Dynamic Analysis of Lever Mechanism for Manufacturing of Raw Tyres

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The give paper is closely connected with the analysis of the normal force relating to the winding mechanism referring to production or manufacturing of raw tyres. The attention is mainly paid to the calculation of normal force during the manufacturing process when the individual constituents of raw tyre are pressed-in. The dynamic analysis as well as the calculation of the given normal force was done for raw truck tyre. The simulation of the movement and dynamic analysis for the given kinematic conditions as well as appropriate input values were solved in Solid Works – modeling computer program. Courses of normal forces for the first one set and the second one set of winding arms in dependence on lever position are in graphitic form. Based on the dynamical analysis, it can be concluded that, the second one set of winding arms does not have any influence on the quality of the produced car tyre.

Keywords: dynamic analysis, finite element method, lever mechanism, manufacturing of raw tyres

1 Introduction

The technological process of raw tyre production [4], [5], [13], [14] is closely connected with the utilization of tyre building drum where it is also necessary to wind the given constituent parts of tyre around its bead plies and then, the given constituent parts must be forced-in or pressed-in mutually in the area which is determined by bead ply and constituent part which is called crown of tyre. The crown can be found at sidewalls of tyre. It can be seen in the figure 1.

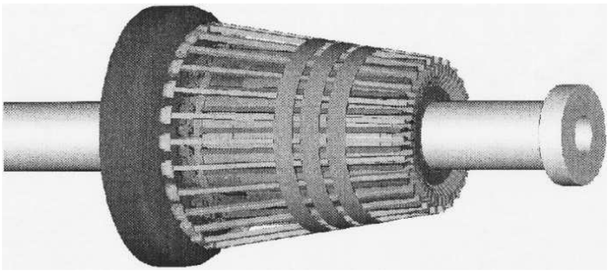

***Fig. 1** The technological process of mutual pressing-in for constituent parts of tyre*

The mentioned procedure has been done by usage of tyre building drums and there is also utilized the specific or special mechanism which is called winding mechanism. The tyre lever building drum, mentioned hereinbefore, contains one winding mechanism in its each one half. From the construction or the structural aspect, the given and specific mechanism can be designed in two different ways. The one construction design consists of one (the first one) set of winding arms at which the rollers are mounted and another construction design consists of two (the first one and the second one) sets of winding arms with mounted-in rollers while these mounted-in rollers follow each other in a stagger way.

2 Dynamic analysis normal force of the lever mechanism

The kinematic and dynamic analysis [1], [2], [3], [6], [7], [12] of the lever mechanism of winding arms has been done by relaxation method in the computer program SolidWorks. The basic position means that the lever is in horizontal plane. Te operation position means that the roller traces the profile of the tyre. The shifting or movement of lever is performed in the interval x <0-255 mm> and at the same time when there is the shift or movement of the lever, there is also the performance of another operation at which the lever is turned in the direction from the axis y and moreover, the shifting or movement of lever is given by specific angle φ<0-30°>. The required stiffness for individual flexible components or constituents as well as any other required values were obtained in an experimental way. The principle of relaxation can be seen in the figure 2 where there is the relaxation of individual entities which are subjected to motion equations (1), (2) and the given motion equation can be used for determination of kinematic parameters or values for movement of individual entities in the system and in addition, the appropriate reactions can be also found out by this way.

Motion equations:

Body 2:

$$
\begin{aligned}
m_2\ddot{x}_T &= \sum F_{ix} = -A_x + B_x + F_h + (F_{k_1} + F_{k_2} + F_{k_3})\sin\varphi \\
m_2\ddot{y}_T &= \sum F_{iy} = A_y - B_y - G_2 - (F_{k_1} + F_{k_2} + F_{k_3})\cos\varphi \\
I_A\ddot{\varphi}_2 &= \sum M_{iA} = B_x(446\sin\varphi + 58{,}5.\cos\varphi) + B_y(446\cos\varphi - 58{,}5.\sin\varphi) + \\
&\quad + F_{k_1}.219{,}5 + F_{k_2}.169{,}5 + F_{k_3}.119{,}5
\end{aligned}
\qquad (1)
$$

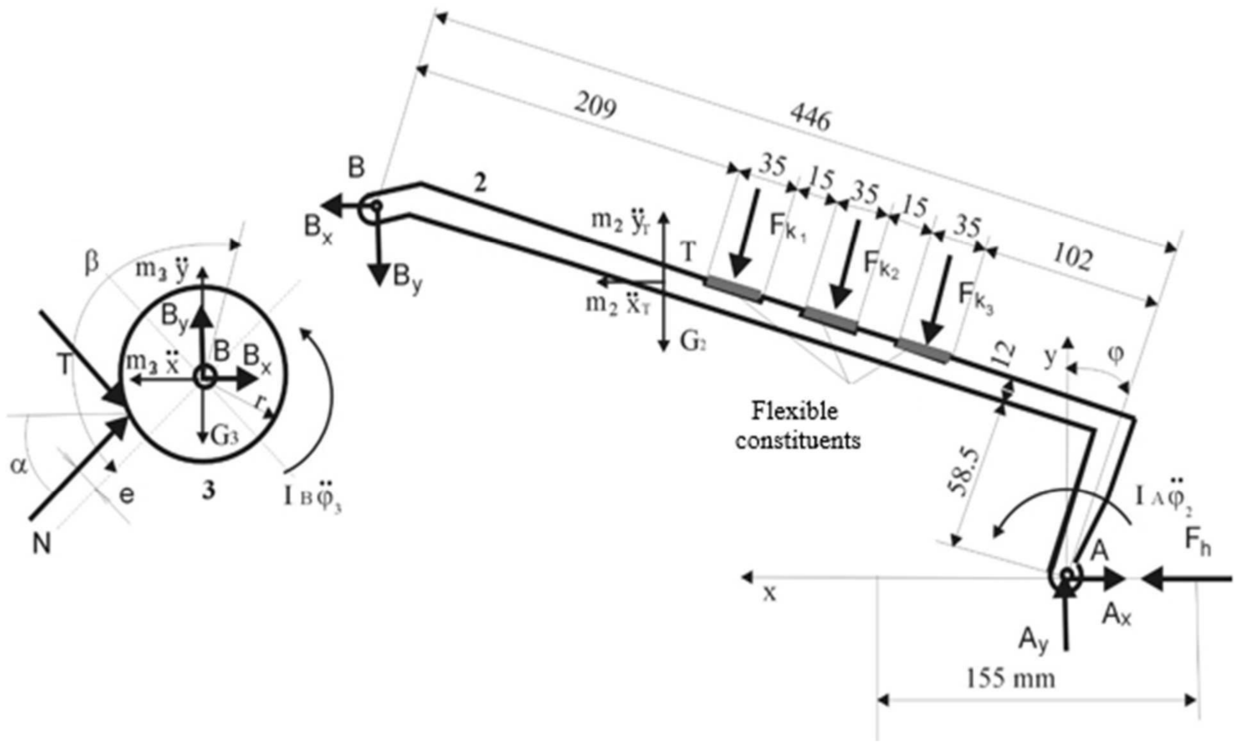

***Fig. 2** Relaxation of individual bodies*

Body 3:

$$
\begin{aligned}
m_3\ddot{x} &= \sum F_{ix} = -B_x - N.\cos\alpha - T.\cos(90^\circ - \alpha)\\
m_3\ddot{y} &= \sum F_{iy} = B_y - G_3 + N.\sin\alpha - T.\sin(90^\circ - \alpha)\\
I_B\ddot{\varphi}_3 &= \sum M_{iB} = T.r - N.e
\end{aligned} \tag{2}
$$

Matrix representation of (1) and (2) motion equations, which are transferred to matrix representation of (3) and then it is:

$$
\begin{bmatrix}
-1 & 0 & 1 & 0 & 0 & 0\\
0 & 1 & 0 & -1 & 0 & 0\\
0 & 0 & -446.\sin\varphi - 58{,}5.\cos\varphi & -446.\sin\varphi + 58{,}5.\cos\varphi & 0 & 0\\
0 & 0 & -1 & 0 & -\cos(90^\circ - \alpha) & -\cos\alpha\\
0 & 0 & 0 & 1 & \sin(90^\circ - \alpha) & \sin\alpha\\
0 & 0 & 0 & 0 & r & -e
\end{bmatrix} .
\begin{bmatrix} A_x\\ A_y\\ B_x\\ B_y\\ T\\ N \end{bmatrix} =
$$

$$
= \begin{bmatrix}
m_2\ddot{x}_T - F_h - (F_{k_1} + F_{k_2} + F_{k_3})\sin\varphi\\
m_2\ddot{y}_T + G_2 + (F_{k_1} + F_{k_2} + F_{k_3})\cos\varphi\\
I_A\ddot{\varphi}_2 + F_{k_1}.219{,}5 + F_{k_2}.169{,}5 + F_{k_3}.119{,}5\\
m_3\ddot{x}\\
m_3\ddot{y} + G_3\\
I_B\ddot{\varphi}_3
\end{bmatrix} \tag{3}
$$

The computational model of the mechanism for the first one set as well as the second one set of winding arms can be seen in Fig. 3 and Fig. 4. The simulation of the movement and dynamic analysis [9], [10] for the given kinematic conditions as well as appropriate input values were solved in Solid Works – modeling computer program.

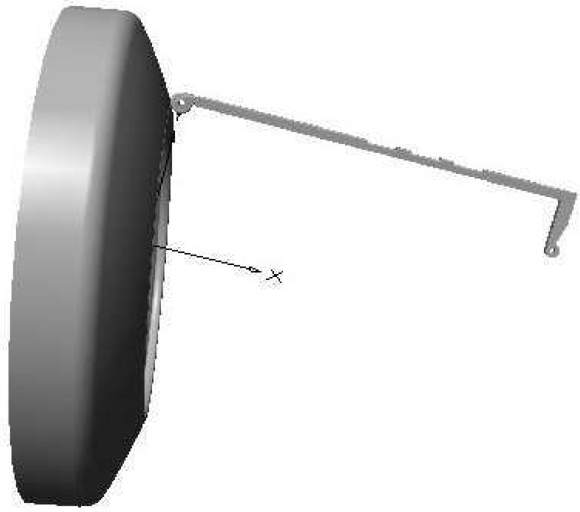

***Fig. 3** Computational model of the mechanism for the first one set of winding arm*

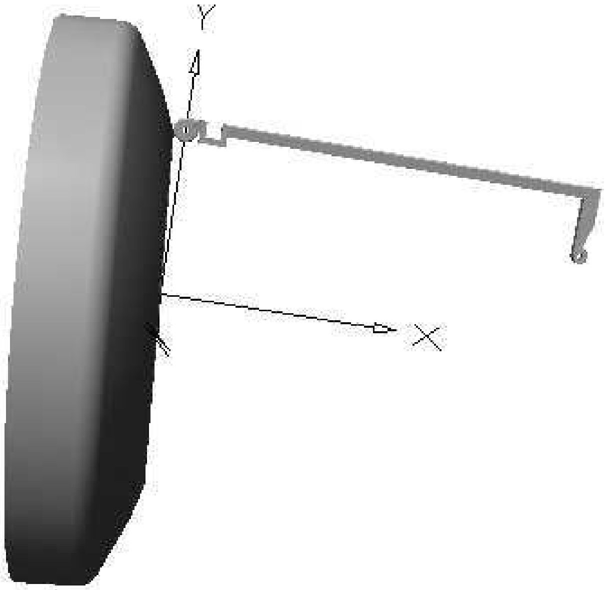

***Fig. 4** Computational model of the mechanism for the second one set of winding arm*

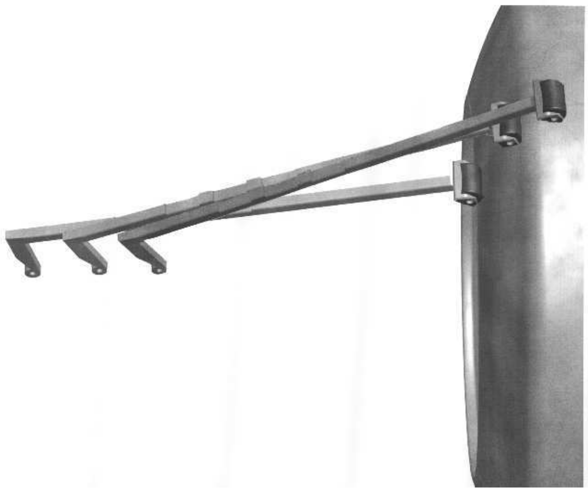

***Fig. 5** The simulation of the movement of mechanism*

***Fig. 5** The finite element model with the distribution of stress in the lever*

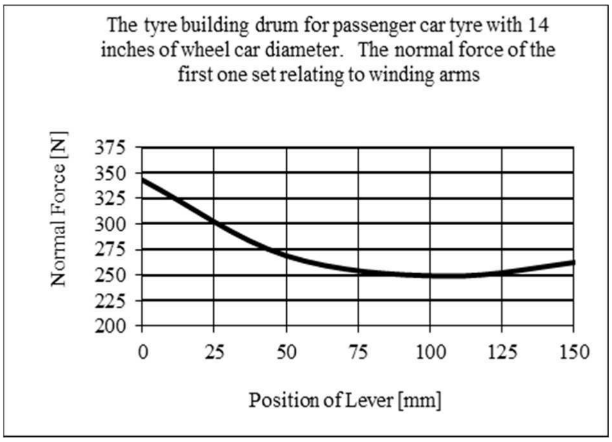

***Fig. 6** Course of normal force for the first one set of winding arms in dependence on lever position*

The simulation of the movement of the mentioned mechanism can be seen in the figure 5. The finite element method (FEM) [8], [11] was used for creation of finite element model which is shown in the figure 6. The given model can be used for determination of appropriate loading as well as distribution of stress for individual constituents or components of mechanism. The figure 7 and figure 8 show the values of normal forces in dependence on the position of the lever.

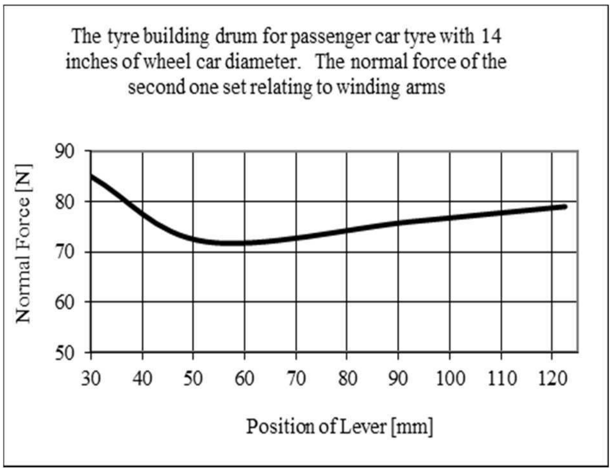

***Fig. 7** Course of normal force for the second one set of winding arms in dependence on lever position*

3 Summary

In relation to the raw passenger car tyre which has 14 inches, the value of the normal force of the first one set of rollers is four times higher than the value of the normal force of the second one set of rollers, referring to winding arms at the beginning of the winding process. Based on the mentioned fact above, it can be concluded that the second one set of winding arms of building drum is not important for the forcing-in or pressing-in, relating to individual constituent parts. The second one set of winding arms does not have any influence on the quality of the produced car tyre.

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References

[1] B. PAUL (1979). *Kinematics and Dynamics of Planar Machinery*, (1979), Prentice-Hall, New Jersey.

[2] V. BRÁT (1976). *Handbook of kinematics with examples*, SNTL, Prague, (1976), (in Czech).

[3] I. DELYOVÁ, D. HRONCOVÁ, P. FRANKOVSKÝ (2014). Analysis of Simple Mechanism Using MSC Adams, *Manufacturing Technology*, Volume 14, (2014), ISSN 1213-2489, pp. 141-145.

[4] J. KRMELA (2008). *Systems Approach to the Computational Modeling of Tyres*, Monograph, (2008), p., ISBN 978-80-7399-365-8, pp. 102.

[5] D. ONDRUŠOVÁ, M. PAJTÁČOVÁ (2011). *Rubber components and their influence on rubber properties and enviromental aspects of production*. 1st Ed. Spolok Slovákov v Poľsku, Krakow, (2011), ISBN 978-83-7490-385-1, pp.166.

[6] A. SAPIETOVÁ, M. SAGA, B. HYBEN, M. SAPIETA (2014). Effective methods of parameters refinement of machinery in the program MSC ADAMS, *Applied Mechanics and Materials* 611 (2014), pp. 67–74.

[7] A. SAPIETOVÁ, V. DEKÝŠ, M. VAŠKO (2010). A numerical model of rotating machine having unbalance and the measurements of its dynamical properties, *Metalurgija* (Metalurgy) 49 (2010), pp. 503–507.

[8] KLIMENDA, F., SOUKUP, J., ZMINDAK, M. (2016). Deformation of Aluminium Thin Plate, *Manufacturing Technology*, Volume 16, (2016), ISSN 1213-2489, pp. 124-129.

[9] STANKOVIČOVÁ, Z., DEKÝŠ, V., NOVÁK, P., SAPIETA, M. (2015). Numerical Simulation of Thermoelastic Stress Analysis, *Manufacturing Technology*, Volume 15, (2015), ISSN 1213-2489, pp. 925-930.

[10] HANDRIK, M., SÁGA, M., PECHÁČ, P., KOPAS, P. (2015). Analysis of Force Conditions of the Hot Forming Machine in Rolling-Out of Bearing Rings, *Manufacturing Technology*, Volume 15, (2015), ISSN 1213-2489, pp. 821-825.

[11] ŽMINDÁK, M., MEŠKO, J., PELAGIĆ, Z., ZRAK, A. (2014). Finite Element Analysis of Crack Growth in Pipelines, *Manufacturing Technology*, Volume 14, (2014), ISSN 1213-2489, pp. 116-122.

[12] J. VAVRO, M. KOPECKÝ, M. SÁGA, M. FANDÁKOVÁ (2004). *Nové prostriedky a metódy riešenia sústav telies II*, Digital graphic, Trenčín, (2004), ISBN 80-968337-9-0, pp.197.

[13] VAVRO, J., KOPECKÝ, M., KOŠTIAL, P., HAJSKÁ, H., FANDÁKOVÁ, M. (2004). *The Experimental Measurement of the Tyre Impurities Circulation by the Dynamic Loading and Application of the Experiment Evaluation by the Method of the Active Factor Experiment*, Machine Dynamics Problems, Warsaw University of Technology, (2004), pp.8.

[14] JÁN VAVRO, HELENA HAJSKÁ, JÁN VAVRO ML., ALENA VAVROVÁ (2011). *Nové mettódy a prístupy experimentálnej mechaniky pri identifikácii vád a porúch výrobkov*, Spolok Slovákov v Poľsku, Krakow, (2011), ISBN 978-83-7490-461-2, pp.265.

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