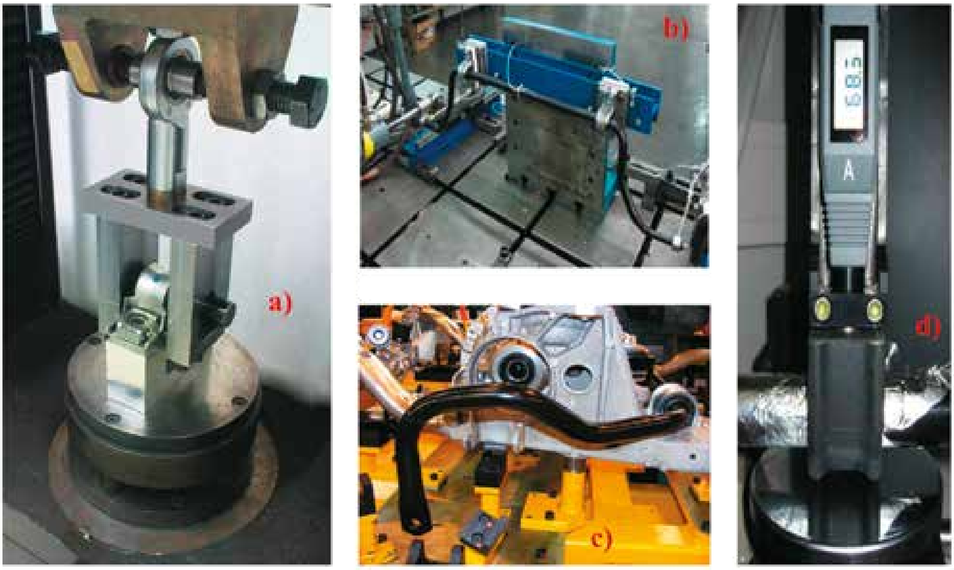

Fig. 14. a) Measuring station for bearing rigidity (source: TKF&S GmbH)
b) Measuring station for bearing strength (source: TKF&S GmbH)
c) Fastening / mounting of bearings of the car LandRover L405VA (source: TKF&S GmbH)
d) Measuring station for Shore hardness of flexible bearings (method A according to the DIN 53505 standard) (source: TKF&S GmbH)

Rys. 15. Shore hardness measurement of flexible bearing of stabilizer bar L405VA on the stand shown in Fig. 14

3. Conclusions

The bearing of stabilizer bars has to fulfil important functions. On the one hand, it functions as fastening – axle/chassis connection and generates a secondary rate which improves the action of stabilizer bars. Therefore the construction must involve the computations (FEM). The correct construction and designing guarantee a trouble-free operation.

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