Defence Science Journal, Vol 47, No 2, April 1997, pp. 251-257

Some Studies on Life of Track Pin Rubber Bushes

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ABSTRACT

Track pin, an important component in the tracks of heavy armoured vehicles, is made of steel surrounded by rubber bush. This construction enables the pin to transmit the torsional loads. As the failure of track pin makes the vehicle immobilised, it is important to ensure a specified life for these pins. As the pin is made of rubber and steel, the theoretical studies become difficult. An attempt has been made to find out the parameters that influence the life of track pins. A finite element method is used to estimate the stresses in the rubber. The temperature rise due to the torsional loads, computed using the energy equation, is found to be 64.86 °C for 1800 s at a speed of 30 km/hr, close to that obtained from actual field measurements.

1. INTRODUCTION

An armoured vehicle, which generally weighs about 550-600 kN, is designed to travel on hard and cross-country terrains. A suitable drive for this type of terrain condition is an endless chain fixed to a set of sprockets as shown in Fig. 1.

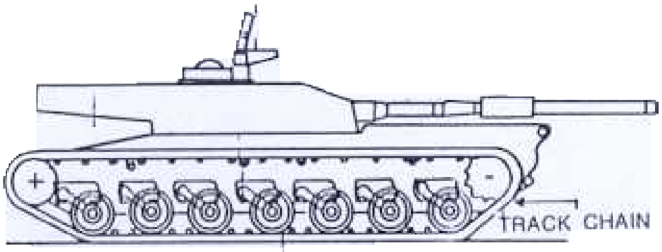

Figure 1. Track chain

A schematic diagram of track link is shown in Fig. 2. The track link block has two bores separated by a distance. Two such blocks are connected by means of track pins and the end connectors. A typical pin is shown in Fig. 3. It consists of a circular steel rod. The rubberised bushes are embedded on to the steel pin with intervals between the bushes. When this pin is inserted into the block hole, the compression of bush takes place and the rubber fills these intervals and transforms into a full cylindrical shape.

The relative movement between the blocks is accommodated by twisting of rubber bush. The life of the track is mainly dependent on the rubber bush.

Received 06 March 1995, revised 16 September 1996
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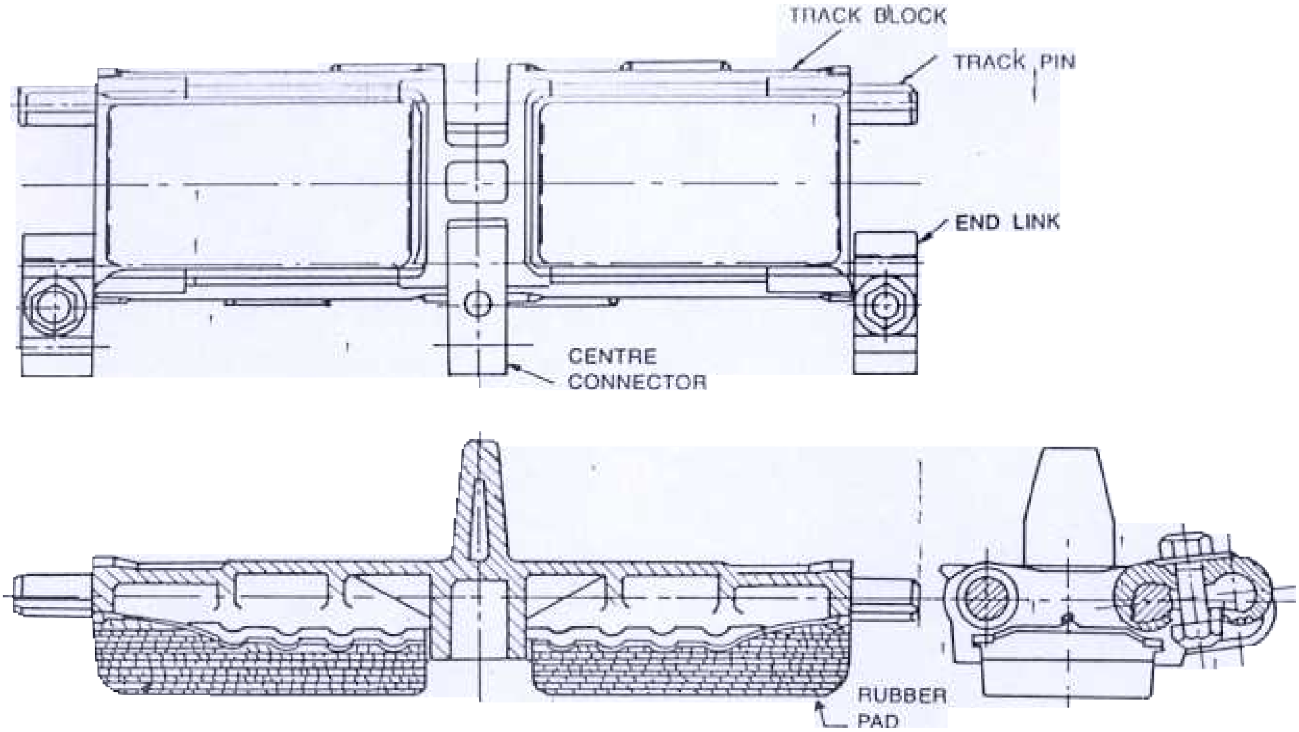

Figure 2. Track chain with pads

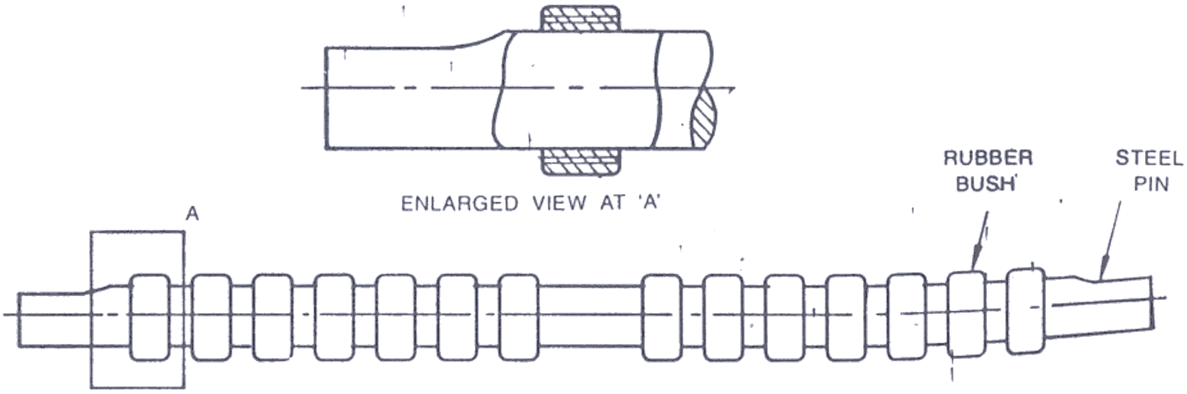

Figure 3. Track pin

The life of rubber bush is dependent on the stresses due to the filling of rubber into the block, the external load due to track tension, the shear load due to the blocks relative movement and the temperature rise due to the hysteresis of these loads. In trials, it was noticed that these track pins were failing at 30 per cent of the expected life.

The understanding of possible causes for the premature failure by analytical methods will greatly help in modifying the design, with reduced experimental cost. The pin construction and assembly into the housing is a complex one. A numerical method, such as finite element analysis, is well suited for estimating the stresses in the rubber. Energy equations are employed for evaluating the rise in temperature.

The pin and the bush are made of steel and rubber, respectively. Rubber is a non-linear elastic material with lower Young's modulus and higher Poisson's ratio as compared to steel. A finite element analysis (FEA) package ABAQUS is used for stress analysis.

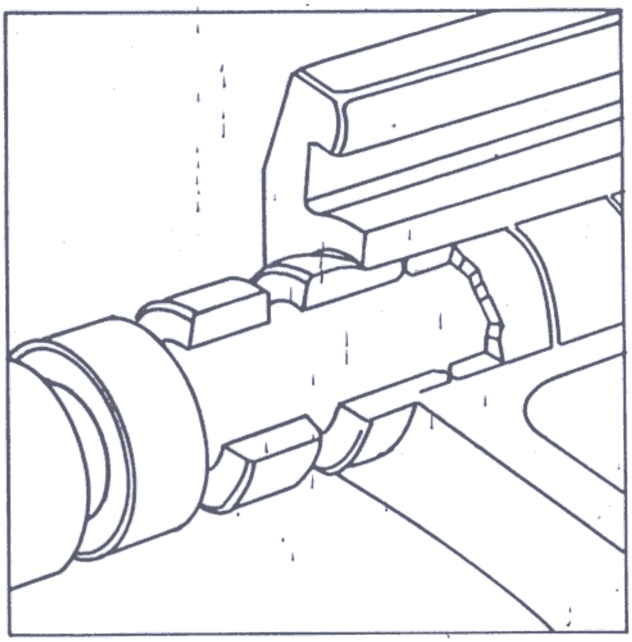

Figure 4. Insertion of the track pin into the track block bore

2. FINITE ELEMENT MODEL

The insertion of rubber bushes into the track block bore is shown in Fig. 4. The load due to insertion is axisymmetric in nature akin to internal pressure. The stress-strain relationship of the rubber is nonlinear[5-8]. The external loads or the displacements are given as the input in increments for such materials. When the bushes are inserted into the bore, they elongate in the axial direction till two adjacent bushes get in touch with each other. The load is applied in terms of displacements. As the displacements are large, they are divided into a number of steps and are given as the input by increment. Within the increment, iterations are done to bring the model to equilibrium before the next increment is applied. This process is continued till the final displacement is obtained. The algorithm used for this step is RIKS[1] which is well suited for large elastic deformation problems.

The following assumptions are made in the analysis:

(a) Rubber behaves as an incompressible material. (No change occurs in its volume during the insertion),

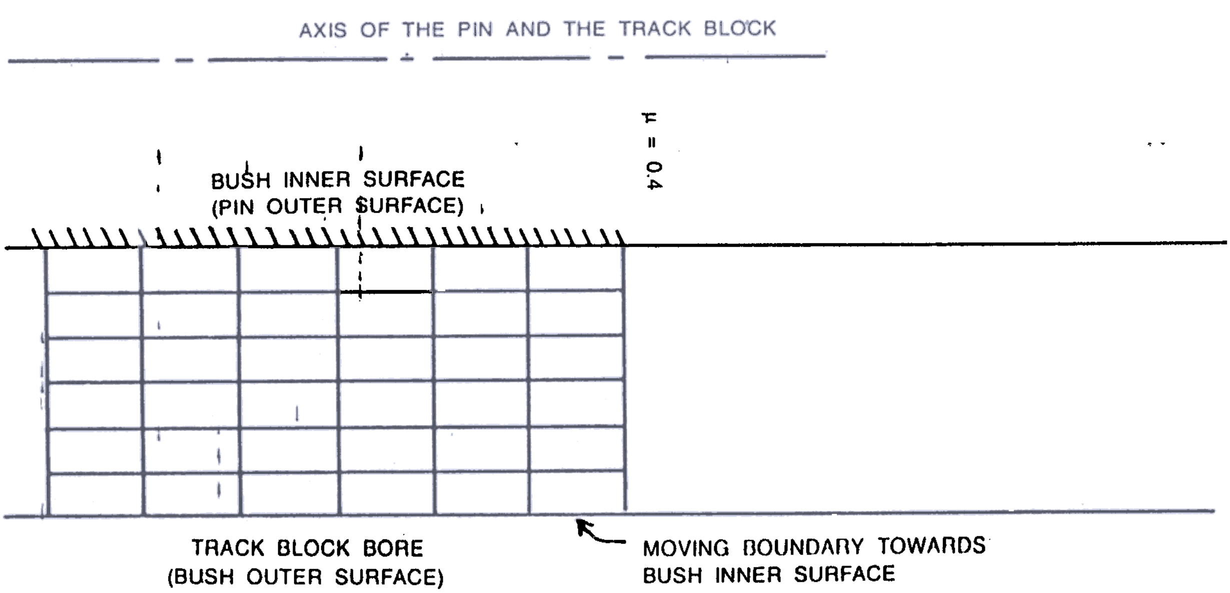

Figure 5. Discretisation of the bush model

(b) The inner surface of the bush is rigidly fixed to the steel pin irrespective of the axial forces developed during insertion.

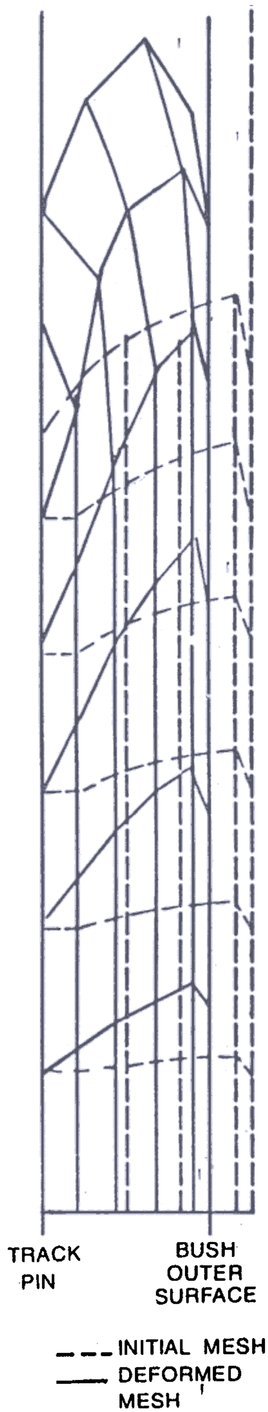

Figure 6. Deformed mesh of the compressed bush

(c) The coefficient of friction between the outer surface of the rubber and inner bore of the block surface is equal to the corresponding values of the metal-rubber contact.

(d) Only one bush is considered in the analysis to estimate the amount of extrusion.

3. MODELLING

An axisymmetric finite element mesh using quadrilateral elements is shown in Fig. 5. The inside surface of the rubber bush is in contact with the rigid steel pin; hence the displacements on this surface are restrained. During the insertion of rubber bushes into the block bore, the bush expands in the axial direction. As the inner layer is rigidly fixed, the side faces of the bush make contact with the steel pin. This makes the element distorted. The outer face of the bush is allowed to slide and a suitable friction coefficient is specified for both stick (0.7) and sliding (0.4). Assumption of sticking friction at the track pin-rubber bush interface, constitutes the worst possible case.

The deformed mesh of the compressed bush is shown in Fig. 6. A nonlinear formulation developed by Mooney-Rivlin[2,6] for large deformations of hyperelastic material is used in the present analysis. The constants for rubber incorporated in the analysis for C_{01} and C_{10} are 0.55 N/mm^2 and 0.22 N/mm^2, respectively. The rubber material chosen is extremely strong under compressive and shear loads.

4. PRECAUTIONS IN ANALYSIS

As the rubber bush undergoes a large deformation, the element distortion is to be monitored carefully. The large distortion may result in unfavourable element geometries leading to inaccuracies in the element stiffness and stress values. To overcome this situation, rezoning technique has been applied at intervals, to tune the finite element mesh to an acceptable geometry. In this analysis, the rezoning is done after approx 65 per cent of the displacement is applied. The remaining displacement is applied after rezoning.

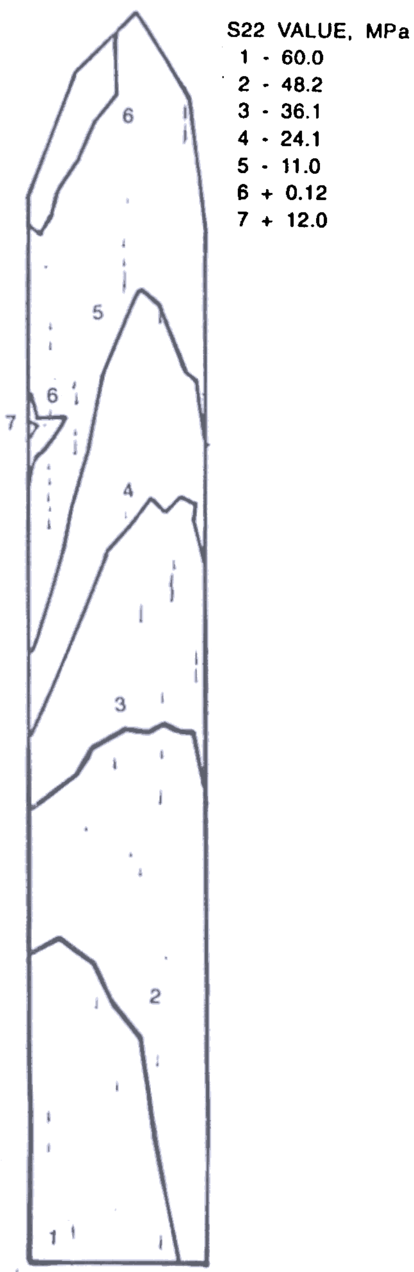

Figure 7. Stress contour of the compressed bush

The analysis continued till outward diameter of the bush is equal to the bore diameter of the block.

5. ANALYSIS

5.1 Calculation of Stresses

The displacement and the stresses are computed using the procedures explained in the earlier sections. The stress contours of the compressed bush are shown in Fig. 7. It can be noted from the figure that the stresses are compressive in bonded zone and tensile at the junction of the pin and end face of rubber bush. The stresses developed due to insertion of bushes into the block are compared with the allowable tensile strength (27 MPa) and found to be within limits. In Fig. 7, the tensile stress value is maximum at contour No. 7 due to the assumption of sticking friction at the track pin-rubber bush interface compared to that of any other non-sticking case.

The drive load on the pin is asymmetric in nature. The stresses developed due to this load are not presented in the current analysis and the work in this direction is under progress.

5.2 Calculation of Temperature

In addition to the stresses developed in the rubber, another cause of failure could be due to temperature rise in the rubber[3] because of the hysteresis characteristic of the material. For finding out temperature rise, axial stiffness is evaluated by giving a unit displacement in the axial direction. The axial stiffness is connected to the torsional stiffness as shown in Section 6.

6. TEMPERATURE CALCULATIONS FOR RUBBER BUSHES

1 Torsional stiffness of the bush, Kt (Nm)

$$K_t = K_a/A \; J/2(1+\mu)$$

where

A = Area (m^2)

J = Polar moment of inertia (m^4)

K_a = Axial stiffness of the bush (N/m)

μ = Poisson's ratio

2. Number of cycles/s of the bush (f_φ)

V = Vehicle speed (m/s)

l = Length of the travel by the bush for one revolution (m)

f_t = Number of torsional cycles, the bush undergoes for one revolution.

$$f_\varphi = \frac{V * f_t}{l} \text{ cycles/s}$$

Number of cycles for a time of 1800 s (f_n)

$f_n = f_\varphi$ 1800 cycles

4. Strain energy of the bush for f_n cycles (U) (N m)

$U = 1/2 * K_t * \theta * f_n$ (N m)

θ = Twist angle of the bush in radians

K_t = Torsional stiffness of the bush (N m)

5. Heat generated in the bush (q) (N m)

$q = U \tan \partial$ (N m).

$\tan \partial$ = Heat generating factor[4]

U = Strain energy of the bush (N m)

6. Heat generated/unit volume (Q) (J/m^3)

$Q = q/V$

q = Heat generated in the bush (N m)

V = Volume of the bush (m^3)

7. Temperature rise in the bush, (ΔT) (^{o}C)

$\Delta T = Q/\rho * C_p$

ρ = Density of the rubber, 950 kg/m^3

C_p = Specific heat of rubber, 1420 J/kg ^{o}C

For Q (per unit Vol.) = 87495796 J/m^3

ΔT = 87495796/(950 * 1420) = 64.86 ^{o}C

7. RESULTS & DISCUSSION

The finite element analysis is a suitable method for computing the stress values, and it is found that the stresses are well below the accepted values. The temperature rise due to the torsional load is 64.86 ^{o}C for 1800 s at a speed of 30 km/h. This temperature was verified in field and found to be nearer to the analytical values. It is found that there is a considerable degradation of rubber properties above 60 ^{o}C. Hence the properties of rubber are changed by appropriate variations in chemical composition. The modified material is being used in the Services and it is found that the life of rubber has gone up by 100 per cent.

From the above studies, it is concluded that in the design of tracks, the temperature rise due to the hysteresis energy play a greater role as compared to the initial stresses that are developed because of the insertion of the bushes in the block.

ACKNOWLEDGEMENTS

The authors are thankful to Shri M. Natarajan, Director, Combat Vehicles Research & Development Establishment (CVRDE), Avadi, for extending all the facilities and granting permission to publish this paper. The authors also acknowledge Shri R. Santhanam, Jt. Director (MBT), Shri J.L. Mohindroo Dy Director (Running Gear Division), CVRDE, Prof C.S.Krishnamoorthi and Dr R. Krishnakumar of Indian Institute of Technology Madras, for their valuable guidance and useful suggestions.

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