Research Inventy: International Journal of Engineering And Science
Vol.4, Issue 5 (May 2014), PP 21-25
Issn (e): 2278-4721, Issn (p):2319-6483, www.researchinventy.com

Dynamic Analysis of Timing Chain System of a High Speed Three Cylinder Diesel Engine

[1] R. V. Mulik, [2]Prof. M. M. Joshi, [3]Dr. S. Y. Gajjal, [4]S. S. Ramdasi and [5]N. V. Marathe
[1, 4 and 5] *The Automotive Research Association of India, Pune, India*
[2, 3] *NBN Sinhgad School of Engineering, Pune, India*

ABSTRACT: *The current trend in automotive industry is to achieve compact, efficient, reliable systems. Engine timing drives used in engines are one of the most critical systems. Timing belts are subjected to excessive elongation and wear, while timing gears contribute excess mass and inertia in the system. Hence timing chains are preferred widely, in various high performance engines, both in gasoline and diesel engines. Chain drives are easy to assemble and adjust, highly efficient, durable, reliable, compact and capable of attaining a wide range of power and speed capacities. In spite of these advantages their complex dynamic behavior is not well researched. The major objective of the current work is to develop timing chain drive for a high speed three cylinder diesel engine and investigate about its durability. The scope of the work includes developing a simulation model in suitable simulation software and its dynamic analysis. The results are expressed in terms of parameters such as contact forces and normal forces between different components and link tension forces etc.*

***Keywords*:** Chain Drive, chain tension.

I. INTRODUCTION

Automotive engine is an area where large numbers of researches were done by many researchers. Engine timing is such an aspect of research which correlates the valve timing and injection timing in an automotive engine. This phenomenon of timing governs many parameters of engine performance and is required to be as precise as possible. To achieve proper timing at injectors and valves, timing drives are needed to be studied and analyzed for their dynamic behavior. The timing chain considered in the current work, transfers motion from engine's crankshaft to the camshaft that operates the valves and to Fuel Injection Pump (FIP) which controls fuel injection timing. The dynamics plays a vital role in the function, performance and life of the component. The dynamics of a timing chain drive affect the functioning of other components of an engine such as valve train, crankshaft etc. The purpose of this work is to investigate the dynamic analysis of the timing chain with a dedicated simulation software

II. OBJECTIVES

The major objectives of this project are as follows –

- To develop a simulation model of the timing chain system on a dedicated simulation software.
- To carry out dynamic analysis of the timing chain simulation model.
- To find out chain tension, contact forces between chain and other components like sprocket, chain guides, etc..

III. TIMING CHAIN SYSTEM ARRANGEMENT

ARAI has designed high performance, state of art 3 cylinder diesel engine. Timing drive system used in the engine is bush chain drive system. Figure 1 shows layout of the chain drive system in engine.

As shown in the Figure 1, one of the chains (Cam-chain) runs over Duplex sprocket and Cam sprocket. The speed ratio between the duplex sprocket and cam sprocket is 0.5. It is supported and guided by two guides, one movable guide and one fixed guide. A hydraulic tensioner is provided to the movable guide. The tensioner facilitates the chain to be tightened whenever it gets loosen.

Another chain (FIP Chain) runs over the duplex sprocket and the FIP sprocket. Speed ratio between duplex sprocket and FIP sprocket is 0.75. Similar to the Cam-chain, it is provided with one movable guide, one fixed guide and a hydraulic tensioner. Engine speed is 4000 rpm.

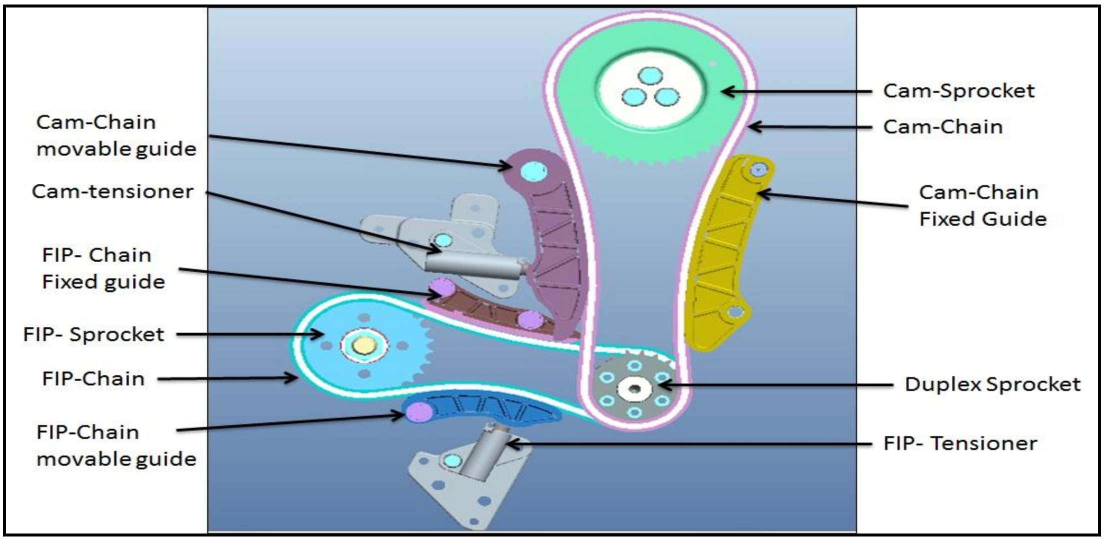

Figure 1: Timing chain Layout

IV. MATHEMATICAL MODELING

A simulation model of a three cylinder engine bush timing chain system has been developed in GT V-Train software as shown in Figure 2. Figure 3 shows the 2D representation of the timing chain in the software. The condition of external load (i.e. torque) for which chain drive system is designed is specified to the camshaft and FIP shaft. Kinematics of the chain drive system for these loading conditions is satisfying the requirements and now the aim is to check design for the dynamic point of view(and redesign wherever required). Detail design of sprockets, chain guides and number of chain links is carried out. Input data required regarding the same is specified to the software simulation environment accordingly.

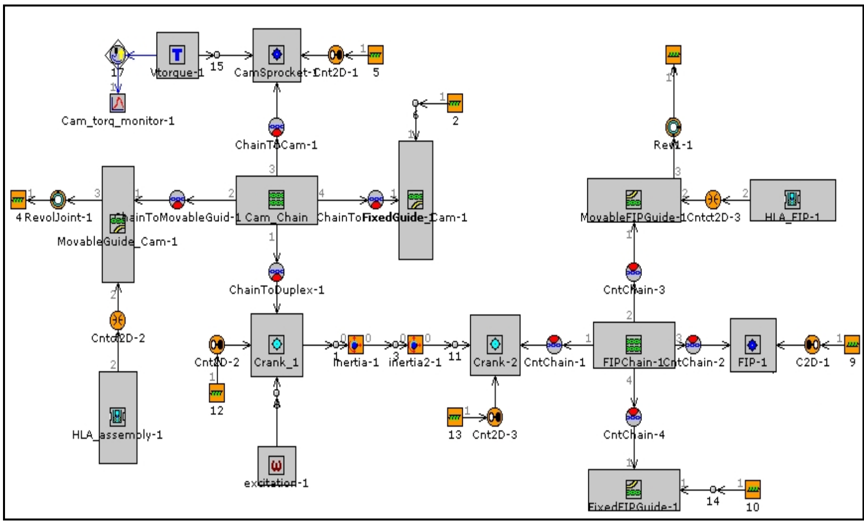

Figure 2: Mathematical model of Timing chain Layout

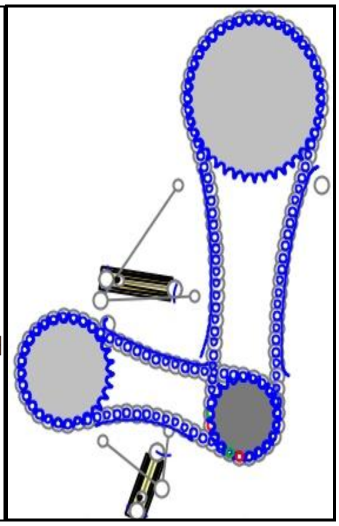

Figure 3: 2D layout of timing chain

1. Results & Discussions

The results we obtained in terms of chain-sprocket contact forces, chain guide contact forces, tensioner plunger-guide contact forces, and normal forces between different components, external torque acting on the chains, sprockets, hub load, and link tension forces etc. The following section focuses on few important results out of them. Figure 4 shows the variation of tension force between the chain links with reference to the driver rotation angle θ.

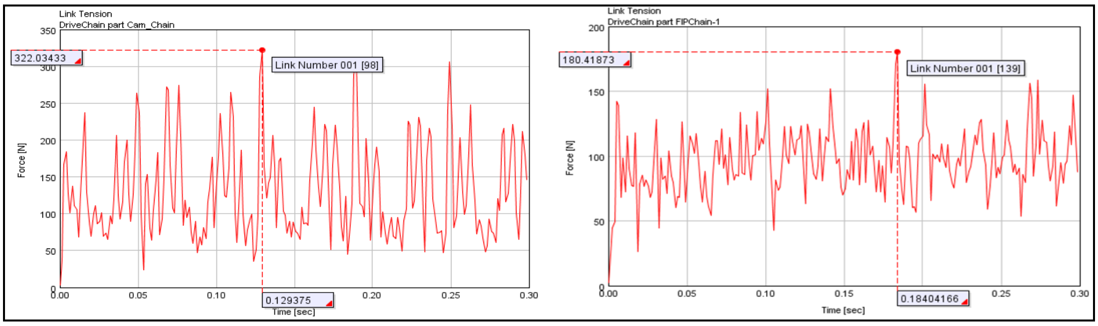

Figure 4: Maximum chain tensions in Cam-chain and FIP Chain

It was noticed that the maximum chain tension in cam side chain was 322 N whereas the maximum chain tension in FIP side chain was 180 N. The breaking load of the chain was much higher and is 10500 N. Hence, both the chains are safe and reliable from tensile failure point of view.

External forces acting on a sprocket include the forces acting on sprocket in X and Y direction due to chain pull. Figure 5 shows the external forces acting on the duplex sprocket. The term crank-1 represents the portion of duplex sprocket connected to cam sprocket through chain whereas the term crank-2 represents the portion of duplex sprocket connected to FIP sprocket. The maximum external force on crank-1 in X direction was 519 N and 614 N in Y direction. Similarly the maximum external force on crank-2 in X direction was 441 N and426 N in Y direction. These values are very small as compared to the maximum permissible load that can be sustained by duplex sprocket.

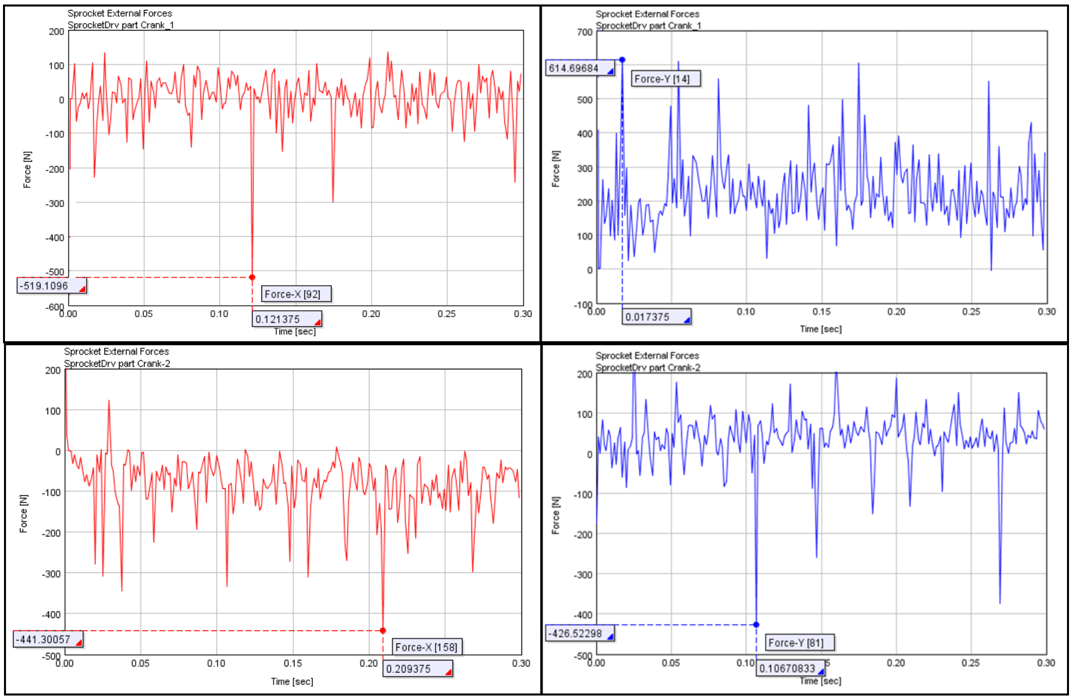

Figure 5: Maximum external forces on Duplex sprocket

The contact forces between the chains and guides and chains and sprockets are major parts of investigation. Figure 6 shows the variations of Total contact force of cam chain with sprockets and guides. Figure 6(A) shows the variation of contact force between cam-sprocket and Cam-chain w.r.t driver rotation angle ‘θ’. The maximum value of which is 446 N. Similarly Figure 6(B), (C), (D) shows contact force variation between Cam-chain and fixed guide, cam-chain and Duplex sprocket and cam-chain movable guide respectively. The maximum values recorded for above parameters were 572 N, 356 N and 279 N respectively.

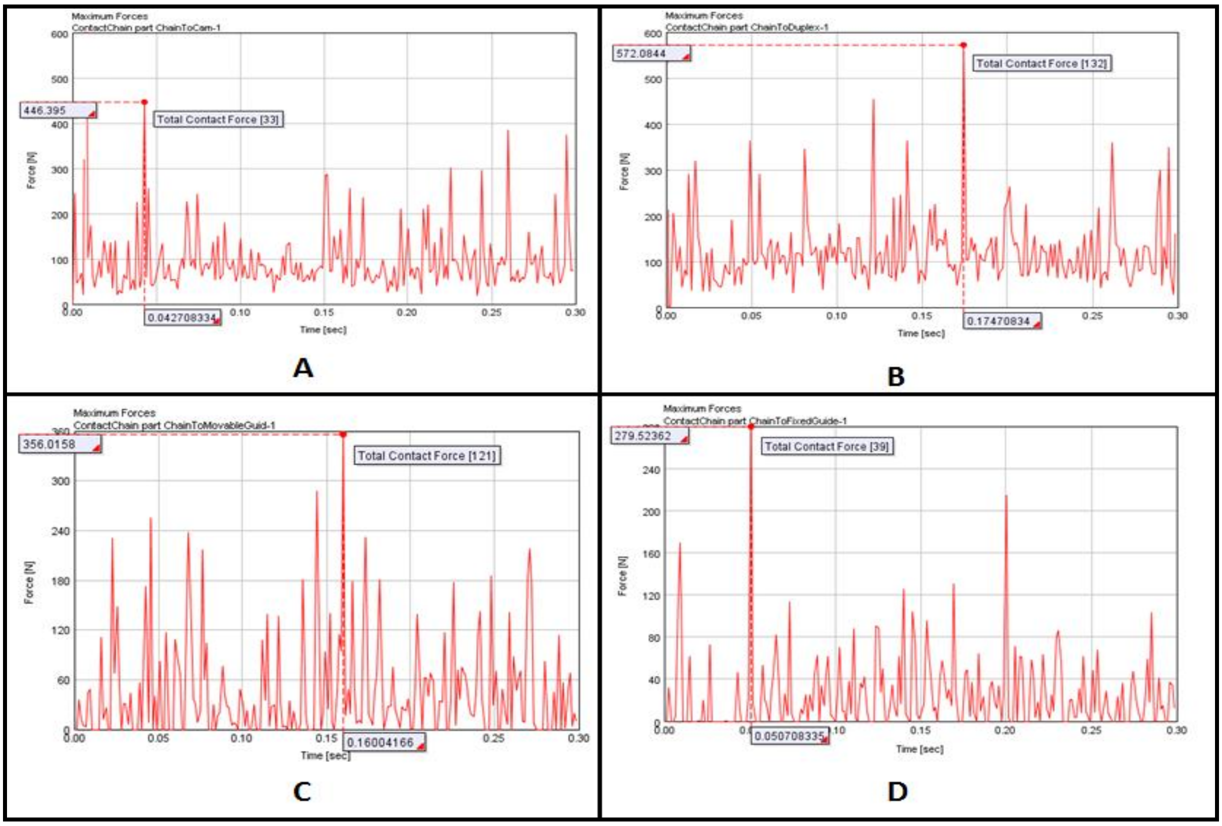

Figure 6: Total Contact forces A: Between Cam chain and Cam Sprocket, B: Between Cam chain and crank-1 sprocket, C: Between Cam chain and Cam movable guide, D: Between Cam chain and Cam fixed guide

Figure 7 shows similar contact force variation for FIP-chain. The maximum contact force between FIP- Chain and duplex sprocket was 433 N and same was 472 N between FIP- chain and FIP sprocket.
The contact force between FIP-Chain and movable guide is noticed to be 264 N. The maximum contact force between the FIP chain and fixed guide is 142 N.

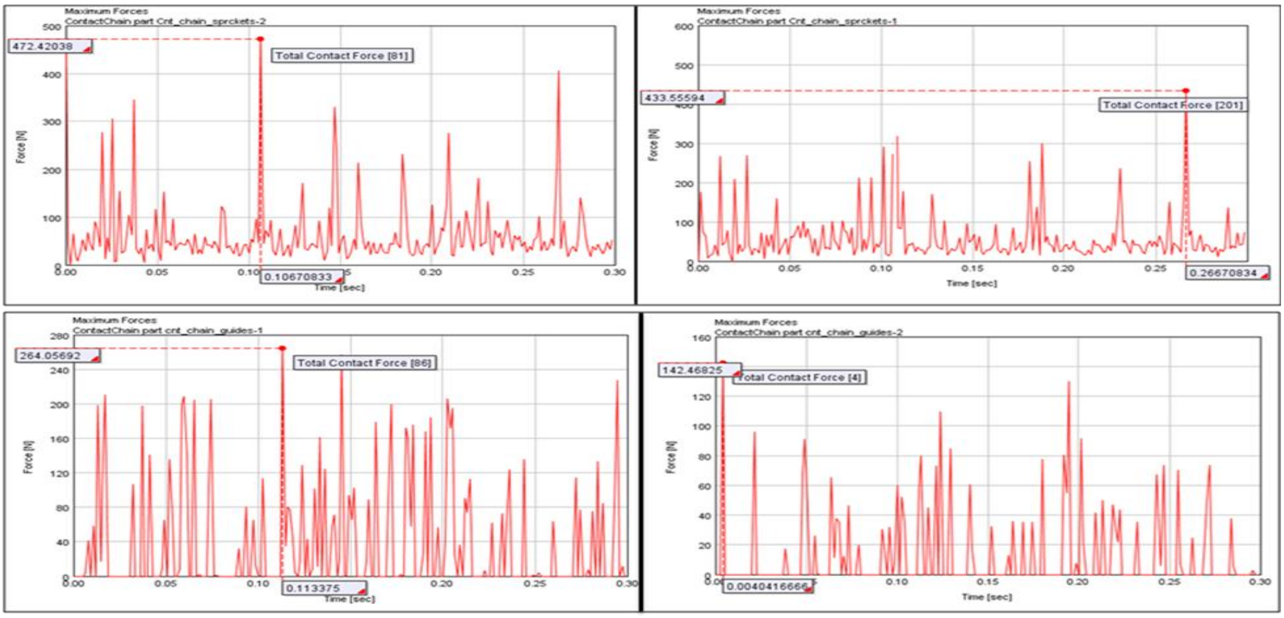

Figure 7: Total Contact force between FIP-chain and other connected components

V. CONCLUSIONS

The results presented above show that the external forces and loads can be easily sustained by the timing chain components. The obtained values for the contact forces, tensions etc. were much below the maximum permissible values. The layout designed is compact, functionally and dynamically stable and safe and can be implemented in actual engine. The current layout can be modified further to a single chain layout for more compact and reliable design. The current methodology thus proves to be a fair solution to analyze timing chain drives, a vital component of an engine.

REFERENCES

[1] C. Pereira, J. Ambrósio, A. Ramalho , "Contact Mechanics In A Roller Chain Drive Using A Multibody Approach", 13th World Congress in Mechanism and Machine Science, Guanajuato, México, 19-25 June, 2011

[2] Dong Chengguo, Meng Fanzhong, "Dynamic Simulation and Analysis of Automotive Engine's Timing Silent Chain System", 5th Asian Conference on Multibody Dynamics 2010 August 23-26, 2010, Kyoto, Japan

[3] Friedrich-Wilhelm Speckens, Jürgen Buck, Rainer Lach,"Marked Progress in Both Technique and Handling of Valve Train and Valve Train Drive Calculation on Commercial Platforms", SAE 1999-01-0560, (1999)

[4] Gerhard Hippmann, Martin Arnold and Marcus Schittenhelm, "Efficient simulation of bush and roller chain drives"

[5] Hiroshi Takagishi , Atsushi Nagakubo, "Multi-Body Dynamic Chain System Simulation Using a Blade Tensioner", SAE 2006-32-0067

[6] Ing. Pavel NOVOTNÝ, Ph.D., Brno University of Technology, Prof. Ing.Václav PÍŠTĚK, Dr Sc., Brno University of Technology , 'Dynamics of chain timing drive' .

[7] James C.conwel , " Experimental investigation of chain tension and roller sprocket impact force in roller chain drives".

[8] Motoyasu Sakaguchi, Shinji Yamada, Masao Seki, Yojiro Koiwa, Takahiro Yamauchi and Tomohiro Wakabayashi, "Study on Reduction of Timing Chain Friction Using Multi-Body Dynamics", SAE 2012-01-0412

[9] R. S. Dwyer-Joyce, R. Lewis, A. Ward and E. A. Patterson, "Determination of Impact Stresses in an Automotive Chain Drive Component", SAE 2006-01-0766

[10] Sine Leergaard Pedersen, "Simulation and Analysis of Roller Chain Drive Systems", Ph.D. thesis, Department of Mechanical Engineering, Solid Mechanics, Technical University of Denmark.

[11] Yeongching Lin, Sheng-Jiawhwang, Pete pandolfi, Sam McDonald, "The dynamic analysis of automotive timing chain system".