WEAR OF GEAR OF CIRCULAR-ARC TOOTH-PROFILE "EFFECT OF HELIX ANGLE AND OIL VISCOSITY"

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ABSTRACT

The paper presents the results of an experimental investigation carried out at Mansoura University Laboratories aiming at studying the effect of change of helix angle and lubricating oil on wear of relatively new type of gearing of circular-arc tooth-profile. Eighteen pairs of gears of 6 D.P., 91.5 mm pitch diameter and different helix angles were run in power circulating gear test rig at different speeds and transmitting different loads, the gears lubricated with oils of different viscosities. Results showed that wear increases with increasing helix angle and decreases with increase of oil viscosity. Variations of amount of wear with all the test variables are presented.

INTRODUCTION

Helical gears of circular-arc tooth-profiles are conformal gears with point contact between teeth changing to an elliptical area under load.(1-3)* Contact between these gears is along the face and no progressive contact occurs on the profile.

In a previous paper(4) the experimental results of a research program carried out at Mansoura University Laboratories on the effect of load and speed on wear of this type of gearing are presented.In this paper the experimental results showing the effect of change of helix angle and viscosity of lubricating oil on wear are introduced.

THE TEST RIG

The test rig is of the power circulating type where two pairs of gears are carried by two shafts running on rolling bearing as shown in Fig.(1). The driving shaft carries a graduated torque coupling to measure the transmitted torque. The driven shaft is composed of two parts connected together by a flange coupling. The rig is loaded by applying dead weights at the end of a lever fastened to each flange, thus twisting each part of the shaft relative to the other. The rig is driven by a 8/10 HP A.C. motor running at speeds 1500 and 3000 RPM respectively.

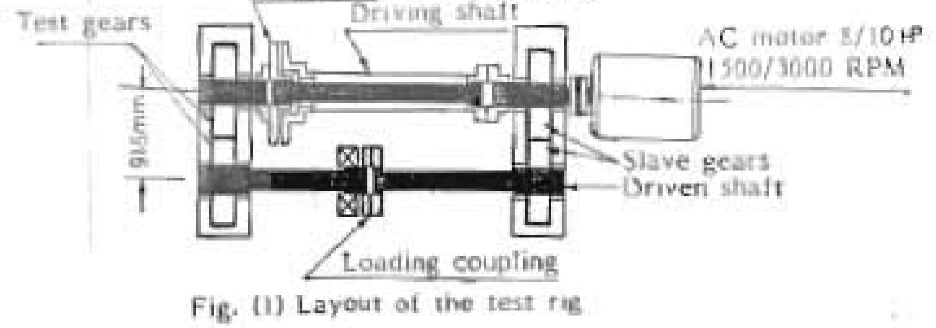

Fig. (1) Layout of the test rig

* Numbers in brackets designate referances at end of paper

TEST GEARS

The test gears were supplied by the General Electric Company Ltd, Rugby, England. They are of the CirCarC type and the pinion is made of MM 4135 steel and the wheel is made of MM 4164 steel. The test gears are of 6 D.P. (4.23 module), 91.5 mm pitch diameter, 25° normal pressure angle, 1.2 overlap ratio, 0.423 mm backlash and 1.6 μ surface roughness. They are of different helix angles, number of teeth and face width. Table (1) give dimensions and specifications of the test gears. Fig.(2) shows the dimensions of the gear blank.

Specifications	Test pair (1)	Test pair (2)	Test pair (3)
Helix angle, deg .	22.3	33.6	42.25
Face width, mm	42	29	24
Number of teeth	20	18	16
Axial pitch, mm	35	26	19.8
Blank diameter, mm	103.735+ 90.17*	103.735+ 90.17*	103.735+ 90.17*
Radii of curvature in normal plane, mm	4.23+ 4.68*	4.23+ 4.68*	4.23+ 4.68*
Radii of curvature along helix angle, mm	113.2+ 128.6*	56.12+ 61.1*	36.2+ 39.4*

+ For pinion * For wheel

Table (1) Dimensions and specifications of the test gears.

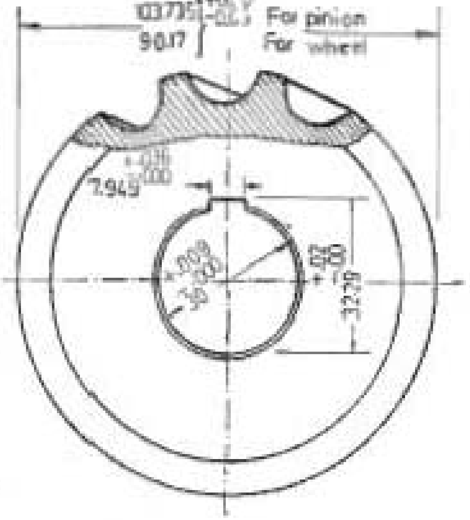

Fig (2) Dimensions of the gear blank

EXPERIMENTAL PROCEDURE

Wear of CirCarC gears was investigated at 22.3,33.6 and 42.25° helix angles using lubricating oils of 200,462 and 653 C.st. at 40°C. kinematic viscosity. The applied tooth loads varying from 1000 to 3000 kp at interval of 200 kp corresponding to transmitting loads varying from 671 to 2516 kp, transmitting torques varying from 31 to 115 kp.mt. and the test speeds equal 1500 and 3000 RPM. Thus the transmitting power ranges from 64 to 482HP

Tests were carried by using dip lubrication system, the initial temperature of the lubricating oil is 90°±3, using heating coils, sensor and temperature indicator mounted on the test gear box to control the oil temperature. The characteristics of the lubricating oils used in this investigation are given in table (2)

The deposited removed metal after wear was measured by weighing the test gears before and after each test by a digital and analoge balance of accuracy 1×10^{-5} gram and capacity 2000 gram, type Chyo Jupiter C2-2000, Serial No. 30559 made in Japan. The test gears were washed before weighing by using an ultrasonic cleaning tank type No. 323/201, serial No. 337226, 40 KHz frequency, 150 watts output and 220x130x150 mm internal dimensions made in W.Germany and then dried by a stream of compressed air.

EXPERIMENTAL RESULTS AND DISCUSSION

A. Effect of Helix Angle

Fig. (3, 4 and 5) show the change of the weight of removed metal with the change of applied tooth load at different speeds for test pairs (1, 2 and 3) respectively and lubricated by oil no.(B). These curves show that wear increases firstly

Characteristics	Oil (A)	Oil (B)	Oil (C)
Kinematic viscosity at 40 °c	653	462	200
Kinematic viscosity at 50 °c	333	253	118
Kinematic viscosity at 100 °c	32.4	30.8	17.6
Specific gravity	0.91-0.97	0.901	0.894
Pour point, max. °F (°c)	(- 3)	5 (- 15)	-10 (- 23)
Flash point, min. °F (°c)	(26[illegible])	465 (241)	405 (207)
Viscosity index	70 average	95 min.	92 min.
Timken OK load 40lb (18 kp)	- - - - -	passes	passes

Table (2) Characteristics of the lubricating oils

at lower rate with nearly linear relation and increases suddenly till failure. They also show that wear of wheel of the concave teeth is more than that of the pinion with its convex teeth. This may be due to the Hertzian indentations which is more in the concave from the effect of load of the convex.

Fig.(6 and 7) show the change of the weight of removed metal with the change of helix angle at different applied tooth loads for wheel of concave teeth and pinion of convex teeth and running at speeds of 1500 and 3000 RPM respectively using lubricating oil (B). These curves show that the change of helix angle increases slightly the amount of wear when the gears run under light tooth loads. For higher transmitted tooth loads the amount of wear increases at a higher rates. For decreasing the helix angle, the radii of curvature, Hertzian area of contact and sliding velocity along the face width increase. Thus reducing the amount of wear.

B- Effect of Oil Viscosity

Fig.(8 and 9) show the change of the weight of removed metal with the change of oil viscosity at different applied tooth loads for test pair (I) at speeds 1500 and 3000 RPM respectively. They show very clearly that wear decreases with increase of oil viscosity at lower rate and nearly linear relation for light loads, while wear decreases with oil viscosity at higher rate for higher applied tooth loads. With increase of viscosity the oil film increases which carries higher loads with continuous formation between contacting teeth. But for light viscosity oil film is liable for cutting under load together with its sensitivity to surface roughness and Hertzian deformations. Thus it could be concluded that the stability of oil film with higher viscosity decreases the amount of wear for contacting teeth under the same load and speed .

Fig.(10) shows the change of the weight of removed metal with the change of oil viscosity for different test pairs of gears and speeds at applied tooth load = 2000 Kp. They show very clearly that wear at speed 3000 RPM is greater than wear at 1500 RPM for all test pairs of gears, this difference decreases at higher rate with increasing the oil viscosity and decreasing the helix angle of the test gears. This is due to the increase of the load applied on the tooth by a dynamic increment caused by the dynamic errors in transmission. Also with increase of speed the temperature of the oil increases due to the generated friction between the teeth. This increase of temperature decreases the viscosity of oil which accordingly decreases the load carrying capacity of the oil film and increases wear .

CONCLUSIONS

1- Wear of gears of circular-arc tooth-profile increases with increasing the helix angle at lower rate and nearly linear relation for light loads. The rate of increase of wear is higher for higher applied tooth loads .

- Wear of test gears decreases with increasing the oil viscosity for different helix angles, tooth loads and speeds.
- Effect of change of oil viscosity in reducing wear is more applicable for higher tooth loads.
- With increase of speed and higher tooth load wear increases. This increase decreases for higher oil viscosity and lower helix angle.

5- Wear of gears of concave teeth is more than wear of gear of convex teeth for the same working conditions and most experimental tests.

ACKNOWLEDGEMENTS

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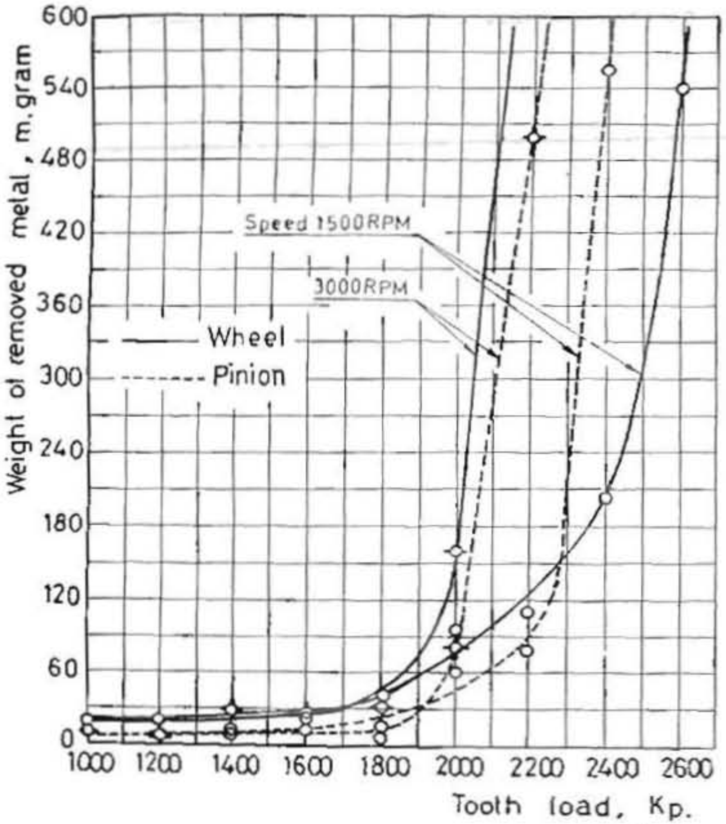
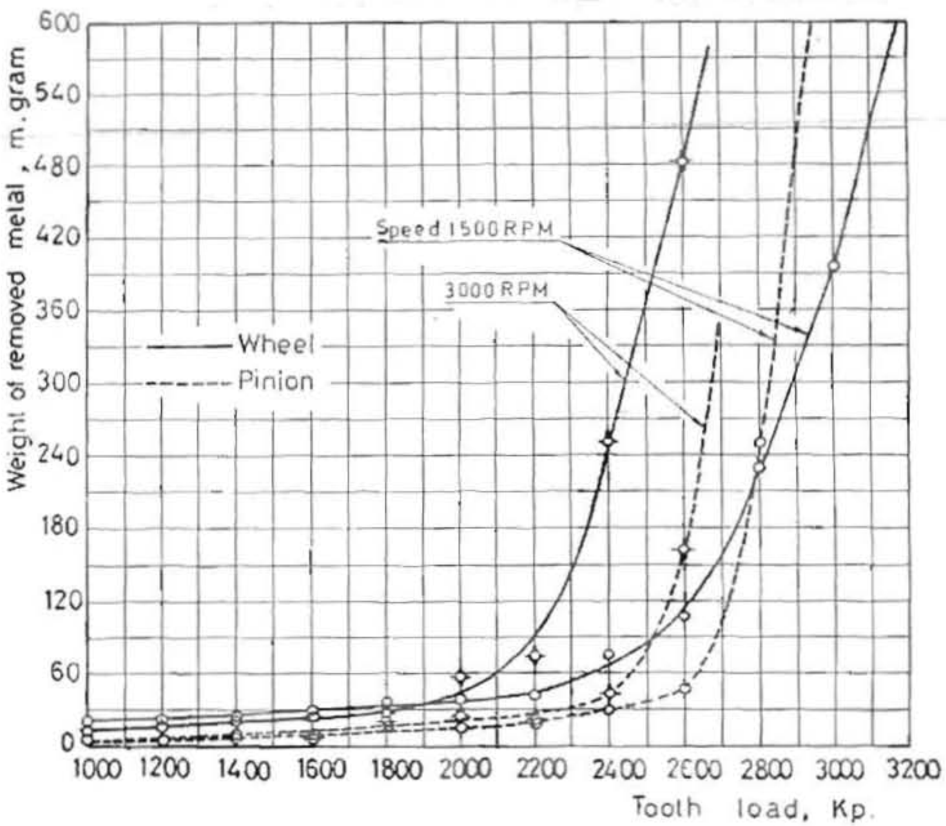
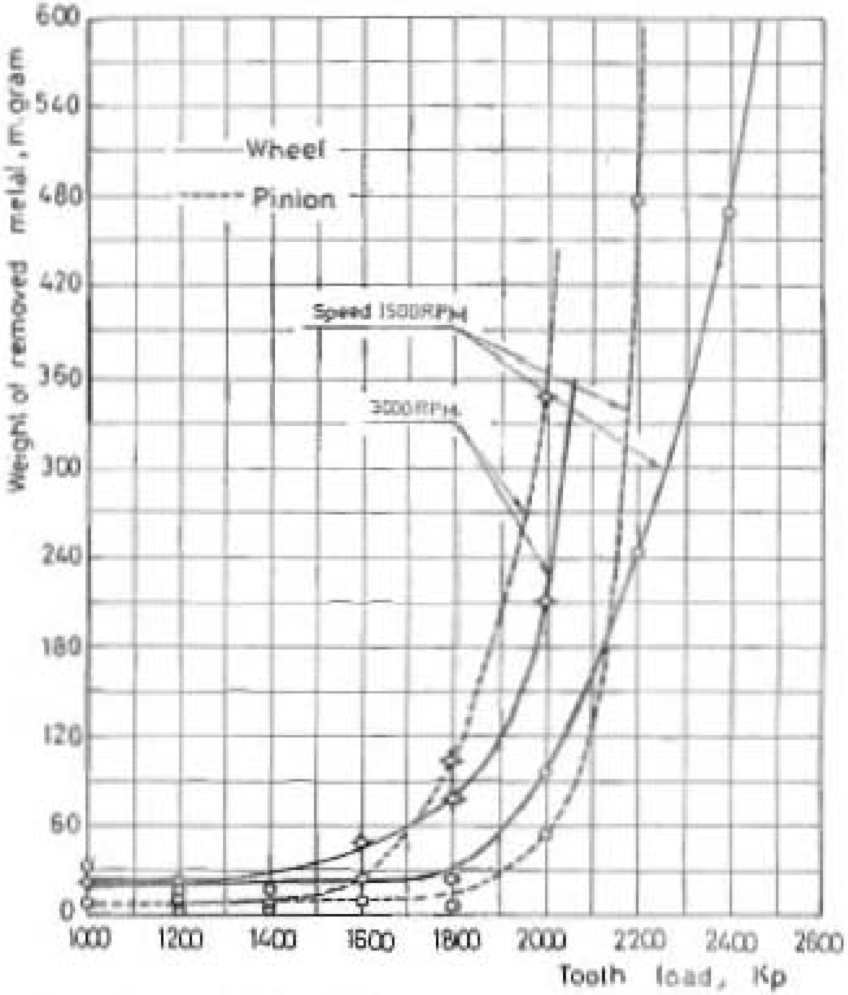


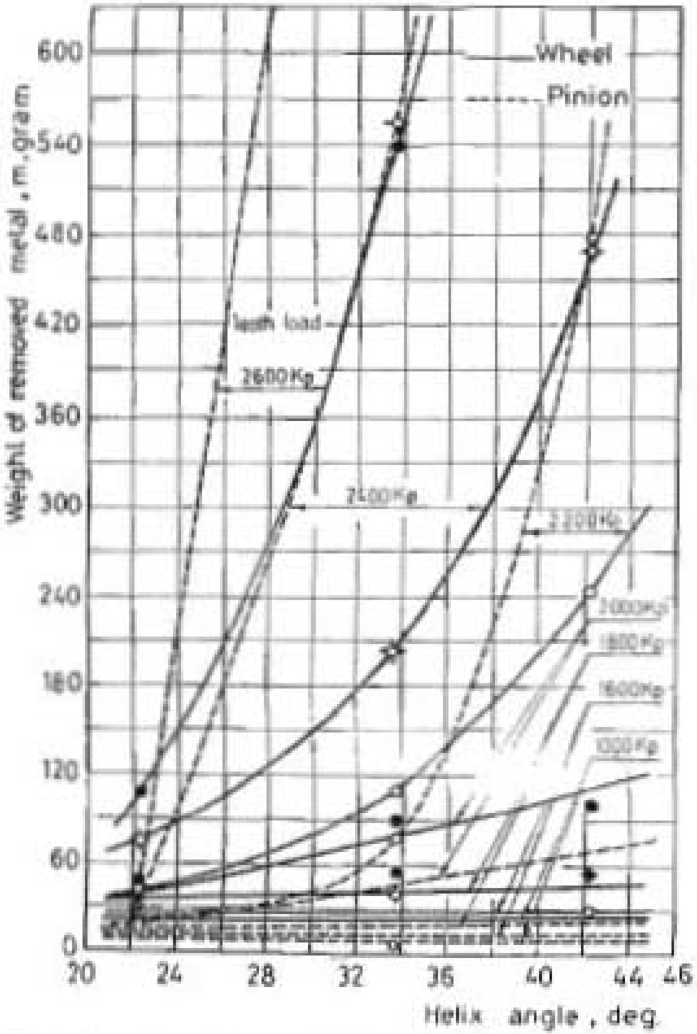
Fig(4) Change of weight of removed metal with applied tooth load at different speeds for wheel of concave teeth and pinion of convex teeth using pair(2) and oil(B)



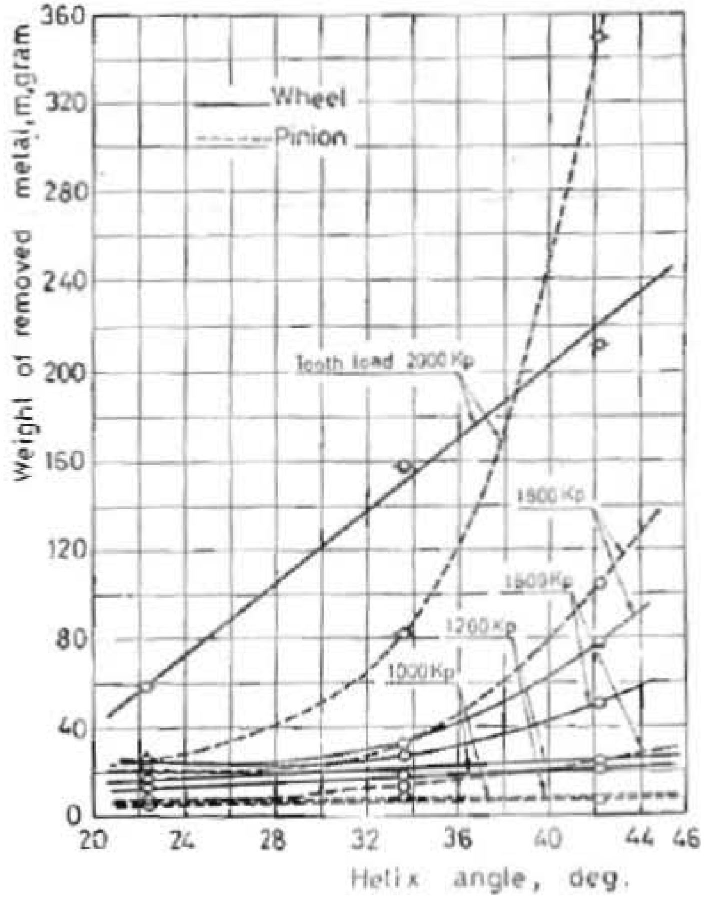
Fig(3) Change of weight of removed metal with tooth load at different speeds for wheel of concave teeth and pinion of of convex teeth using pair(1) and oil (B)



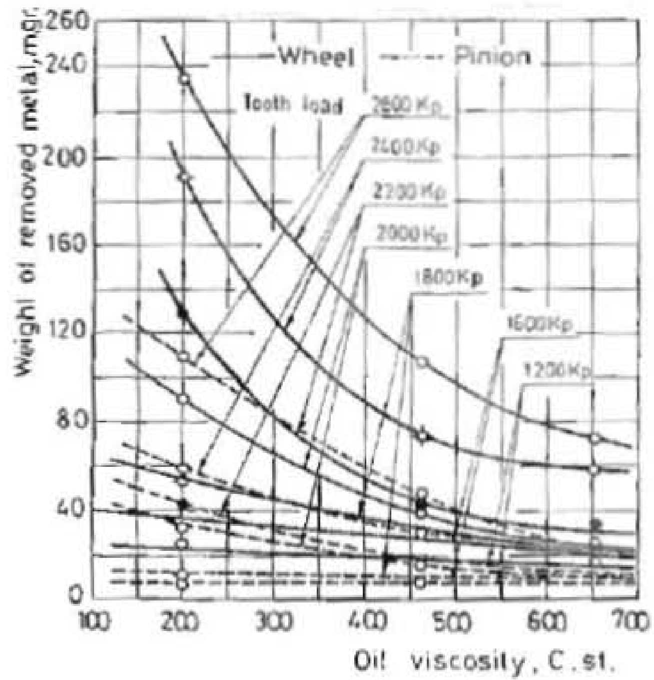
Fig(5) Change of weight of removed metal with applied tooth load at different speeds for wheel of concave teeth and pinion of convex teeth using pair(3) and oil (B)



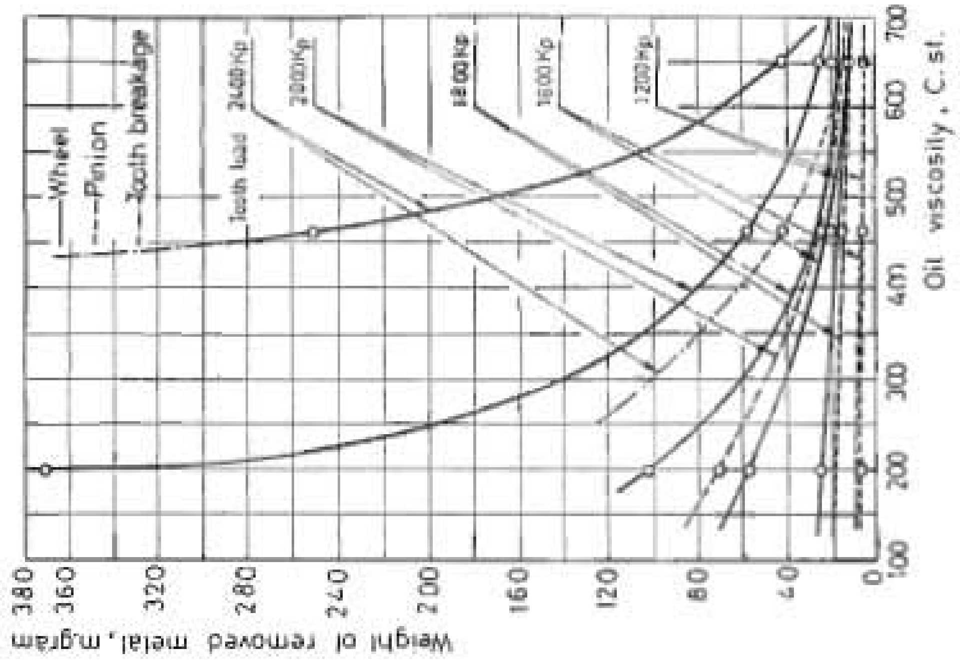
Fig(6) Change of weight of removed metal with helix angle at different applied tooth loads for wheel of concave teeth and pinion of convex teeth at speed 1500RPM and oil (B)



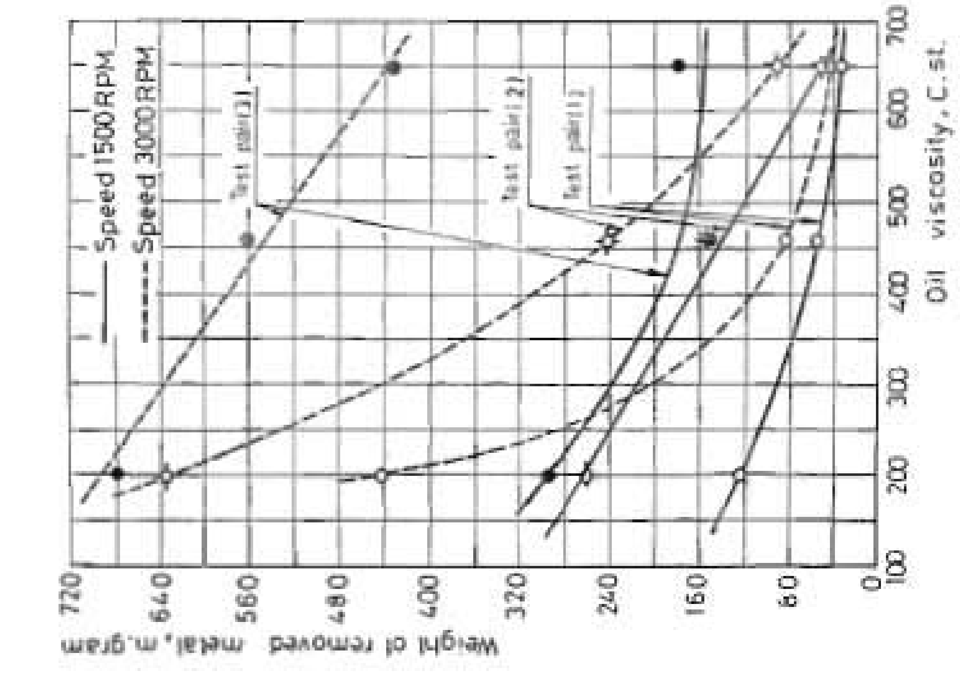
Fig(7)Change of weight of removed metal with helix angle at different tooth loads for wheel of concave teeth and pinion of convex teeth at speed 3000RPM,oil B



Fig(8)Change of weight of removed metal with oil viscosity at different tooth loads for pair(1) using speed 1500 RPM



Fig(9) Change of weight of removed metal with oil viscosity at different tooth loads for pair(1) using speed 3000 RPM



Fig(10) Change of weight of removed metal with oil viscosity for different test pairs and speeds at applied tooth load = 2000 Kp