Influence of the silent chain link geometry on the link / chain guide contact

M T Lates¹ and C C Gavrila¹

¹Product Design, Mechatronics and Environment Department, “Transilvania” University of Brasov, Brasov, Romania

latesmt@unitbv.ro

Abstract. The mechanical behaviour of the chain drive transmissions is influenced of the contacts between elements being in relative motions, as: sprockets and links, links and pins and links and tensioning guides. These contacts have a complex behaviour and due to that it is required to be analysed separately, in order to find out their influences on the dynamical behaviour and on the tribological properties of the entire transmission. The article presents the analysis of the influence in the case of silent chain link geometry on the link/chain guide contact. It is studied the variation of the local normal maximum pressures and the variation of the contact area’s width with the main radius of the chain link and with the normal applied force. The analysis is based on the finite element modelling. Finally there are given conclusions regarding the practical applications of the obtained results.

1. Introduction
The efficiency of the mechanical transmissions is influenced mainly by the lubricants used in order to reduce the friction between the elements being in contact, by the materials used in the construction of the mechanical parts and by the local geometry (dimensions and shapes) of the contact zone between the mechanical elements being in relative motions [1, 2, 3, 4, 5, 6].

Chain drives are characterised by high loading capacities. Due to this characteristic, the chain drive transmissions are used widely in the automotives industry and in the construction of the mechanical systems as industrial robots, machine tools and machines use in agriculture and mining industry. The main problems are represented by their efficiency and the noises developed during their functioning [7, 8, 9, 10]. The literature offers directions in order to reduce the friction and the noises [11, 12, 13]. One solution is represented by the silent chains; in this case the chains links have teeth with are gearing with the sprocket and, due to this, a reduction of the noise is obtained.

Generally, the friction developed in a chain drive transmission can be split in the friction in the chain links, the friction between the chain links and the sprockets and the chain links and the tensioning guide [7, 1, 12, 14]. Regarding the tensioning guide, the active part of it is made by polyamides which are characterised by small friction coefficients in combination with steel elements, small wear, high endurance and good mechanical behaviour at high loadings and high temperatures [15, 16, 17, 18, 19, 20].

The frictional behaviour of the chain link – tensioning guide contact (the mechanical efficiency, the wear and the level of the noises) is influenced by the geometrical characteristics of the contact area [8, 10, 12]. According to this, the paper studies the influence of the toothed chain link geometry on the contact with the tensioning guide.
2. The model

The theoretical analysis is achieved by using the finite element method based software Ansys 15.0; the geometrical model is made in Catia V5R18 – figure 1. The toothed chain link is in contact with a tensioning guide made by a polyamide type material which has the radius $R=120$ mm.

![Figure 1. The geometrical model.](image1)

The geometry and the dimensions of the toothed chain link are presented in figure 2. For the finite element based analysis only the radius $R=4$ mm is considered variable with values in the range of: 3.5; 3.75; 4; 4.25; 4.5 – figure 3. Other main dimensions are kept frozen in order to keep unmodified the values of the chains pitch, the height, the length and the width of the link, the diameters of the pins.

![Figure 2. The toothed chain link.](image2)

By reducing the radius, the length of the contact zone between the link and the guide increases; high value of the radius produce a decrease of the length for the contact zone between the link and the guide.

Figure 4 presents the finite model of the link/guide contact. The tensioning force which is applied on the guide has the values of: 10 N, 15 N, 20 N, 25 N, 30 N; the holes where the pins are mounted are clamped. The links are made by steel and the guide is made by polyamide. The material data are: $E_1$, $E_2$ represent the Young’s modulus for the skate and the link and $\nu_1$, $\nu_2$ represent the Poisson’s coefficient of the two materials (for steel – the link, $E_1=2\cdot10^5$ MPa, $\nu_1=0.266$; for plastic – the skate, $E_2=2.2\cdot10^3$ MPa, $\nu_2=0.38$ [21]).
Figure 3. The link shapes.

Figure 4. The finite element model.

3. Results and conclusions
The results of the finite element analysis presents as graphs, the variation of the contact pressure and of the contact areas half width with the normal tensioning force and the radius of the chain link.
Figure 5. The variation of the maximum contact pressure.

Figure 5 presents the variation of the maximum contact pressure with the normal tensioning force which is applied on the guide and the radius of the chain link. The value of the maximum contact pressure increases with the increasing of the normal force and increases slightly with the increasing of the chain link’s radius; higher values for the increasing of the contact pressure with the chain link’s radius are obtained for higher normal forces.

The variation of the width of the contact area is presented in figure 6. The value of the width increases with the increasing of the normal force but is decreases slowly with the increasing of the chain link’s radius; higher values for the decreasing of the width with the chain link’s radius are obtained for higher normal forces.

Figure 6. The variation of the width of the contact area.

According to the results, small values of the contact pressures are obtained in the case of small values of the chain links radiiuses and these results offers the conditions for good lubrication of the contacts between the chain links and the guide; also small values of the width of the contact area are obtained in the same conditions. The minimum values of the chain links radius could be chosen depending on technological and dynamics behaviour constraints, while the variation of the radius is influencing the inertial characteristics if the chain.
References
[1] Cretescu N, Neagoe M and Saulescu R 2016 Kinematic and dynamic analysis of a 4DOF parallel robot with flexible links Mechanisms and Machine Science 46 pp 473-481
[2] Neagoe M, Saulescu R, Jaliu C and Cretescu N 2016 Novel speed increaser used in counter-rotating wind turbines Mechanisms and Machine Science 46 pp 143-151
[3] Saulescu R, Neagoe M and Jaliu C 2018 Conceptual synthesis of speed increasers for wind turbine conversion systems Energies 11-2257
[4] Saulescu R, Neagoe M and Jaliu C 2016 Improving the energy performance of wind turbines implemented in the built environment using counter-rotating planetary transmissions Materials Science and Engineering 147 (1)
[5] Ciobanu D, Jaliu, C and Saulescu, R 2014 Chain Tracking System for Solar Thermal Collector Applied Mechanics and Materials 658 pp 35-40
[6] Ciobanu D 2011 Conceptual design of a solar thermal system with dish solar collector Journal of Environment and Engineering Management 10 (8)
[7] War X and Dwyer-Joyce R S Model experiments on automotive chain drive systems Elsevier Science 39 pp 851-861
[8] Pedersen S L 2005 Model of contact between rollers and sprockets in chain-drive systems Archive of Applied Mechanics 74 pp 489-508
[9] Metilkov S A, Berezhnii S B and Yunin V V 2008 Wear of hinges in roller drive chain Russian Engineering Research 28-9 pp 839-844
[10] Metilkov S A and Yunin V V 2008 Influence of wear of a roller drive chain on transmission fitness Russian Engineering Research 28-8 pp 741-745
[11] Hyakutake T, Inagaki M, Matuda M, Hakamada N and Teramaki Y 2001 Measuring of friction in timing chain Society of Automotive Engineers of Japan 22 pp 343-347
[12] Fink T and Bodenstein H 2011 Friction reduction potentials in chain drives MTZ Worldwide Edition 72 pp 46-51
[13] Sergeev S A and Moskalev D V 2009 Parametric Optimization of Chain-Transmission Sprockets Russian Engineering Research 29-5 pp 452-455
[14] J van Ruiten van J, Proost R and Meuwissen M 2012 How the choice of the polyamide type in timing chains tensioning systems affects the CO2 emission and fuel economy of internal combustion engines Presentation at VDI Ventiltrieb un Zylinderkopf
[15] Mouhmid B, Imad A, Benseddiq N and Lecompte D 2009 An experimental analysis of fracture mechanics of short glass fibre reinforced polyamide 6.6 (SGFR-PA66) Journal of Composite Science and Technology 69 pp 2521-2526
[16] De Monte M, Moosbruger E and Quaresimin M 2010 Influence of temperatura and thickness on the off-axis behavior of short glass fiber reinforced polyamide 6.6 – quasi-static loading Journal of Composites 41 pp 859-871
[17] Chiu F-C and Kao G-F 2012 Polyamide 46/multi-walled carbon nanotube nanocomposites with enhanced thermal, electrical and mechanical properties Journal of Composites 43 pp 208-218.
[18] Gordon D H and Kukureka S N 2009 The wear and friction of polyamide 46 and polyamide 46/aramid-fibre composites in sliding–rolling contact Wear pp 669-678
[19] Buccella M, Dorigato A, Pasqualini E, Caldara M and Fambri L 2012 Thermo-mechanical properties of Polyamide 6 chemically modified by chain extension with Polyamide/Poly carbonate blend Journal of Polymer Research 19 pp 9935-9944
[20] Akiyama M, Yamaguchi T, Matsumoto K and Hokkirigawa K 2010 Friction and wear of polyamide 66 composites filled with RB ceramics particles under dry condition Tribology Online 5 (2) pp 87-91
[21] Pereira C M, Ramalho A M and Ambrosio J A 2011 A critical overview of internal and external cylinder contact force models Nonlinear Dynamics 63 pp 681-697