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DYNAMIC ANALYSIS OF ROLLER CHAIN LINK

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ABSTRACT—*In this paper a system of chain drives has been selected to study the dynamic analysis in roller chain drives. A unique feature of the work is presented in this study is that impact, polygonal action, and external periodic load have been included through chain tension and boundary condition and periodic length change length is also considered.*

Keywords—Polygonal action,Chordal action,Perriodic length.

I. INTRODUCTION

Chain drive dynamics became of interest to the automobile industry with the rise in importance of noise, vibration & harshness (NVH). Vibration and noises generated by chain transmission during the high speed application is the main problem of dynamic research. The major difficulties in the study of the roller chain drives are related with the way that the roller chain wraps around the sprockets, forming a polygon. This effect, called the polygonal action, together with the impact between rollers and sprockets participates in the creation of the noise and vibrations on the roller chain drive and to determine the chain drive load capacity and its service life.

A chain drive is extensively used in an industrial application. It is seen that it is used right from small capacity machine to heavy capacity machine. During machine operation the chain of a chain drive receives variable load and thus induces variable tension in it. The linkage member of a chain experiences this varying tension during complete work cycle. Evidences says that due to this varying load condition the chain itself vibrates which provides impact loads on its sprockets and thus it enhances the wear and tear of a chain drive. Hence it is inevitable to see the effect of varying load condition of a specific unit on its performance by estimating its vibrations.

II. GEOMETRIC RELATIONSHIPS

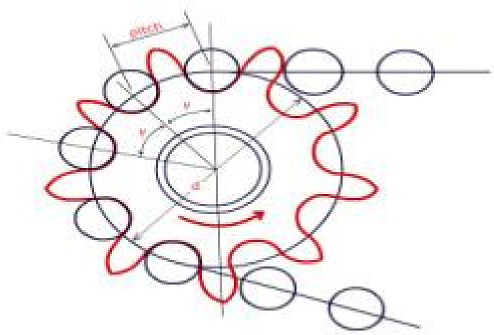

Fig : **Geometry of chain on sprocket wheel**

$\alpha = \frac{360}{z}$ --eq. (1)

Where,

z is the number of teeth on the sprocket.

From the figure, it can be proved that

$sin\left(\frac{\alpha}{2}\right) = \left(\frac{p/2}{D/2}\right)$ ---eq. (2)

Or

$$D = \frac{p}{sin\left(\frac{\alpha}{2}\right)}$$

$\therefore D = \frac{p}{sin\left(\frac{180}{z}\right)}$ ---eq. (3)

The velocity ratio I of the chain drives is given by,

$i = \frac{n1}{n2} = \frac{z2}{z1}$--eq. (4)

Where

n1, n2=speeds of rotation of driving and driven shafts [rpm]

z1, z2=number of teeth on driving and driven sprockets.

The average velocity of the chain is given by,

$$v = \frac{\pi Dn}{60 * 10^3}$$

Therefore $v = \frac{\pi pn}{60*10^3}$--------------------------------------eq. (5)

Where

V is the average velocity in m/s.

The length of the chain is always expressed in terms of the number of links or

L=Ln*p ---eq. (6)

Where

L = length of the chain (mm)

Ln = number of links in the chain

The number of links in the chain is determined by the following relationships:

$Ln = 2\left[\frac{a}{p}\right] + \left[\frac{z1+z2}{2}\right] + \left[\frac{z2-z1}{2\pi}\right] * \left[\frac{p}{a}\right]$ ------------eq. (7)

Where

a = centre distance between axes of driving and driven sprockets [mm]

z1 = number of teeth on the smaller sprocket.

z2 = number of teeth on the larger sprocket

$$a = \frac{p}{4}\left[\left(Ln - \frac{z1 + z2}{2}\right)\right] + \sqrt{\left(Ln - \left(\frac{z1 + z2}{2}\right)\right) - 8\left(\frac{z2 - z1}{2\pi}\right)x^2}]$$

III. POLYGONAL EFFECT

The chain passes around the sprocket as a series of chordal links. This action is similar to that of a non-slipping belt wrapped around a rotating polygon. The chordal action is illustrated in fig .3.8 where the sprocket has any four teeth. It is assumed that the sprocket is rotating at a constant speed of (N) rpm. In fig. the chain link AB is at a distance of $[\frac{D}{2}]$ from the centre of the sprocket wheel and its linear velocity is given by,

$Vmax = \frac{\pi Dn}{60*10^3}$m/s----------------------------[a]

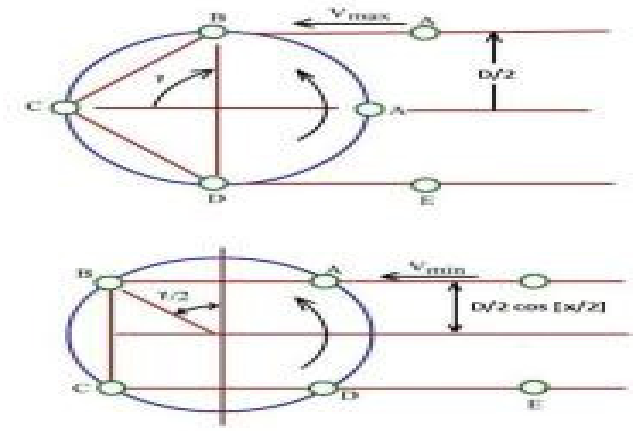

Fig:**Polygonal action of chain**

As the sprocket rotates through an angle $\left[\frac{\alpha}{2}\right]$, the position of the chain link AB is shown in figure. In this case, the link is at a distance of $\frac{D}{2} * cos\left[\frac{\alpha}{2}\right]$ from the centre of the sprocket and its linear velocity is given by,

$$Vmin = \frac{\pi Dncos\left[\frac{\alpha}{2}\right]}{60 * 10^3} m/s$$

It is evident that the linear speed of the chain is not uniform but varies from Vmax to Vmin during every cycle of teeth engagement. This results in a pulsating and jerky motion. The variation in velocity is given by

[Vmax-Vmin]$\propto$ $[1 - cos\left[\frac{\alpha}{2}\right]]$
Or
[Vmax-Vmin]$\propto$ $[1 - cos\left[\frac{180}{z}\right]]$

As the number of teeth (z) increases to ∞, $\boldsymbol{cos}\left[\frac{\mathbf{180}}{\boldsymbol{z}}\right]$ or $\left[\frac{\mathbf{180}}{\infty}\right]$, cos (0°) will approach unity and [Vmax-Vmin] will become zero. Therefore the variation will be zero. In order to reduce the variation in chain speed, the number ofteeth on the sprocket should be increased. It has been observed that the speed variation is 4% for a sprocket with 11 teeth, 1.6% for a sprocket with 17 teeth and less than 1% for a sprocket with 24 teeth.
For smooth operation at moderate and high speeds, it is considered a good practice to use a driving sprocket with at least 17 teeth. From durability and noise considerations, the minimum number of teeth on the driving sprocket should be 19 or 21.
It is evident that linear speed of the chain is not uniform but varies during every cycle of tooth engagement. This results in a pulsating and jerky motion to the chain and the driven sprocket. This is called "Chordal speed variation", and is plotted in Fig. 3.9.

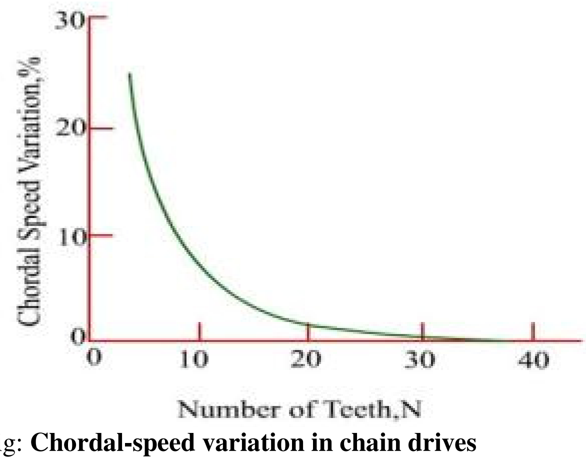

Fig: **Chordal-speed variation in chain drives**

The failure of roller chains is mainly due to wear on the rollers and pins. The chain is elongated due to wear in the joints and as a result the rollers shift with respect to the teeth on the sprocket. When the sprocket is made of large number of teeth (with shorter pitch), even a small elongation of the chain displaces the chain with respect to the teeth on sprocket to a greater extent, leading to improper meshing. This limits the maximum number of teeth on the sprocket. For roller chains, the recommended maximum number of teeth for the sprocket wheel is about 100 to 120.

IV. DYNAMIC ANALYSIS OF ROLLER CHAIN LINK

In this section dynamic behavior of a link of a roller chain has been explained. For this purpose a case has been chosen and dynamic analysis is performed for one articulation of the chain.

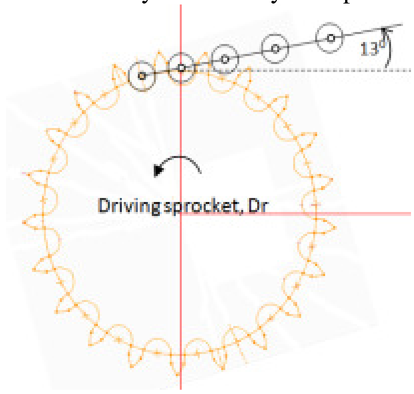

Fig: **Schematic diagram of driving sprocket**

The analysis is initiated by considering position shown in figure 1.1 as the reference position. With reference to this position, the sprocket is rotated in anticlockwise direction with an angular displacement of 2^0 and therefore dynamic analysis is carried out at 0^0, 2^0,4^0,6^0,8^0,10^0,12^0,14^0,16^0 and 18^0 for one articulation i.e 17^0.

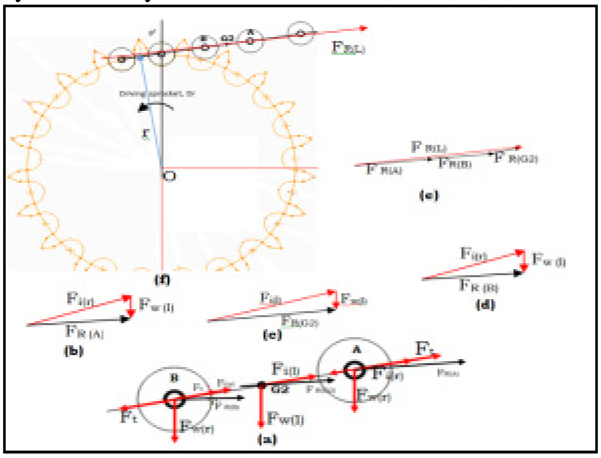

Figure 1.1**: Schematic diagram of chain drive system at 0**

Table 4.1 Calculation of forces

Point of application	Forces (N)	Resultant (N)	
B	F_t = 1851.4 $F_{w(r)}$ = 0.2 $F_{i(r)}$ = 1.2	$F_{R(B)}$ = 1.16	$F_{R(L)}$ = 1.7 N
G2	$F_{w(l)}$ = 0.1 $F_{i(l)}$ = 0.6	$F_{R(G2)}$ = 0.585	
A	F_t = 1851.4 $F_{w(r)}$ = 0.2 $F_{i(r)}$ = 1.2	$F_{R(A)}$ = 1.16	

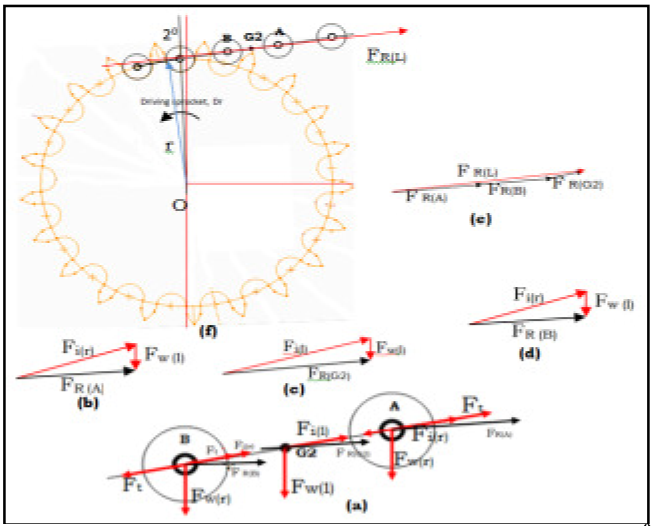

Figure 1.2**: Schematic diagram of chain drive system at 2^0**

Table 1.2: **Calculation of forces**

Point of application	**Forces (N)**	**Resultant (N)**	
B	$F_t = 1851.4$ $F_{w(r)} = 0.2$ $F_{i(r)} = 1.2$	$F_{R(B)} = 1.16$	
G2	$F_{w(l)} = 0.1$ $F_{i(l)} = 0.6$	$F_{R(G2)} = 0.585$	$F_{R(L)} = 2.8$ N
A	$F_t = 1851.4$ $F_{w(r)} = 0.2$ $F_{i(r)} = 1.2$	$F_{R(A)} = 1.16$	

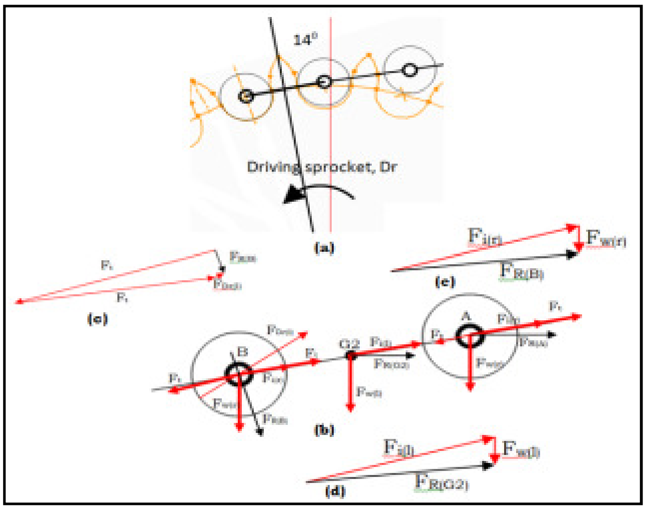

Figure 1.3: **Schematic diagram of chain drive system at 14^0**

Table 1.3: **Calculation of forces**

Point of application	**Forces (N)**	**Resultant (N)**	
B	$F_t = 1851.4$ $F_{w(r)} = 0.2$ $F_{i(r)} = 1.2$	$F_{R(B)} = 99$	

	$F_{Dr(l)} = 2.4$		
G2	$F_{w(l)} = 0.1$ $F_{i(l)} = 0.6$	$F_{R(G2)} = 0.585$	$F_{R(L)} = 3.4$ N
A	$F_t = 1851.4$ $F_{w(r)} = 0.2$ $F_{i(r)} = 1.2$	$F_{R(A)} = 1.16$	

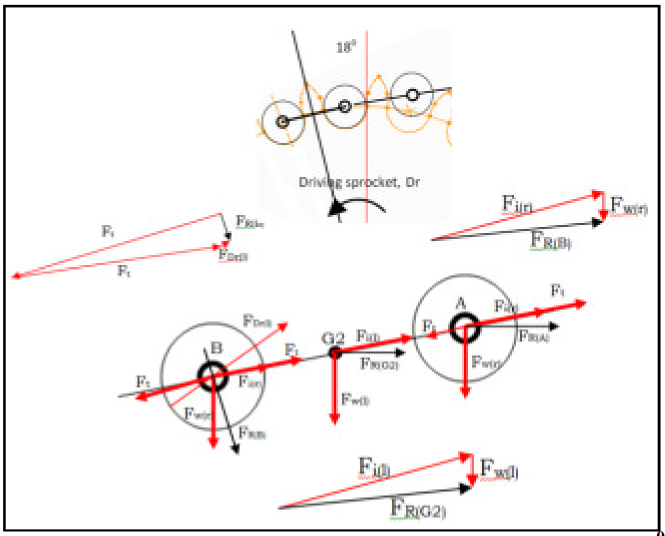

Figure 1.4**: Schematic diagram of chain drive system at 18^0**

Table 1.4 **:Calculation of forces**

Point of application	**Forces (N)**	**Resultant (N)**	
B	$F_t = 1851.4$ $F_{w(r)} = 0.2$ $F_{i(r)} = 1.2$ $F_{Dr(l)} = 2.4$	$F_{R(B)} = 149$	$F_{R(L)} = 50$ N
G2	$F_{w(l)} = 0.1$ $F_{i(l)} = 0.6$	$F_{R(G2)} = 0.585$	
A	$F_t = 1851.4$ $F_{w(r)} = 0.2$ $F_{i(r)} = 1.2$	$F_{R(A)} = 1.16$	

V. CONCLUSION

Based on the present work the following some important conclusions have been drawn:

1) The dynamics of a link of a chain drive during one articulation is always non-linear.
2) The rigorous literature review indicates that there is unique feature of work is presented in this study is that impact, polygonal action havebeen included through chain tension and periodic length is also considered.
3) An attempt is being made to understand the relationship between chordal speed variation [%] & number of teeth [N] & it has been revealed that number of teeth on the sprocket should be increased.
4) It is evident that linear speed of the chain is not uniform but varies during every cycle of tooth engagement. This results in a pulsating and jerky motion to the chain and the driven sprocket. This is called “Chordal speed variation”.

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