International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 21 (2018) pp. 15284-15289

Statistical Analysis of the Pressure Profile Variations of Hydraulic Circuit in CNC Machine

Ramesh. S[1*], S. Denis Ashok[1], Shanmukha Nagaraj[2]

[1] School of Mechanical Engineering (SMEC), VIT University, Vellore-632014, India.
[2] Department of Mechanical Engineering, R V College of Engineering, Bangalore, India.

Abstract

The analysis of the hydraulic power pack is important, so that we can reduce the energy losses, increase the performance and design the system in such a way that it will meet our requirement. The present hydraulic systems are more energy consuming; this is because the hydraulic motor running at constant rpm results in pumping extra oil. This leads to unnecessary flow of oil through the circuit and heats up the oil which in turn reduces the viscosity of the oil. Also, reduction in energy consumption, reduction in noise as well as cost effectiveness of the hydraulic system is of great importance in present day machinery design. Based on the pressure requirement, the hydraulic power pack can have one pump or two pumps. This requirement of pumps (i.e., either single pump or dual pump) can be obtained by analyzing the pressures required in the cylinder. Every industry aims low cost and high reliable hydraulic system, which consume less power and has lower energy losses. Hence to carry out task it is required to setup up actual working profile for the machine and its pressure characteristics for the complete working cycle. A dynamically compatible pressure profile was generated that was achieved by using variable frequency drive to the constant speed motor. The basic pressure profile was generated using the pressure variation in the cylinder for the various applications like clamping and automatic tool changer. The simulation was carried out in automation studio for both hydraulic circuits with and without VFD and are studied using mathematical model provided.

Keywords*:* Hydraulic power pack, pressure profiles, mathematical model, automatic tool changer, automatic pallet clamper

INTRODUCTION

In present day scenario, the consumption of energy is to such a level that if the same trend continues then after some time in the future the sources of energy will get exploited. Conservation of energy in a hydraulic power pack is nothing but reducing the amount of energy which is being consumed. In order to reduce the consumption of energy much experimentation are carried out and incorporation of variable frequency drive is one among those.

Variable frequency drives coupled with induction motors of constant speed is a solution to control the fluid flow and the system pressure. Using such combination has several advantages such as energy economy, ease of control, easy to maintain compared to traditional ones.

Figure 1: Hydraulic power pack

HYDRAULIC POWER PACK

Hydraulic power pack comprises the prime mover, pump, variable frequency drive reservoir, pressure relief valve etc. The fluid from the reservoir passes through a filter, where foreign particles are removed. The prime mover is usually an electric motor, which supplies the necessary mechanical power to drive the pump. The pump in turn supplies the required input power to the fluid to convert it into hydraulic power. Basically, the pump increases the pressure of the confined fluid by continuous pumping operation.

Hydraulic power pack in CNC machines is used for various applications. Some of them include: Tool clamp / de-clamp operation, Pallet clamp / de-clamp operation, Hydro motor for arm rotation or turret rotation, Automatic Tool Changer, Rotational axis clamp / de-clamp operation.

International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 21 (2018) pp. 15284-15289

Existing Hydraulic Power Pack circuit

Figure 2 explains the schematic representation of the existing hydraulic circuit used by machine tool manufacturers.

Working of Hydraulic Power Pack: (Cylinder is in motion)

Piston moves when the DCV is switched in either direction. When the system is actuated, the hydraulic oil flows into the cylinder from DCV, which induces a drop in pressure. Constant oil flow is obtained as the motor runs at constant rpm. A very small fraction of oil flows to the reservoir via PRV while rest of the oil is used in moving the actuator.

Hydraulic kit is used for the experimentation purpose to study the feasibility of the motor coupled with VFD for the applications of clamping and operation of automatic tool changer in a CNC machine. For the experiment to be conducted, it was essential to create an actual working profile for the machine and its pressure characteristics during the working cycle. The pressure variation in the cylinder for the different applications like clamping pressure and automatic tool changer are presented in the figure 1.

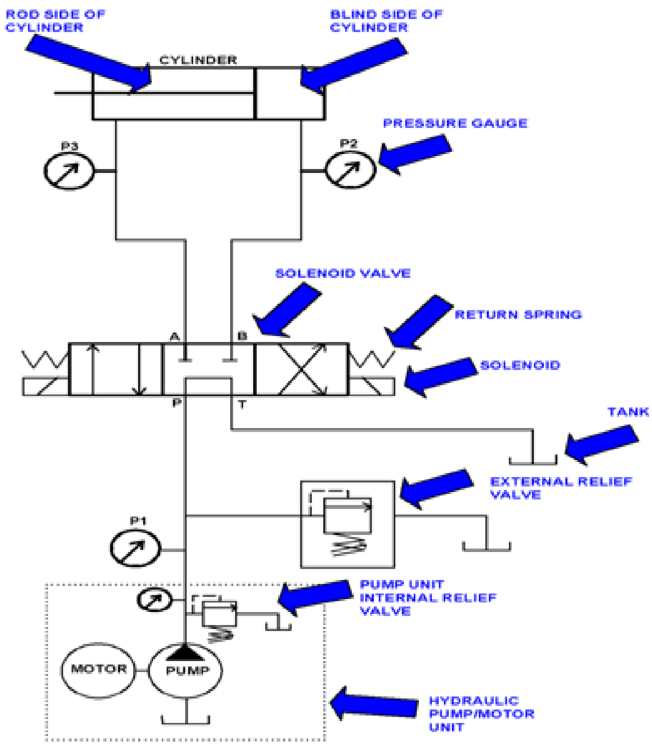

Figure 2: Existing hydraulic Circuit [16]

Pressure inside the cylinder depicts the improvement of working and the respective forces on the cylinder. Function of the pump is to supply oil to all the components of the machine and not just the work tool driven by the cylinder. It also has to respond to all the change in loading conditions such as clamping forces, automatic tool changer etc. Pressure requirements vary depends upon the application as shown in Figure 3.

Problems with the existing Hydraulic Circuit

- The present hydraulic systems are more energy consuming.
- Hydraulic motor running at constant rpm results in the extra oil being pumped to the reservoir via pressure relief valve.
- Oil flow through pressure relief valve during clamped position.
- Oil temperature increases in the reservoir.

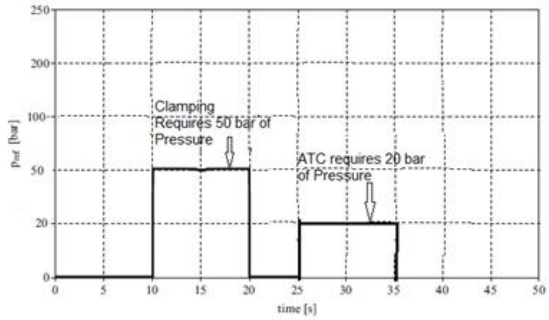

Figure 3: Variation of pressure based on application

Figure 4: Hydraulic system accommodated with hydraulic power pack

The pressure variation plots can be obtained by using the following formulae:

- The movement equation for the piston is;

$$\left(p_A \cdot A_A\right)-\left(p_B \cdot A_B\right)=M_t \cdot \frac{d^2x}{dt^2}+Bc \cdot \frac{dx}{dt}+F_{at}$$

- By using the mass conservation equation, the inflow and the outflow from the chamber can be written as;

$$q_{VA}=A_A\frac{dx}{dt}+\frac{V_A}{\beta e}\cdot\frac{dp_A}{dt}$$

$$q_{VB}=A_B\frac{dx}{dt}-\frac{V_B}{\beta e}\cdot\frac{dp_B}{dt}$$

- The effect of pressure on the control orifices;

$$q_{VA} = Cd.A_3.\sqrt{\frac{2}{\rho}.(p_S - p_A)} - Cd.A_4.\sqrt{\frac{2}{\rho}.(p_A - p_R)}$$

$$q_{VB} = Cd.A_6.\sqrt{\frac{2}{\rho}.(p_S - p_B)} - Cd.A_5.\sqrt{\frac{2}{\rho}.(p_B - p_R)}$$

- Using total flow coefficient, the flow through working ports is given as;

$$q_{VA} = Kv.\frac{U}{U_n}.\sqrt{\Delta p_i}$$

$$q_{VB} = Kv.\frac{U}{2U_n}.\sqrt{\Delta p_i}$$

OBSERVATION AND ANALYSIS

The following are some of the simulations of pressure profile variations in the hydraulic power pack:

Normally, it is used for clamping.

Pressure – profile variations:

When pressure port P is connected to the port A of the actuator and port B is connected to the tank port T.

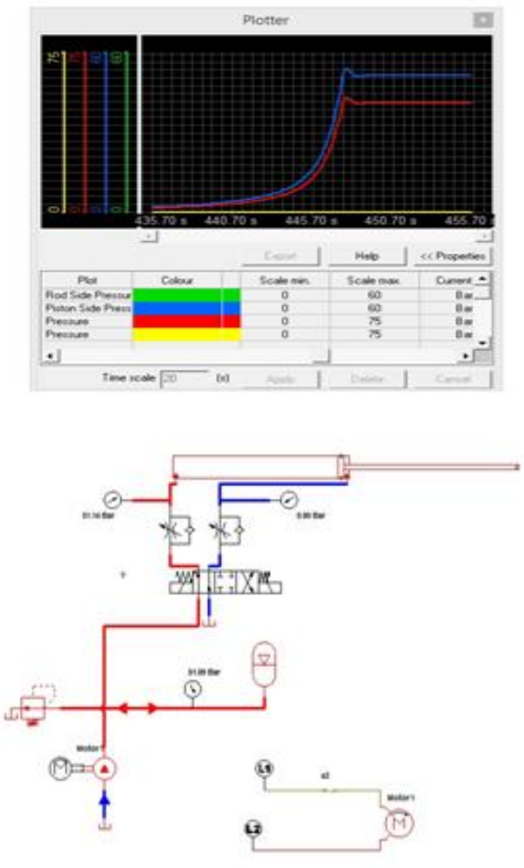

Figure 5: End of extension stroke

Piston Pressure and Pressure in the system (Indicated by pressure gauge) increases to maximum set pressure of 50 bar once the piston reaches to rod end position.

This indicates further flow of oil is not required into the cylinder as the cylinder is used for clamping application. But constant speed motor running at 1500rpm and helps pump to draw oil from tank and returns through pressure relief valve this increases the oil temperature.

- Blue line explains that piston pressure reaching to set pressure of 50 bar.
- Red line indicates that pressure is the system reaching to maximum set pressure of 50 bar.

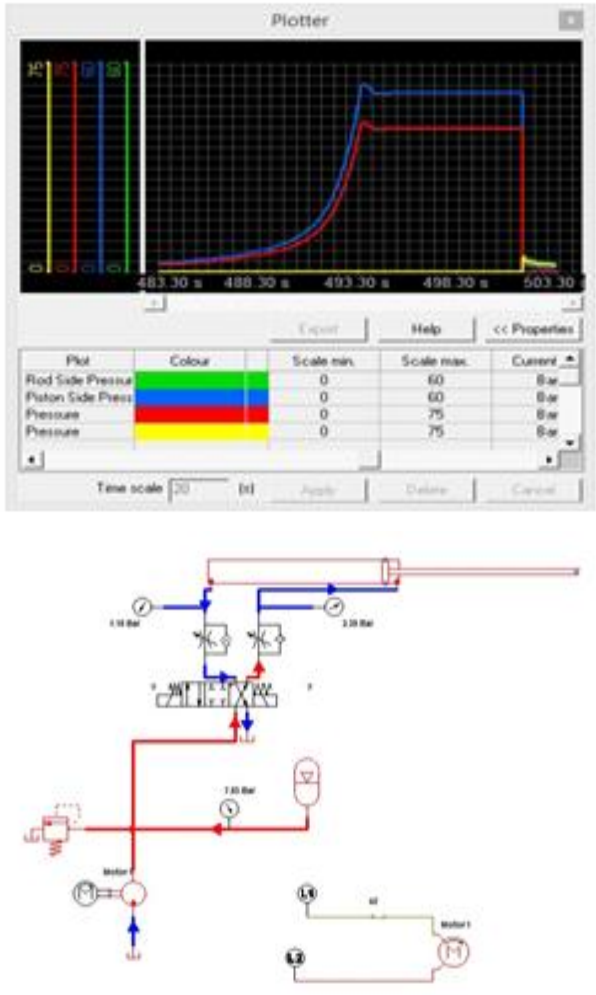

Figure 6: Starting of the retraction stroke

Figure 6 shows that the pressure in the system (piston pressure and system pressure) reaches to maximum set pressure of 50 bar from zero pressure once the extension stroke is completed and once the retraction stoke begins pressure instantly drops to zero pressure from 50 bars.

International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 21 (2018) pp. 15284-15289
© Research India Publications. http://www.ripublication.com

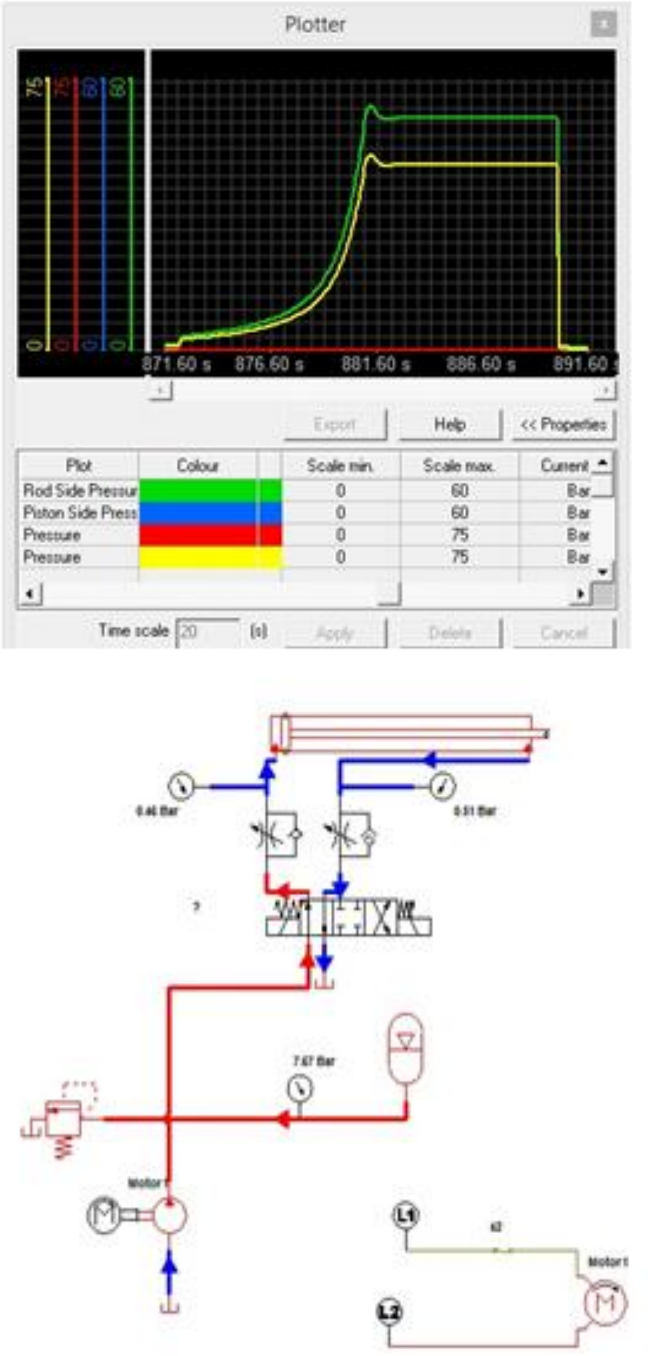

Figure 7: At the start of extension stroke

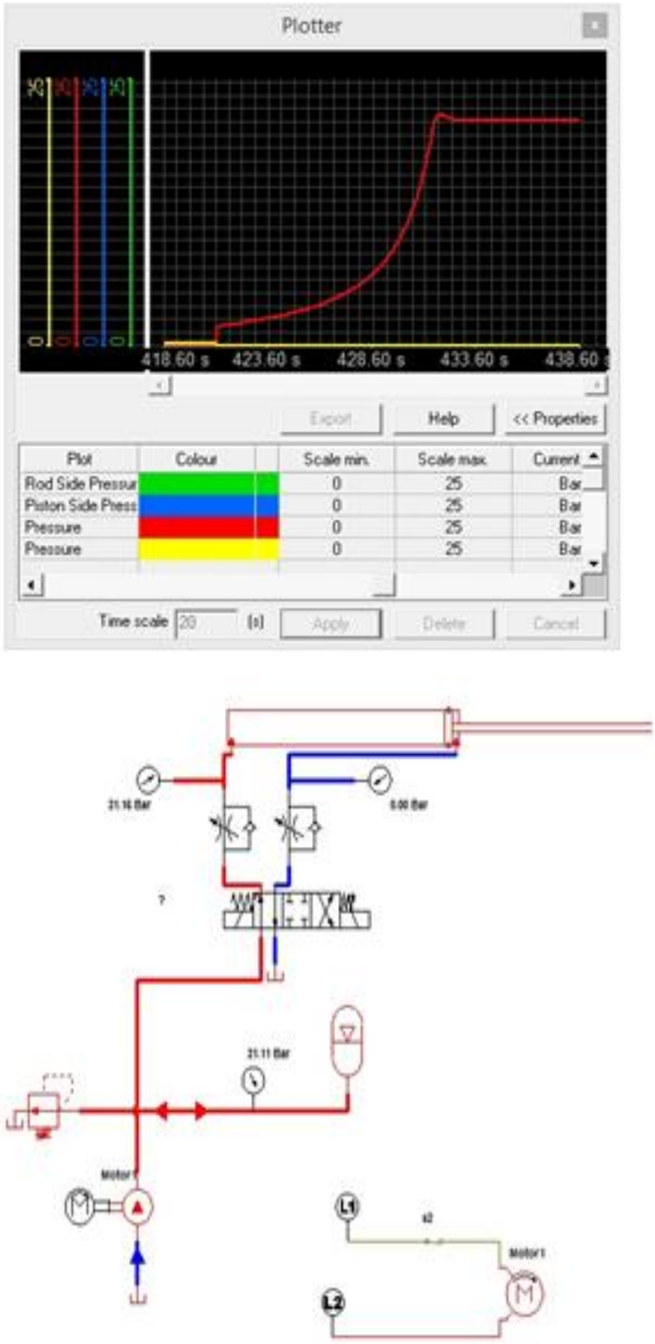

Figure 8: At the end of extension stroke

Figure 7 explains that the system pressure and the rod side cylinder pressure gradually increase to set pressure of 50 bar as the extension stroke starts and shows constant nature in the second position of DCV. In the third position both the pressures drop to zero bar.

The simulation of pressure profile variations in the hydraulic power pack, when it is used for automatic tool changer [ATC] is as follows:

Figure 8 graphs explains that as the piston completes its extension stroke, the main line pressure rises to the cutoff pressure of 20 bar and return line pressure reaches zero bar.

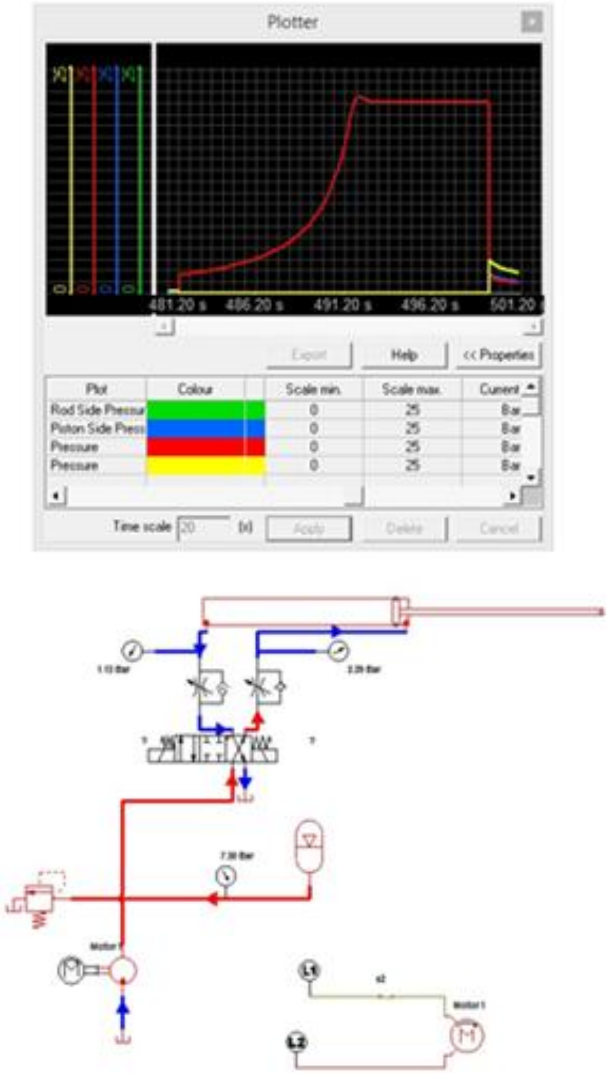

Figure 9: Starting of retraction stroke

Figure 9 explains that the system pressure in the main pressure line gradually increases to the cutoff pressure of 20 bar in the third position of the direction control valve i.e. retention stroke and then remains at the constant pressure till the piston reaches the end position. Once the end position is reached no further flow takes place and the pressure reduces to zero bar.

CONCLUSION

A dynamically compatible pressure profile was generated that was achieved by using variable frequency drive to the constant speed motor. The simplified pressure profile was generated using the pressure variation in the cylinder for the various applications like clamping and automatic tool changer simulated using automation studio software and they are studied using the mathematical model provided. The pressure profile variations in the cylinder for clamping operation and the operation of automatic tool changer, for extension and retraction strokes are obtained and studied.

REFERENCES

[1]. SalamAL-Rbeawi and Fadhil Kadhim et al., 2017, "*The impact of hydraulic flow unit & reservoir quality index on pressure profile and productivity index in multi-segments reservoirs*", Petroleum, Vol. 3, Iss. 4, pp. 414-430.

[2]. AminGholami, Mohammad AliAghighi and Sheik S.Rahman et.al., 2017, "*Effect of non-uniform pore pressure fields on hydraulic fracture propagation*", Journal of Petroleum Science and Engineering, Vol. 159, pp. 889-902.

[3]. SalemAl-Rbeawi et.al., 2017, "*Analysis of pressure behaviors and flow regimes of naturally and hydraulically fractured unconventional gas reservoirs using multi-linear flow regimes approach*", Journal of Natural Gas Science and Engineering, Vol. 45, pp. 637-658.

[4]. Minoru Yamashita, Takuya Mori and Makoto Nikawa et.al., 2017, "*Hole making process of metal and composite sheets by impact hydraulic pressure*", Procedia Engineering, Vol. 207, pp. 1558-1563.

[5]. Peter Radziszewski and Adam Moore et.al., 2017, "*Understanding the effect of pressure profile on stirred mill impeller wear",* Minerals Engineering, Vol. 103-104, pp. 54-59.

[6]. HebriS et.al, 2012 "*Variable Frequency Drive Importance in an LPG Plant: Case Study*". J Elec Electron 1:101., Vol. 1, Iss. 1.

[7]. Yu Peng, Yongming Li, Jinzhou Zhao et.al., 2016, "*A novel approach to simulate the stress and displacement fields induced by hydraulic fractures under arbitrarily distributed inner pressure*", Journal of Natural Gas Science and Engineering, Vol. 35, Part A, pp. 1079-1087.

[8]. Mohandas R et al., 2013, "*Energy Saving Mechanism Using Variable Frequency Drives*", International Journal of Emerging Technology and Advanced Engineering, Vol. 3, Iss. 3, pp. 2250-2459.

[9]. A. de Almeida, F. Ferreira, and D. Both, "*Technical and economical considerations in the application of variable-speed drives with electric motor systems*", IEEE Trans. Ind. Appl., vol. 41, no. 1, pp. 18.

[10]. Pinkle J. Bhatt et.al, 2014, "*Energy conservation in automatic fluid flow control using variable frequency drive*", International Journal of Advanced Technology in Engineering and Science, Vol. 2, Iss. 12.

[11]. James Will Gray and Frank J. Haydock, 1996, "*Industrial power quality considerations installing Adjustable Speed Drive Systems*", IEEE Transactions on Industry Applications, Vol. 32, no. 3, pp. 646-652.

[12]. P. Y. Keskar et.al, 1996, "*Specification of variable frequency drive systems to meet the New IEEE 519 Standard*", IEEE Transactions on Industry Applications, Vol. 32, no. 2, pp. 393-402.

[13]. Lawrence Ambs and Michael M. Frerker, 2010, "*The Use of Variable Speed Drives to Retrofit Hydraulic Injection Molding Machines*", a report submitted to department of mechanical university of Massachusetts Amherst.

[14]. M. K. Langfeldt, 1980, "*Economic considerations of variable speed drives*", presented at ASME Energy Technology Conference and Exhibition.

[15]. Rajendra kumar Patel. et al., 2015, *"Energy Conservation Opportunity with a Variable Frequency Drive in Boiler Feed Pump"*, International Journal of Application or Innovation in Engineering & Management (IJAIEM), Volume 4, Issue 2, pages 181-188.

[16]. Ramesh. S *et al, 2018, "*Design of An Energy Efficient Hydraulic Regenerative circuit" IOP Conf. Series: Materials Science and Engineering, 310 (218) 012041 doi: 10.1088/1757-899X/310/1/012042.