Comparative Study of Performance of Hydrodynamic Journal Bearing with a Bio-Lubricant and ISOVG 100

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ABSTRACT

Journal bearing is a mechanical component that provides support to shafts in rotating machinery such as turbines in hydro power plants, rotor of ships, turbine of thermal power station etc. It works on the principle of hydrodynamic lubrication in which a thin film of lubricant is used to provide support to the shafts in rotating machineries. So the perfect function of journal bearing majorly depends on selection of proper lubricant. In the current scenario the majority of industries use petroleum oil as a lubricant in journal bearing due to this concentration of petroleum oil in earth crust decreasing rapidly and the wastage of petroleum oil causes hazardous impact on the environment. Comparative study of common synthetic lubricant ISO VG 100 with castor and soybean oil has been carried out. The friction forces and the fluid film Pressure Distribution are calculated analytically and compared with experiment data. Rapid consumption of petroleum resources and environmental risks alarms to use eco-friendly alternative. Mixture of castor-soybean oil is a non- edible sourced Bio-lubricant shows low coefficient of friction, anti-wear capability, low environmental hazard. The recent research states that castor oil improves the load carrying capacity as it has high in viscosity.

Keywords
Journal bearing, Pressure distribution, castor oil, soybean oil, ISO VG 100.

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Introduction

Lubricant is a medium that reduces wear and friction by formation of thin oil film in between the contacting areas of two mating bodies. Removal of heat, prevention against corrosion, transmission of power is the basic functions of lubricating oil. Lubricant roles as seal between the two moving boundaries layers and hence close in and remove the wear particles forms in between them. To perform this role lubricating oil must have some specific chemical and physical characteristics. The viscosity of the lubricant is the principal characteristic of the lubricating oil which greatly impacts the friction and wear reduction and thus increases the overall efficiency of power transmission. P.G. Nikolakpoulos et al. [1] compared three types of lubricants such as mineral oil, a synthetic oil and a bio-based (AWS-100 SAE-10W40 SAE-30) are used in order to examine their effects on the tribological behaviour of hydrodynamic journal bearings. Lubricants are experimentally and analytically examined for several arrangements of load and journal rotational velocity.

P. A. Narwade et al. [2] study and compare the friction forces and friction coefficient of jatropha oil with petroleum oil such as XT 46 and 20W40 for different l/d ratios with the help of journal bearing tester. And they conclude that they got maximum pressure distribution for jatropha oil as compared to synthetic oils, So they said it is beneficial to use. The main point where bio lubricants are ahead is their biodegradability which acts as a non pollutant for the environment. On low operating temperature Jatropha oil generates high torque but power loss is high, due to high viscosity. The viscosity of the jatropha reduces very rapidly as l/d ratio increases, so jatropha can be used for high l/d ratio journal bearings. Jatropha oil shows the intermediate hydrodynamic behavior for pressure and load carrying capacity as that of the synthetic oil. Jatropha oil shows several good characteristics high viscosity and increased load carrying capacity hence can be used as alternative bio-lubricant for journal bearing application.

S. Khasbage et al. [3] presented a tribological study of popular synthetic lubricant ISO VG 32, 46, 68 and SAE-40 oil with Jatropha oil. Tribological properties of Jatropha were computed experimentally and the performance of hydrodynamic journal bearing using Jatropha Bio-lubricant is theoretically investigated and validated analytically by using CFD Software. The theoretical results for maximum pressure at different eccentricity ratio and journal speed have been evaluated. They conclude that Jatropha Bio lubricant gives the intermediate hydrodynamic behaviour for pressure and load carrying capacity as that of the ISO VG 32 and ISO VG 46. In paper both theoretical and analytical results show enhancement in maximum Pressure and load carrying capacity of the Jatropha bio-lubricant rises with increase in journal speed and eccentricity ratio. Jatropha oil shows several good characteristics high viscosity and increased load carrying capacity hence can be used as alternative bio-lubricant for journal bearing application.

Sriram et al. [4] tested bio oils such as rapeseed oil and soya bean oil under the different operating conditions in the JBTR and the results are compared with the SAE20W40. They conclude that Soybean oil appear to be very low in viscosity leading to higher heat generation. The oil film thickness formed by soya bean oil was very much low, leading to some metal-to-metal contact in between the journal and shaft. Therefore they concluded that soya bean oil as a raw vegetable oil is not suitable for the lubrication purpose in journal bearing.

B. Bongfaa et al [5] investigated tribological performance of crude Nigeria-based castor oil and compared with 20W-50 high quality crankcase oil, to see its suitability as base oil for lubricating oils. The experiment was conducted using a four-ball tester. Their results showed that unrefined castor oil has superior friction reduction and load bearing capability in an unformulated form than the commercial oil; can compete positively with the commercial oil in wear protection when formulated with suitable anti-wear agent, hence can be a good alternative base stock for crankcase oils suitable for Nigeria serviced vehicles, and plants engines from tribological, environmental, and non-food competitive points of view.

Pattiwar et al. [6] presented study the performance characteristics of the journal bearing experimentally having different geometries operating with commercial Mobil grade lubricants that are used in power plants. Three grades of Mobil lubricants (DTE 24, DTE 25, and DTE 26) have been considered during the study. TiO2 nanoparticle additives have also been considered during the study as a lubricant additive to examine the performance of journal bearings. An elliptical journal bearing shows the superior performance than that of a plain bearing. And they also conclude that the performance characteristic is improved using TiO2 nanoparticle additives in the lubricating oils for both plain and elliptical journal bearings. After addition of TiO2 nanoparticle additives, the pressure distribution increases. At the same time, the temperature rises in an elliptical bearing operating with Mobil DTE 24, Mobil DTE 25 and Mobil DTE 26 containing TiO2 nanoparticle reduces up to 73.60 %, 68.18 % and 70.26 % respectively.

M.O A. Mokhtar et al. [7] presented development of wear in plain hydrodynamic journal bearings under repeated cycles of starting and stopping by experimentally. The wear which occurred caused easily discernible but localized changes in diametric clearance, surface finish, and roundness of the bearing's bore and these changes were measured after various numbers of operating cycles had been completed. They Studied of the location, within the bearings of the wear which arose, showed that it was caused entirely by the sliding which occurred during starting and that no significant contribution to the wearing process was made during stopping. It was also observed that, once an initial rapid phase of wearing was completed, the surface finish of the hardened steel shaft was reproduced in the regions of the bearing surface which continued to be worn.

Castor-Soybean Bio-Lubricants

Castor oil is a vegetable oil derived from castor beans shown in figure 1. It is mainly used in soaps, paints, dyes, inks, waxes etc. castor oil is a colorless having boiling point 313◦C and kinematic viscosity is 238.1 centi-stock. The main source of castor oil is a ricinoleic acid.

Due to high viscosity it resists the flow of oil inside the bearing and causes problems such as high heat generation and friction losses etc. so pure form of castor oil is not suitable as a use of lubricant.

Soybean oil is vegetable oil derived from beans of soybean shown in figure 2. Soybean oil mainly used in oil paints, food, drying oil etc. The kinematic viscosity of soybean oil is 31.6 centi-stock. Due to its low viscosity if the pure form

Figure 1 Castor beans

Figure 2 Soybean beans

of soybean oil is used as journal bearing lubricant then there will be enhance of metal to metal contact between the shaft and journal.

Analysis showed that viscosity of castor oil is higher compare to ISO VG 100 engine oil and viscosity of soybean oil is lower compare to both oils. But mixture of castor-soybean (at 70%-30%) oil have same viscosity compare to ISO VG 100.

Problem Statement

The mineral and synthetic oil used are non-ecofriendly and it causes oil pollution. So, bio oils are been used as an alternative for synthetic oil. These are the pollution free; it can last longer, it has better properties pour point, flash point, viscosity index, viscosity acidity etc. Bio oils are used for pressure distribution and load carrying capacity of journal bearings. It gives high load carrying capacity.

Hydrodynamic Journal Bearing

Hydrodynamic journal bearing is the very important component of rotating machine. The working performance of hydrodynamic journal bearing depends upon the working performance of its lubricant during the lubrication. The journal speed and eccentricity ratio play an important part in working performance of journal bearing. A finite length Journal with l/d ratio 1 is used throughout the study.

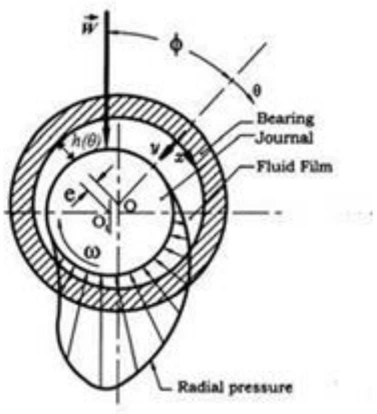

Figure 3 Schematic diagram of journal bearing

Journal Bearing Set-Up

The system consists of vertically mounted journal driven by a variable speed motor. Load is applied radially to the bearing with a loaded lever. Journal bearing assembly is immersed in lubricant and electronic sensor measure the foil film pressure. Angular position of the pressure sensor with respect to the load line is varied and pressure is recorded. Pressure is plotted as a function of angular position of Cartesian or polar form to demonstrate the pressure distribution. Test variables are Journal speed, radial load and lubricant viscosity.

Figure 4 Journal bearing test-rig

Table 1: Specification of test-rig

Parameter	Specification
Journal Diameter	40mm
Bearing Length	40mm
L/D Ratio	1
C/r	0.01
Radial clearance	0.1mm
Radial Load	Up to 750 N; steps of 150N
Speed	150 to 2000 rpm; continuously variable

Methodology

Castor oil has higher viscosity compare to ISO VG-100. To reduce viscosity of castor oil, Soybean oil is used. First three batches are prepared of castor-soybean oil at 50-50,60-40, and 70-30 respectively. After than it send to test viscosity and viscosity index number to ANALUBE LAB, Charusat . The values of viscosity and VIN shown in table 2. To used as alternative for synthetic oil ISO VG-100, Castor-soybean(70-30) mixture oil selected to compare. To conduct experiment and compare them two speed and two radial loads are selected. Selected speeds are 250 rpm and 500 rpm where selected radial loads are 300N and 450N. For experiment 30 minutes time duration are taken.

Table 2 : Kinematic Viscosity and VIN of oil

Lubricants	Kinematic Viscosity (cst)		Viscosity Index Number
	At 40° C	At 100° C	
Castor oil	238.1	18.9	89
Soybean oil	31.6	7.38	212
Castor-Soybean (70-30)	108.3	13.11	117
Castor-Soybean (60-40)	89.3	11.9	124
Castor-Soybean (50-50)	78	11.2	134
ISO VG-100	100	90	110

Experiment Result

For the purpose of the experiments four different lubricants were used. One Castor oil, Soybean oil, Mixture of Castor-soybean oil (at 70%-30%) and ISO VG-100 lubricant. RAIMONDI AND BOYD METHOD are used get Analytical calculation of bearing performance. Following are the graph that shows pressure distribution for selected parameter and lubricants.

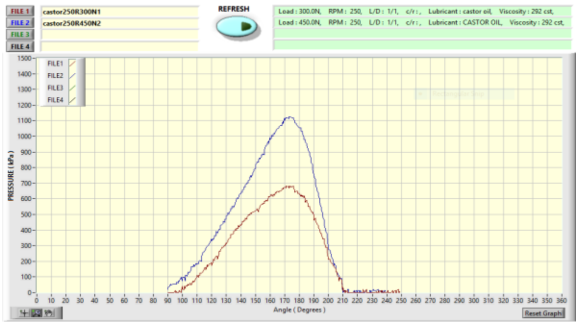

Figure 5 Pressure distribution of castor oil at 250rpm and different loading condition

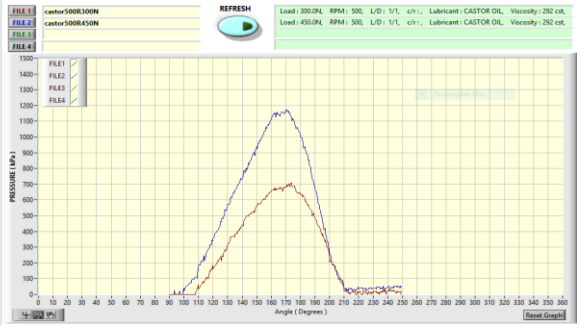

Figure 6 Pressure distribution of castor oil at 500 rpm and different loading condition

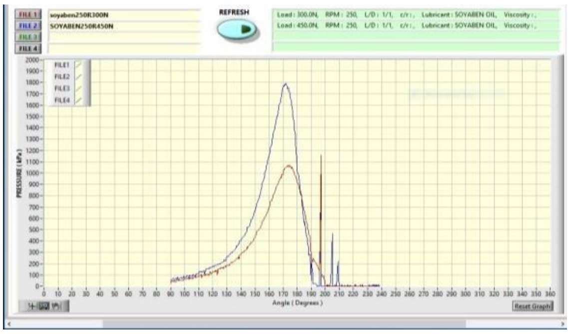

Figure 7 Pressure distribution of soybean oil at 250rpm and different loading condition

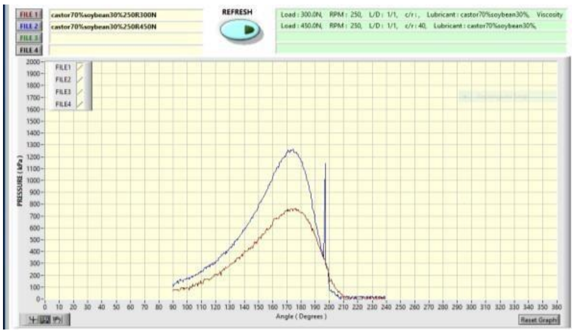

Figure 8 Pressure distribution of mixture of castor-soybean (70-30) oil at 250rpm and different loading condition

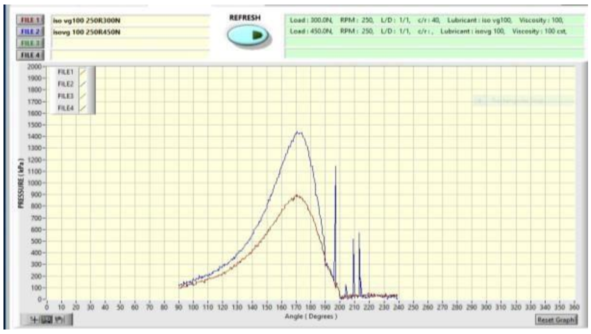

Figure 9 Pressure distribution of mixture of ISO VG-100 oil at 250rpm and different loading condition

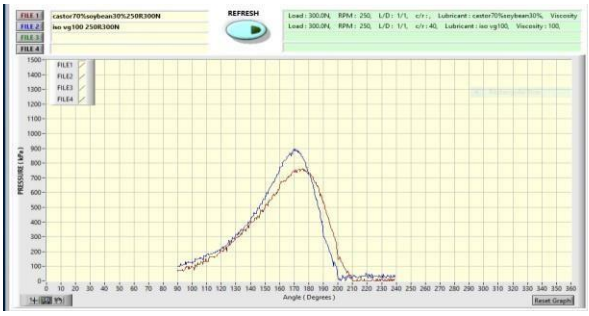

Figure 10 Pressure distribution of mixture of ISO VG-100 oil and Castor- soybean oil(70-30)at 250rpm and 300 N

Figure 11 Pressure distribution of ISO VG-100 oil and mixture of castor- soybean oil(70-30)at 500 rpm and 300 N

Result And Discussion

Four sets of reading are taken for each operating condition to get readings. The film pressure along the periphery of journal bearing is noted down. The pressure rise in fluid film are computed during experimental trial. The values of maximum pressure, eccentricity ratio, Co-efficient of friction, power-loss in friction and maximum pressure angle are taken and calculated from Raimondi-Boyd chart for comparative analysis. The intermediate values of the pressure ratio for eccentricity are calculated using a liner interpolation method. The maximum pressure reading identified during the test and pressure ratio is calculated which is compared as shown in fig.5 to 9. The average pressure p has been obtained for all the cases as shown in Table 3.

foam of bio-oil are not stable compare to synthetic oil as operation time increases. It also observes during experiment that after experiment castor-soybean oil get thicker.

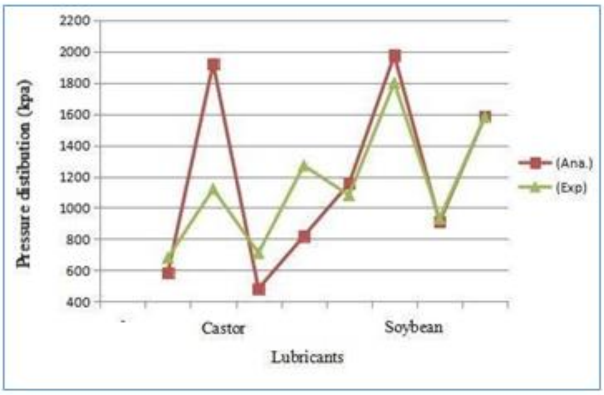

Figure 12 Comparison of Pressure Distribution of castor and soybean oil

These graph figure 12 shows comparison of pressure distribution and and Lubricants of castor oil and soybean oil. Castor oil have higher viscosity. From Figure 5 it can observe that as the load increases, maximum pressure of fluid film increase. Where in soybean oil give higher pressure compare to castor oil because it has lower viscosity. This is due to soybean oil have lower viscosity and viscosity of oil is directly proportional to viscosity. Same as castor, as load increases pressure distribution of soybean oil increases. Soybean have lower viscosity and as temperature increases viscosity of oil decreases. So, there is more chance of metal to metal contact at higher load during operation. The sudden pressure picks are observe in Figure 7,8 and 9 due to Bubble formation between journal and bearing.

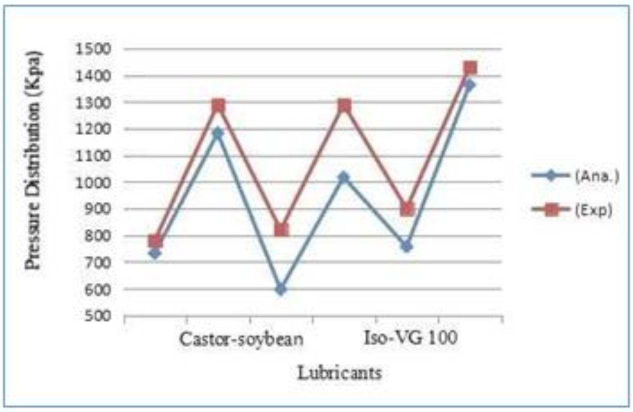

Figure 13 Comparison of Pressure Distribution of castor-soybean oil and ISO VG-100

Figure 13 shows comparison between castor-soybean oil and ISO VG-100 oil. Both gives near value of maximum pressure. It can also observe from figure 10 and 11. it also has been observed that as the load and speed both increases the pressure of fluid film increases. Both oild give same behavior of pressure profile. As both gives near same profile of pressure distribution it can replace ISO VG-100 synthetic oil. But Synthetic oil have additives to enhance performance of lubricant. But pure

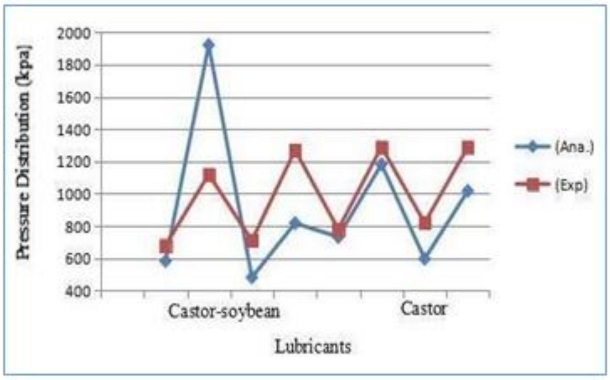

Figure 14 Comparison of Pressure Distribution of castor-soybean oil and Castor oil

Figure 14 shows comparisons between castor oil and castor-soybean (70-30) oil. It observes that at lower speed castor oil gives lower pressure compare to castor-soybean oil. And at higher speed this behavior changes. At same time castor-soybean oil gives higher pressure compare to castor oil.

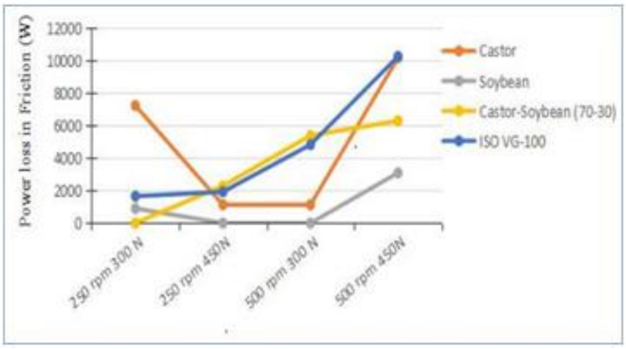

Figure 15 Power-loss of lubricants

Figure 15 shows the power loss in frication for different lubricants at all operating conditions. It has been observed that at lower speed and at lower load castor oil gave higher power loss where at higher speed and at higher load both castor and ISO VG 100 oil gave lower power loss. It also observes that castor-soybean (70-30) oil gave low power loss compare to ISO VG 100 oil.

Table 3 shows Comparisons between Experimental and analytical data for performance analysis at different operating speed. The value of Sommerfeld Number(S), Coefficient of friction (f), Power loss in Friction (Ef), Eccentricity Ratio (ε) and Maximum pressure are calculated by Raimondi and Boyd method and compare it with experimental data and lubricants. And also, Error between Experimental data and analytical data calculated of maximum pressure. It observes that as the speed and load increases error between experimental and analytical data values increases. Experiment gives higher value of maximum pressure compare to analytical data. From table ISO VG -100 and castor-soybean (70-30) oil gives near same values. But ISO VG -100 oil give higher eccentricity near to 0.8-0.9 where castor-soybean (70-30) oil gives eccentricity ratio between 0.7-0.8. From the table it also can observed that error of maximum pressure between theoretical and experimental is high in castor oil, due to higher viscosity. As per the experiment and theoretical data castor-soybean (70- 30) can be replacement of ISO VG 100 synthetic oil.

Conclusion

After testing four oil that castor, soybean, ISO VG 100 and castor-soybean (70-30). We conclude that castor- soybean (70-30) oil got near same result of pressure distribution compare to ISO VG-100 synthetic oil. Main point is that bio-lubricants are ahead is their biodegradability with act as non-pollutant for environment. Pure castor oil gives high power loss, this is because of high viscosity whereas castor-soybean oil gives comparatively low power loss. Both theoretical and experimental result shows enhancement in maximum pressure and load carrying capacity of the castor-soybean oil rises with increases in journal speed. Castor oil have high ricinoileic acid (which provide oxidative stability) and soybean oil have high viscosity index number (VIN) means change in viscosity with respect to temperature is low. Castor-soybean oil show several good characteristics of a viscosity and increased load carrying capacity. Hence can used as alternative bio-lubricant for journal bearing application.

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Table 3 Comparisons between Experimental and analytical data for performance analysis at different operating speed

Oil	Parameter		S	P_{max} (Ana) (kPa)	P_{max} (Exp) (kPa)	Error (%)	f	E_f (kW)	ε	θ_m (degree)
	$speed_{(rpm)}$	$load_{(N)}$								
Castor	250	300	0.05084	583.566	680	16.5	0.046157	7.246	0.78	154.06
	250	450	0.003902	1921.86	1120	-41.72	0.004820	1.135	0.97	172.31
	500	300	0.101695	481.724	710	47.38	0.028359	8.905	0.65	143.64
	500	450	0.06779	817.662	1270	55.32	0.021649	10.180	0.73	150.56
Soybean	250	300	0.006390	1153.396	1080	-6.36	0.005769	0.9057	0.91	170.55
	250	450	0.004260	1975.310	1800	-8.87	6.3×10^{-6}	0.00149	0.97	172.13
	500	300	0.01278	908.750	930	2.34	0.008205	2.576	0.92	166.86
	500	450	0.00852	1584.127	1580	-0.26	0.006581	3.099	0.95	169.22
Castor-Soybean (70-30)	250	300	0.02273	732.42	780	6.49	0.01139	0.00178	0.81	156.43
	250	450	0.0152	1182.716	1290	9.07	0.009740	2.293	0.78	154.26
	500	300	0.04547	596.75	820	37.4	0.01717	5.399	0.79	154.57
	500	450	0.03031	1017.547	1290	26.78	0.01339	6.3066	0.74	150.93
ISO VG-100	250	300	0.01913	756.658	900	18.94	0.01058	1.661	0.89	162.99
	250	450	0.01276	1363.967	1430	4.84	0.008197	1.930	0.93	166.86
	500	300	0.03827	631.74	850	34.5	0.0154	4.835	0.82	157
	500	450	0.02551	1064.534	1330	24.93	0.02181	10.272	0.87	161.56

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