International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 06, June-2015

A Review of Wear in Piston Ring of Internal Combustion Engine

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***Abstract*- The role of piston ring is to maintain an effective gas seal to transfer the heat from piston into cylinder wall and to limit the amount of oil from crankcase to the combustion chamber. The wear between piston ring and cylinder liner affects on the efficiency of the engine. The goal of this study was to study the effect of different parameters related to wear in piston ring.**

Keywords—Piston Ring; Wear; I.C.Engine;

I. INTRODUCTION

An engine is a device which transforms one form of energy into another form. While transforming energy from one form to another, the efficiency of conversion plays an important role. Piston ring in an engine makes an important contribution to high volumetric efficiency by properly sealing the cylinder bore & piston. Piston ring is one of the most important parts of the Diesel /Petrol engines. The main function of the piston rings is to seal between the combustion chamber and the crankcase of the engine. The goal is to prevent combustion gases from passing into the crankcase and oil from passing into the combustion chamber. Two types of ring are used: the upper rings have solid faces and provide gas sealing; lower rings have narrow edges and a U-shaped profile, to act as oil scrapers. The piston ring/engine cylinder bore system important in achieving desired engine efficiency and durability in terms of power loss, fuel consumption, oil consumption, blow by, and even harmful exhaust emissions.

II. LITERATURE SURVEY

U. I. Sjodin, U.L. O. Olofsson [1] has investigated initial sliding wear on a piston ring in a radial piston hydraulic motor. The initial sliding wear during running in of a piston ring used in the form of change of mass and surface roughness investigated. The down motion test rig was developed. Mild wear and sever wear are two types of wear in which mild wear has soft surface that is smoother than the original surface and sever wear forceful surface than original surface. The wear on the piston ring is on the top of the asymmetric topmost at the outer surface contacting the cylinder bore. The result is initially roughness amplitude decreases rapidly, and has decreased by one-third after a sliding distance of 10m.There can be seen that from the fig that mass loss as sliding distance increased.

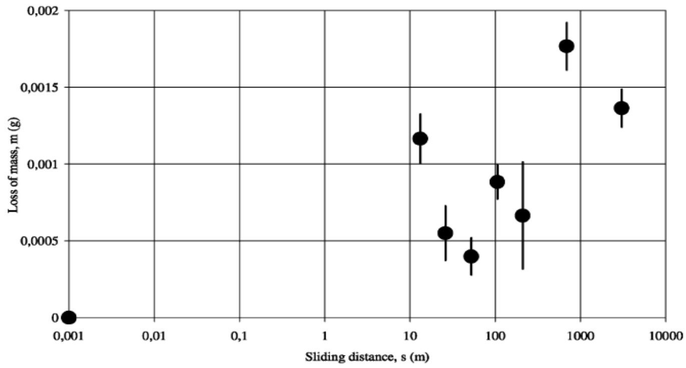

Fig 1.Sliding distance Vs Loss of mass [1]

Simon C. Tung and Young Huang [2] have studied the modeling of wear progression of the piston ring cylinder bore system. The aim of this research is to develop an abrasive wear model for the piston ring cylinder bore system during study state operation. There was temperature, load, oil degradation, surface roughness and material properties considered as parameters. There was volume loss $V_{wear-abrasion}$ due to abrasive wear can be expressed as below which is like to archard's wear equation.

$$V_{wear-abrasion} = \frac{x\,N}{3\,P_W}$$

By incorporating material hardness data, the model can be theoretical in the piston ring /cylinder bore system. After experiment the conclusion is that, Based on a laboratory simulator, a three body abrasive wear model has been developed to model the wear progression of the piston ring/cylinder bore system during steady state operation.

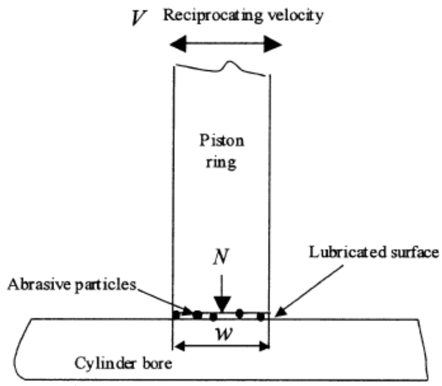

Fig 2.Schematic of the piston ring/cylinder bore simulator system [2]

The wear rate of the engine cylinder bore system is also calculated. From the calculation increase in the wear rate at longer times are attributed to the high oil degradation rate used on this simulation.

John J. Truhan, Jun Qub, Peter J. Blau b [3] have studied on the effect of oil condition and its effect on the friction and wear of piston ring and cylinder liner materials in a reciprocating bench test. The investigation on an improved laboratory test to evaluate the friction and wear behavior of ring and liner material by using realistic (engine conditioned) lubricants. Wear can be expressed as mass loss, volume loss, or depth of wear. Wear depth is good for wear measurement with compare to other method. As the piston is lowered, the load decreases and wear is reduced. There is only small element of piston ring on top position which experiences wear. The viscosity has a minor effect on ring and flat (liner) friction in the boundary-lubricated regime. Viscosity is affected by the soot content and level of oxidation, which could have implications for oil-film thickness and pumping losses. The soot and particulate content have a major effect on wear of the cast iron flat and less of an effect on the ring for the materials studied here.

Zheng Ma et al [4] have studied on the model for wear and friction in cylinder liners and piston rings. The model can predict the effects of surface roughness, asperity contact, and temperature-pressure-viscosity on wear, lubrication and friction of the piston rings and cylinder liner. Wear is predicted based on the surface asperity contact pressure. The major wear mechanism of the cylinder liner wear is abrasion, in top portion during the break-in period. So the Archard wear model is selected for the wear calculation. Oil viscosity decreases at higher temperature. There was the engine speed and load increased step by step from a low level to the full load, full speed condition in 14 break-in-steps. There is observed that there is good agreement between the predicted cylinder bore wear and measurement bore wear. It is also observed that the minimum oil film thickness decreases during the engine break-in-period.

Edward H.Smith [5] has optimizing the design of a piston ring pack using DOE methods. Here ten factors are varied-six describing the ring profile, three ring tensions, & the lubricant viscosity. The work describe in the paper is divided into three part. Design 1: Factors 1-4 were varied, with factors 5-10 fixed at their values in the real engine. Engine speed was 2500rpm Design 2: with engine speed of 3500rpm. Design 3: Factor 1-10 was varied. Engine speed was 2500rpm.There is achieved reducing oil viscosity, top-ring tension, two other ring tensions, scraper-ring offset-ratio, oil-control ring offset-ratio, scraper ring's radius of curvature, halving the compression ring's radius of curvature, halving the oil control ring's radius of curvature.

Murat Kapsiz, Mesut Durat, Ferit Ficici [6] the author had studied friction and wear between cylinder liner and piston ring pair using Taguchi design method. Here parameters are optimized for minimum weight-loss sliding velocity applied load and oil type .The Taguchi design method for two factors at two levels and one factor at four levels was used for the consideration of the plan of experiments. It was selected the array mixed L_{16} $(4^1\ 2^2)$ which has 16 rows corresponding to the number of tests.
Control factor and their levels are shown in below table.

TABLE 1

Control Factor	level				Units
	1	2	3	4	
A. Sliding velocity	60	90	120	150	Rev
B. Load	60	80			N
C. Oil type	15W40	10W40			-

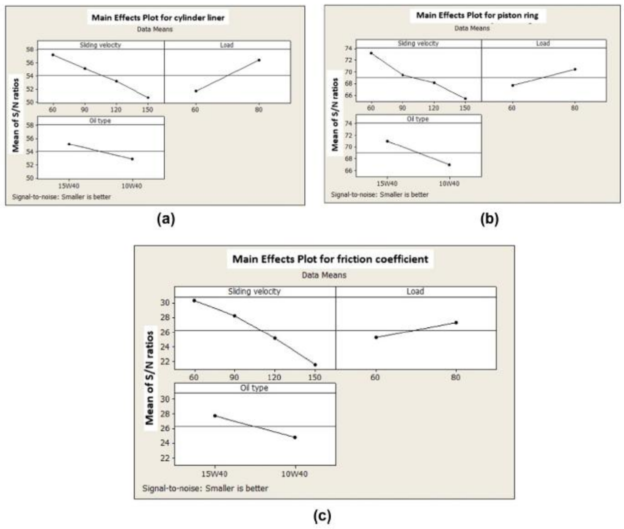

Fig 3.Main effect S/N ratio plots of (a) weight loss of the cylinder liner; (b) weight loss of the piston ring; (c) the friction coefficient. [6]

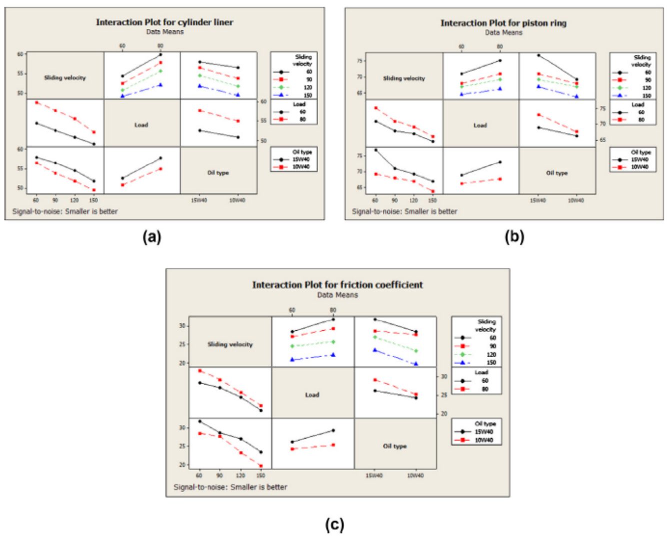

Fig 4.Interaction effect S/N ratio plots of (a) weight loss of the cylinder liner, (b) weight loss of the piston ring, (c) the friction coefficient. [6]

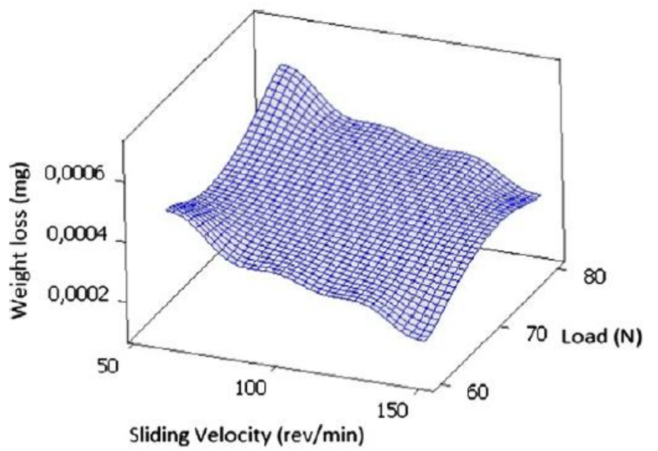

Fig 5.Wear map of piston ring in different load and reciprocating velocity [6]

Then the experimental results are converted into a signal to noise (S/N) ratio. It is observed that sliding velocity have the most significant influence on the both weight loss friction characteristics of CL/PR.

P. C. Nautiyal et al [7] the author have developed an analytical model has been proposed to predict quantitatively the ring wear based on boundary lubrication principles. A quantitative assessment of the friction behavior using actual piston ring and liner combinations under conditions close to tdc of the engine was made so as to the mechanism of wear in a running engine. It has been recognized the maximum wear severity occurs at tdc when the system is working under boundary lubrication.
The results shows that the effect of load, temperature and sliding velocity increase on wear rate.

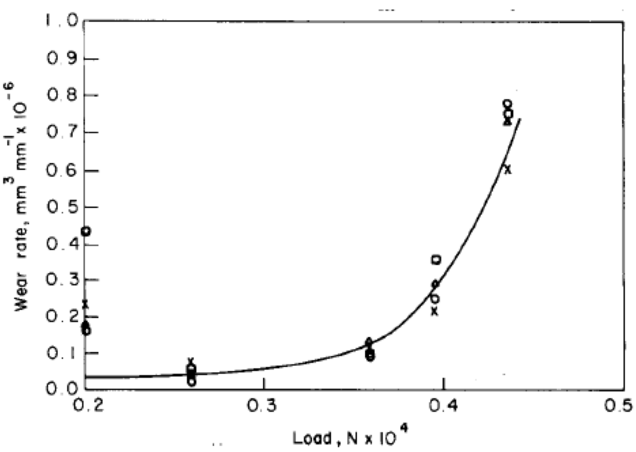

Fig 6.Effect of load on wear rate [7]

M. Priest et al [8] here a numerical model has been developed that predicts the dynamics, lubrication and wear of piston ring interactively for first time. The analysis is divided into two parts. First the model is used to predict the lubrication performance of measured ring packs before & after period of running at constant speed and load: the objective being to establish to change in tribological behavior with observed wear in engine. Secondly, the model is used to predict the lubrication and wear of the top compression ring from the same engine, with the objective of evaluating the correlation between the new model & experiments. The surface roughness of the piston rings & cylinder wall reduced dramatically over starting period. Wear of the new top compression ring was predicted to occur for much of the engine cycle with largest wear rates around top dead centre firing, where the applied loads are high and film thickness low. The understanding of piston ring profile evolution with time and its dependence on complex interactions between lubrication and wear. The lubrication prediction for measured ring profile have highlighted the sensitivity of lubricant film thickness and friction between the piston ring and cylinder wall, to wear of the ring profiles.

U.I. Sjodin, U.L.-O. Olofsson [9] have investigated on the wear interaction between piston ring & piston groove in a radial piston hydraulic motor was studied in regard to mass loss and changes in form and surface roughness. There was a test rig developed which is simulates the tilting movements of pistons at the end of stokes. There were a full factorial with center points design method is used. The wear mechanism is mild wear and piston groove showed a more wear than the piston ring.

L.M.Yang ea al [10] has study of a wear model for assessing the reliability of wave energy convertor. For the study point absorber has been chosen. The convertor has been modeled by using bond graphs a systematic and useful method for systems spanning several energy domains. Here, an abrasive wear model for the piston ring and cylinder is developed during steady state operation. The wear volume loss due to abrasion is expressed by below equation.

$$V_w = K \times N \times x$$

Andrzej Adamkiewicz and Jan Drzewieniecki [11] have study on operational evaluation of piston ring wear in large marine diesel engine based on inspection through cylinder liner scavenge ports. There were two verification method of piston ring wear in which, first visual evaluation of piston ring wear & condition through scavenge port. Second estimation of piston ring wear amount by piston ring gap measurement. Third alternative methods for a wear of piston rings rely on measurement of run-in coating on their surfaces.

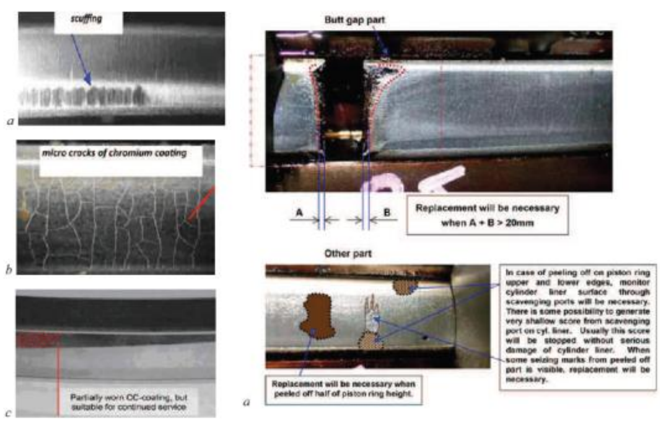

Fig 7.Example of piston rings wear. [11]

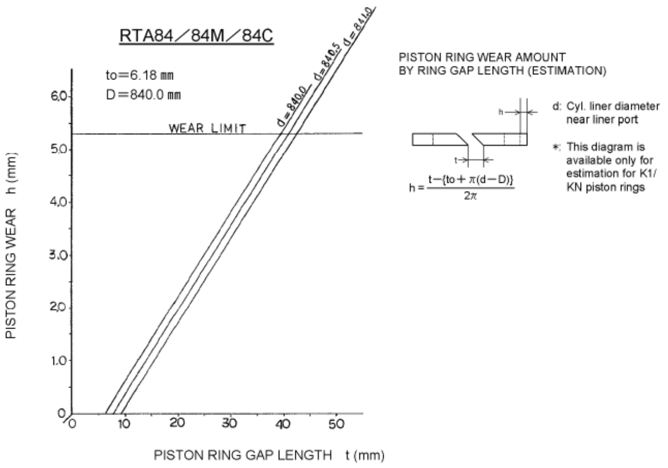

Fig 8.Calculating chart for piston rings wear and gap measurements [11]

Here two types of coating applied first soft plasma thermal sprayed coating of graphite Cu or Sn and second is Mo/Ni Cr/ Cr-C wear resistant coating. Applying of run-in coating-improved cooling effects from the liner that act on the ring at initial running-in period.

S.G.Fritz and G.R.Cataldi [12] have determined in situation piston ring wear in a single cylinder Medium Speed diesel engine using thin film surface layer activation (SLA).The top compression ring wear was quantified over a 500-hour test period for three different types of cylinder liner surface finishing technique. There are lubricating oil consumption rates and motoring friction horsepower requirements were determined. In the data analysis 'static-data', 'dynamic-data'

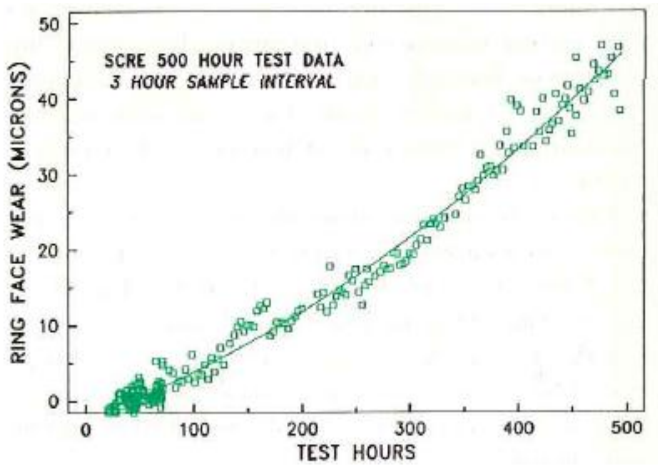

Fig. 9.Piston ring wear measurements with chrome plated liner. [12]

Conducted over 500-hour test period conducted. And for the next data analysis piston ring wear measurements with silicon carbide impregnated and in the next measured with chrome plated liner.
SLA proved to be a best diagnostic tool for determining in situ engine component wear. This technique was found to be quite useful in determining piston ring wear without disassembling the engine. The precision of wear is much greater than with conventional wear measurements.

M.Afazaal, Malik et al[13] have study on to develop hydrodynamic piston top ring lubrication model in initial engine start up by incorporating an elliptical cylinder wear manufacturing error and cylinder head clamping force. The numerical analysis is done based on two dimensional Reynolds equations. There is hydrodynamic pressure field generation & time based lubricating film thickness profile as function of crank rotation are examined and influence of bore out of roundness effect at time of engine start up are investigated. The hydrodynamic film and pressure profile is getting affected due to non-circular bore. From the numerical simulation, the minimum film thickness increases with non-circular bore.

Pavel Novotny [14] has demonstrated the principles of the numerical solution of piston ring dynamics. It considers in mixed lubrication conditions incorporating in a virtual engine &experimental inputs. The computational solution of piston ring dynamics is a very complex problem. It requires multiple numerical approaches supplemented by suitable inputs. For the solution diesel turbocharged engine with three piston ring configuration used. The new simulation algorithm of piston ring dynamics has been developed and incorporated into RingDyn user guided interface. The algorithm is very fast it enables to calculate results during few seconds.

Claudia Lenauer, Christian Tomastik et al[15] have investigation on the effect of bioethanol on the piston ring – cylinder liner system; the tribological tests were carried out on a model tribometer set up, and measuring friction and piston ring wear. Here two types of lubricants fresh and altered were used. The fresh lubricants lead to a lower amount of running in wear and a higher steady- state wear rate. All altered oils lead to a higher amount of running in wear and a lower steady state wear rates than for the fresh oils. A comparison between the result of the tribometer wear measurements and the wear in the real combustion engine environment shows that the trend observed in the engine was replicated in the tribometer. The tribofilm thickness and the wear behavior correlate. The lower steady-state wear rates for the piston rings have a thinner tribofilm on the cylinder liners.

J. Michalski, P. Wos [16] have reports on the effect of cylinder liner surface topography on abrasive wear of piston cylinder assembly in combustion engine. Here engine tests were done on a dynamometer stand and they included 10h of fired running in period and 21h operation of intensified abrasive wear in piston cylinder assembly. Here the distinctions between piston–cylinder assemblies wear of the engines varied by cylinder liner roughness parameters due to different honing settings made. It was noticed that after 10 h of running-in operation the high correlation of the maximum valley depth of the profile with the piston–cylinder assembly wear. And after 21 h of full load operation a similar strong relationship, but referring to the maximum peak height of the cylinder liner profile occurred as well. The wear of rings is relatively high.

Ferit Ficici, Sezer Kurgun[17] has study on the experimental optimization of wear parameters of piston ring coated with molybdenum. Parameters optimize for minimum weight loss based on L27Taguchi design with three parameters load, temperature and revolution with three levels.

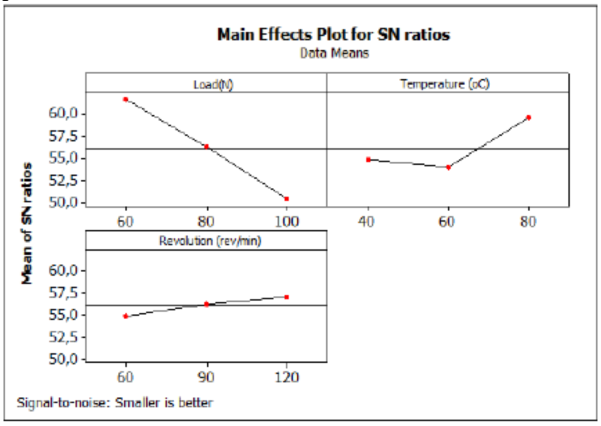

Fig 10.Main effect S/N ration plot of the piston ring

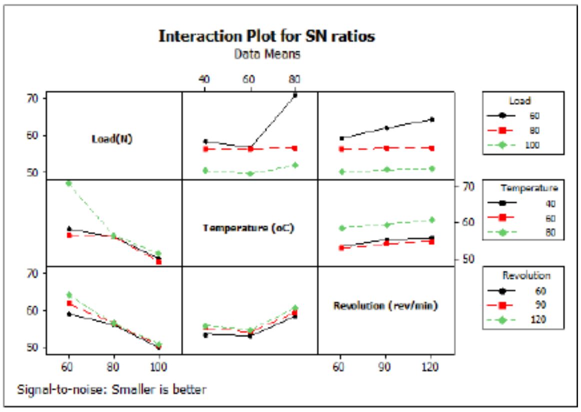

Fig 11.Interaction plot for weight loss of the piston ring.[17]

There is the main effect plot for the S/N ratio and interaction plot for the weight loss of the piston ring is shown in the figure.

The result is load have the most significant influence on weight loss of piston ring. There are good agreement between experimental results and theoretical model.

John J. Truhan, Jun Qu et al [18] have studied on the laboratory test to evaluate piston ring and cylinder liner materials for their friction and wear behavior in realistic engine oils. Here wear test were carried out at 240N for 6h at 100^{0}C with new ring segments. A ring segment was tested against a flat specimen of gray cast iron typical of cylinder liner. Different lubricants like Jet A aviation fuel, mineral oil and a new and engine-aged, fully formulated 15W40 heavy duty oil were used to evaluate the sensitivity of lubricant condition. Wear was measured by weight loss wear volume and wear depth using a geometric model. The result shows that Jet A has higher wear & used 15W40 oil showed least wear.

COCLUSION

The overall conclusion is that the variation of wear is nonuniform. The dominant wear mechanism is mild wear and an abrasive has great influence the amount of wear in engine. Wear was measured by weight loss, wear volume and wear depth using a geometric model. It has been recognize the wear on the piston ring is on the top of the asymmetric crowning when the system is working under boundary lubrication.

After running-in operation the high correlation of the maximum valley depth of the profile with the piston–cylinder assembly wear was noticed. After full load operation a similar strong relationship, but referring to the maximum peak height of the cylinder liner profile occurred. The wear of rings is relatively high. Applying of run-in coating improved cooling effects from the liner that act on the ring at initial running-in period. The results shows that the effect of load, temperature and sliding velocity increase on wear rate. The wear rates at longer times are attributed to the high oil degradation rate used.

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