ANNALS OF THE UNIVERSITY OF ORADEA
Fascicle of Management and Technological Engineering
ISSUE #1, MAY 2016, http://www.imtuoradea.ro/auo.fmte/

FEM MODELING OF THE LUBRICATION IN GUIDE – CHAIN LINK CONTACTS

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Abstract**—**The lubrication in chain drives has a major influence on their dynamic behaviour, wear and lifetime. The paper presents the finite element analysis of the lubrication for a given chain drive with a tensioning guide. The analysis is achieved for different lubricant widths according to the different tensioning forces of the guide. The results are giving information about the forces produced by the oil's pressure in the guide – chain link contacts and the characteristics of the oil flow which is influencing the vibrations in the contact.

Keywords**—**chain drive, guide, lubrication, FEM.

I. Introduction

THE dynamic behaviour of the chain drive transmissions and their durability is highly influenced by the lubrication conditions in the contacts between the tensioning guide and the chain links (lubricant pressure, relative speed between the elements being in contact, lubricant type, tensioning force, the materials of the elements being in contact, temperature, guide and link geometry).

The friction loses in a chain drive is developed due to the relative motions between the chain and the sprockets, between the chain and the tensioning guide and due to the frictions inside the chain. Close to 25% of the friction is produced by the contact between the chain and the tensioning guide [1], [2], [3], [4].

The friction phenomenon in guide/chain link contacts is influenced, for a given chain drive with a given tensioning guide and a given lubricant, on one side mainly by the tensioning guide material (for the part which is in contact with the chain) and, on the other side of the gap between the guide and the chain [3]; this gap is actually determined by the tensioning force and represents the width of the lubricant film, according to the *Reynolds* theory of lubrication [5], [6], [7], [8], [9], [10].

The studies regarding the lubrication of the guide / chain links contacts are only a few and mainly are presenting two aspects [10]. One represents the dependencies between the thickness of the lubricant film, the chain speed and the tensioning force of the guide. The other one is related to the dependencies between the pressure distribution in the contact area, the chain speed and the geometry of the tensioning guide.

The paper studies the lubrication phenomenon in the guide/chain link contacts for a given chain drive with a given tensioning guide and a given lubricant by considering different tensioning forces and different speeds of the chain; the aim is to identify the cases with a steady flow of the oil in order to obtain a good lubrication and small vibrations in the system.

II. The Model

The finite element modelling is developed for a bush chain drive used on a test rig – Fig.1; due to the reason that the width of the oil flow is bigger than the dimensions of the link, it is considered an oil enclosure for an isolated chain link, model which makes reasonable the use of the CFD theory. The lubrication phenomenon is studied for a contact between a link and the guide with the dimensions presented in Fig. 2.

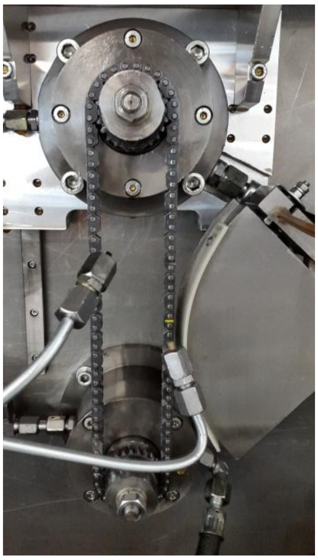


Fig. 1. The chain drive

Depending on the tensioning force of the guide and on the chain's speed, the lubricant widths in the contact area have values in the interval of 0.5 and 800 μm [11]. The finite element model is made for values of the lubricant width between 2 and 100 μm which is related to chain speeds between 2.5 and 10 m/s and tensioning forces between 10 and 30 N [11]. The lubricant oil used in the modelling is a 15w40 [10] type oil with a density of ρ=878.7 kg/m^3 and a viscosity of η=287.23 mPa·s [12].

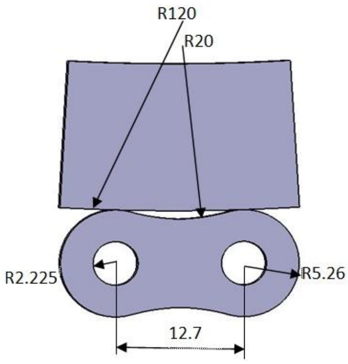


Fig. 2. The geometry of the guide – link contact

The model is made in the CFD module of ANSYS 15.0 software by considering the chain link in an enclosure which contains the oil – Fig. 3; there are imposed non-slip conditions with the walls of the enclosure in order to avoid the turbulence due to the contact with the enclosure's walls.

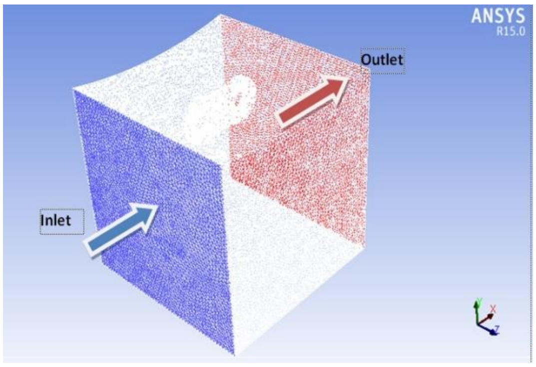


Fig. 3. The CFD model

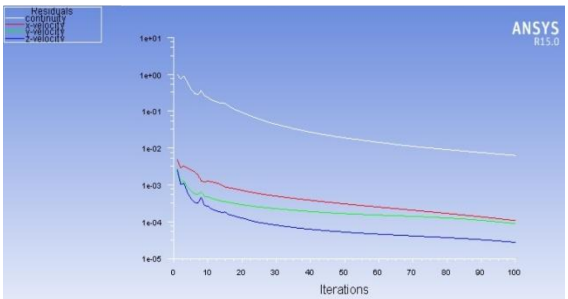


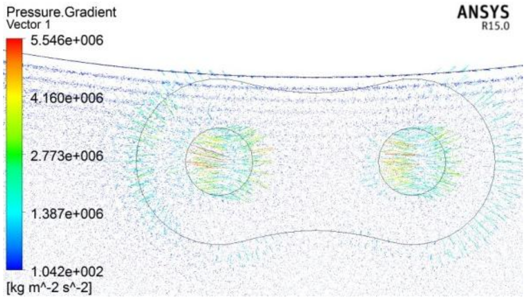
Fig. 4. The evolutions of the residuals

As boundary conditions, at the inlet it is imposed the oil speed between 2.5 and 10 m/s and at the outlet is assumed that the oil pressure is 0 Pa.

The evolution of the residuals is presented in the Fig. 4; according to the graph the convergence is achieved for an imposed residual bellow 0.001% after 30 calculus iterations.

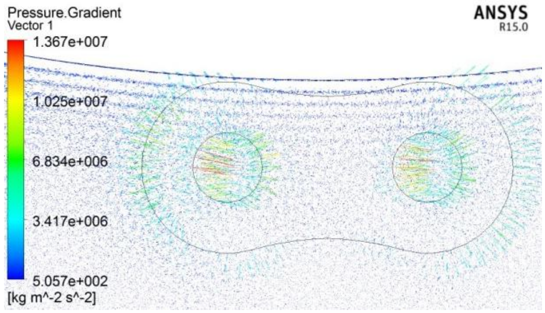
III. The Results

The results obtained after the analysis of the model are referring to the variation of the pressure, lifting force, relative speed and turbulence intensity; this variation is expressed depending on two parameters: the imposed relative speed between the chain and the guide and the lubricant width.



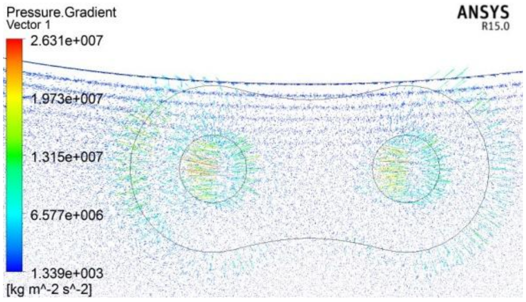
v=2.5 m/s

a



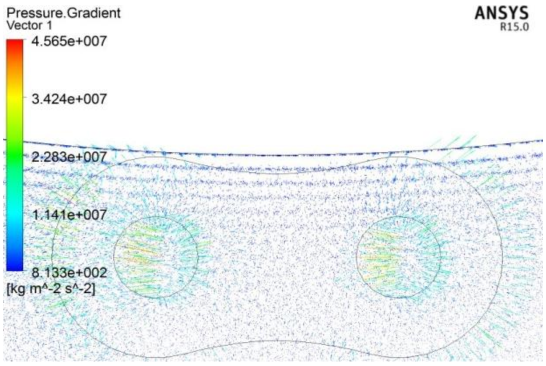
v=5 m/s

b



v=7.5 m/s

c



v=10 m/s

d

Fig. 5. The pressure gradient distribution

Fig. 5 presents the distribution of the pressure gradient for a lubricant width of 100 μm and relative speeds of 2.5, 5, 7.5 and 10 m/s respectively.

The pressure in the area was the lubricant width is minimum is determined by considering two sensors on the chain's link, in the area which is presented in Fig. 6.

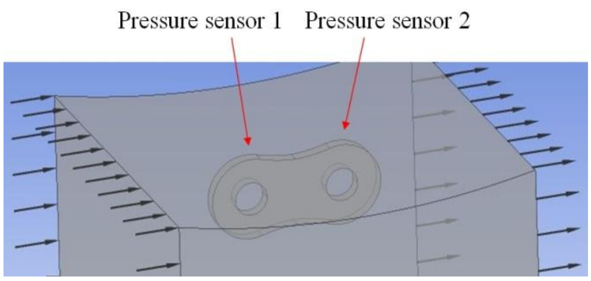


Fig. 6. The pressure sensors

The pressure in the guide – link contact zone is determined as the average of these two measured pressures; the variation of the pressure in the guide – link contact zone is presented in Fig. 7.

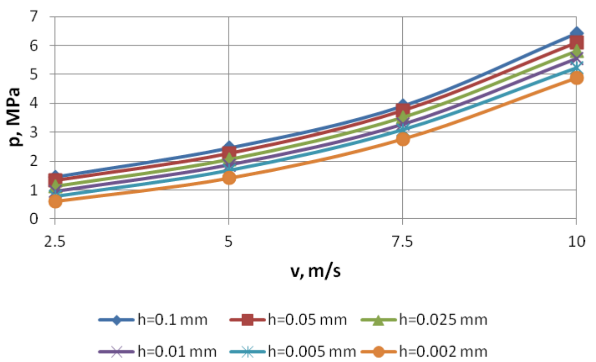


Fig. 7. The pressure vs relative speed

The pressure in the guide – link contact zone is increasing with the increasing of the relative speed between the guide and the chain link; the pressure increases with the increasing of the lubricant width h (Fig. 8) which is equivalent with low tensioning forces of the guide [11].

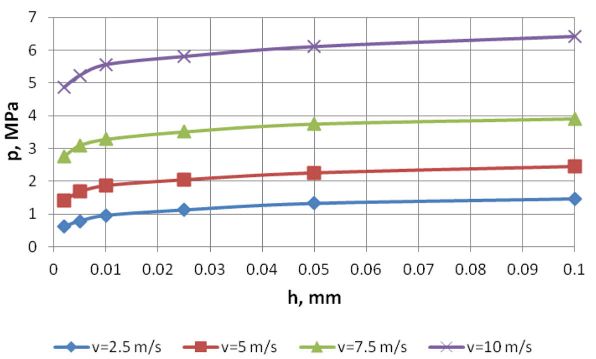


Fig. 8. The pressure vs lubricant width

Due to the pressure from the lubricant in the guide – chain link contact area appears a lifting force which is acting against the tensioning force of the guide – Fig. 9.

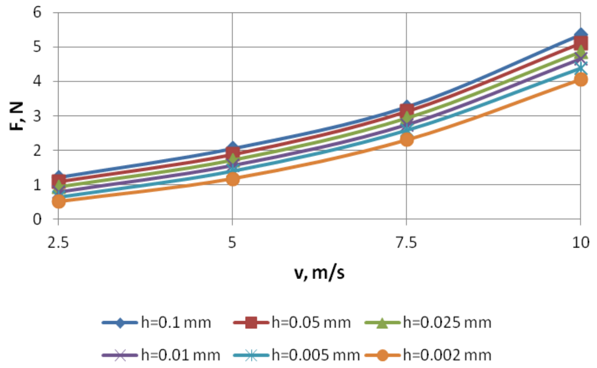


Fig. 9. The lifting force in the guide – link contact

The value of the lifting force is increasing with the increasing of the relative speed between the guide and the chain and is increasing with the increasing of the lubricant width in the guide – chain link contact zone.

Due to the gap between the chain lying and the guide, the lubricant speed has a variation in the guide – chain link contact zone; this local speed is measured by considering a speed sensor in the contact zone as it is presented in Fig. 10.

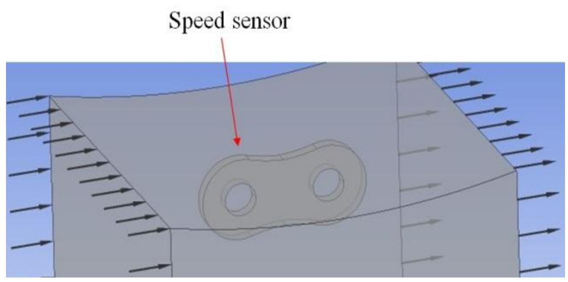


Fig. 10. The speed sensor

The variation of the speed in the contact area is presented in Fig. 11.

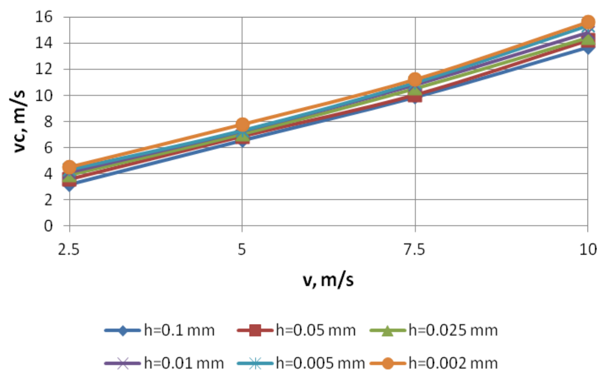


Fig. 11. The speed in the contact area

The oil speed in the contact area is increasing with the increasing of the relative speed between the guide and the chain link and is increasing with the decreasing of the lubricant width (Fig. 12). So, the oil speed in the contact area is increasing in the case of high tensioning forces at the guide.

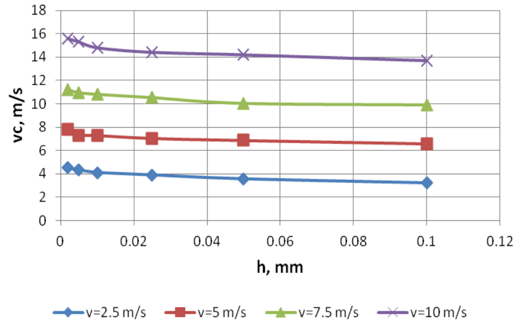


Fig. 12. The speed vs lubricant width

An important parameter which characterises the dynamic behaviour of the guide – chain link contact area is the lubricant turbulence kinetic energy which appears during the flow of the lubricant through the contact zone. The turbulence kinetic energy is measured by considering a turbulence sensor in the contact area as it is presented in Fig. 13.

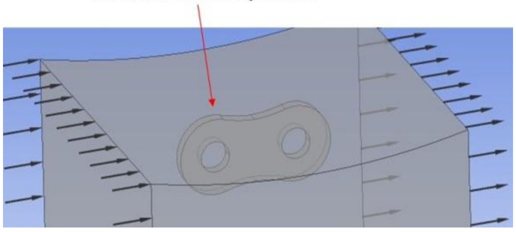


Fig. 13. The turbulence intensity sensor

The variation of the turbulence kinetic energy is presented in Fig. 14. The value of the turbulence kinetic energy increases with the increasing of the relative speed between the guide and the chain link and with the decreasing of the lubricant width which corresponds to high tensioning forces at the guide.

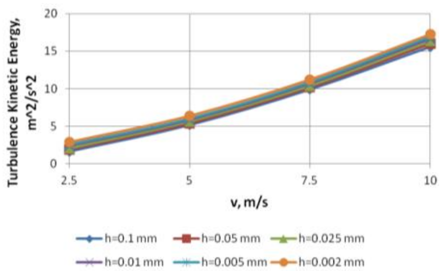


Fig. 14. The variation of the turbulence kinetic energy

IV. CONCLUSION

One of the phenomena which are influencing the chain drive durability and dynamical behaviour is referring to the lubricant flow characteristics [13], [14].

In order to obtain high durability of the chain drive there are preferred the cases when the pressure in the guide – chain link contact area has high values; according to the simulations results, these are the cases when the chain's speed has high values and the lubricant width is high.

For a good dynamical behaviour of the chain drive transmission (small vibrations) there are preferred the solutions with steady flows of the lubricant; the solutions of the simulations presents, in this way, the cases when the chain drives speed has high values and there are small gaps in the guide – chain links contacts.

In conclusion, for both cases there are preferred the cases when the chain drive speed has high values.

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