

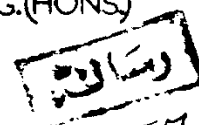
Ref 9902170
C-14 K-12 8897
C-14 K-12 8897

A COMPARATIVE INVESTIGATION INTO
**THE EFFECT OF SURFACE ROUGHNESS
ON
THE STATIC FRICTION
OF
STEEL SURFACES**

THESIS
SUBMITTED AS PART OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF SCIENCE
BY

SAAD ABDEL-RAHMAN ZAGHLOOL , B. SC. ENG.(HONS)

FACULTY OF ENGINEERING
AIN SHAMS UNIVERSITY
CAIRO , JULY -1973



5711



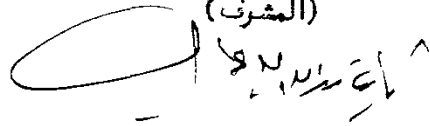
1974 / 9 / 20

EXAMINERS

1) Pro. SABET RIZKILAH GHABRIAL

استاذ التصميم بكلية الهندسة
جامعة عين شمس

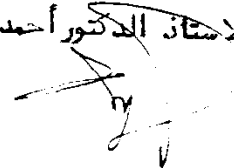
(1) الاستاذ الدكتور ثابت رزق الله غبريال
(المشرف)



2) Pro. AHMED FOUAD RASHED

استاذ القياس بكلية الهندسة
جامعة الاسكندرية

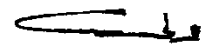
(2) الاستاذ الدكتور أحمد فؤاد راشد



3) Dr. ABD - EL HAMID SHAWHEH SHRIEF

رئيس الهيئة التدريسية
بالتواتر الملحقة

(3) الدكتور عبد الحميد شريف



Supervised by

Prof : S. R. GABRIAL

Dr. : A.K. ABU AKEEL



ACKNOWLEDGMENT

This work was proposed and supervised by Prof. Sabot R. Ghabrial, professor of Machine Design, Faculty of Engineering, Ain Shams University, Cairo.

The author wishes to express with much thanks his indebtedness to Prof. Sabot R. Ghabrial for his deep interest in the subject and for his unfailing continuous help throughout this work.

The author also wishes to thankfully acknowledge the fruitful cooperation and measurement facilities kindly offered by Dr. Abd El-Hamid S. Cherif, Head of the Technical Department of the Armed Forces.

The author is also indebted to all those who were helpful in producing the thesis in its present form.

S U M M U R Y

The object of this investigation was to find out the comparative effect of the various parameters of surface roughness on the static coefficient of friction of steel surfaces. The surfaces were prepared by various machining processes namely, shaping, milling, grinding, lapping and polishing. Wide ranges of surface roughness for each process were obtained through the variation of machining conditions.

Complete study of the geometry of the surface roughness was made with the aim of finding out the most significant parameters regarding the static coefficient of friction.

A special equipment was designed to assess the static coefficient of friction through measuring the critical angle of friction with a precise inclinometer.

The results were plotted in the form of relations between various surface roughness parameters and the static coefficient of friction, the results showed that the most significant parameters were the asperity angle (θ) and the specific process parameter. The specific process parameter is the product of the standard deviation

of peaks distribution (σ_p) and the smoothness index which is the ratio of depth of smoothness (G) and the centre-line-average (CLA) values.

A most fitting empirical relation, as well as a chart, was established.. the relation assumed the following form

$$\mu_s = 0.12 + \left[18 \theta + 60 \log \left(\sigma_p \frac{G}{CLA} \right) \right] 10^{-4} + 0.8\epsilon$$

The relation included the effect of the mutual approach (ϵ) and the maximum scatter in the calculated values of the coefficient of friction was $\pm 5\%$.

Besides and only for ground and polished surfaces relations could be established between the coefficient of friction and both centre-line-average and maximal depth values the empirical relations were as follows:-

for ground surfaces: $\mu_s = 0.116 + .012 (CLA) + 0.8\epsilon$
 $= 0.114 + 0.0033 R_{max} + 0.8\epsilon$

for polished surfaces $\mu_s = 0.107 + .022 (CLA) + 0.8\epsilon$
 $= 0.106 + 0.0046 R_{max} + 0.8\epsilon$

This result is of a great value in the assess
of surface roughness of such surfaces through the measu-
rment of its static frictional resistance.

-oo-

C O N T E N T S

	Page
ACKNOWLEDGMENT.....	iii
SUMMARY	iv
LIST OF TABLES	x
LIST OF ILLUSTRATIONS	xi
INTRODUCTION.....	1
OBJECT AND SCOPE OF PRESENT WORK	2
NOMENCLATURE	4
Chapter I REVIEW OF PREVIOUS WORK.....	5
I Friction.....	5
II Surface Roughness.....	13
Chapter II MEASURING EQUIPMENT AND PROCEDURE.....	20
Test specimen.....	20
Equipment.....	23
1- The Reference Surface Block.....	24
2- The Tilting-rig.....	26
3- Inclinometer.....	28
Principle of action and procedure for friction angle measurement.....	30
Surface roughness measurements.....	32

	Page
Chapter III RESULTS AND DISCUSSION.....	34
I-SIGNIFICANT SURFACE FINISH PARAMETERS REGARDING THE STATIC COEFFICIENT OF FRICTION.....	34
a)Initial asperity angle.....	35
b,c)The standard deviation of peaks distribution and the depth of smoothness.....	38
d)Peaks standard deviation combined with the "Smoothness Index".....	42
II-EMPIRICAL RELATIONS BETWEEN THE STATIC COEFFICIENT OF FRICTION AND THE SIGNIFICANT SURFACE ROUGHNESS PARAMETERS.....	49
III-THE INSIGNIFICANCE OF THE STANDARD SURFACE ROUGHNESS PARAMETERS REGARDING THE STATIC COEFFICIENT OF FRICTION.....	50
CONCLUSIONS.....	65
APPENDICES.....	67

Page

Appendix I : Samples of scatter for the various relations.....	67
Appendix II: Determination of surface roughness parameters and experimental results.....	79
REFERENCES.....	95

-ooo-

LIST OF TABLES

	Page
Table 1- Surface quality and mutual approach for contacting elements.....	27
Table 2- Values of the percentage maximum de- viation for empirical formulae.....	53
Table 3- Experimental results.....	89

-cc-

- x -

LIST OF ILLUSTRATIONS

		Page
16-	Figure	
	1- Mechanical properties of the test specimen material (0.25 % carbon steel).....	21
17-	2- Specimens.....	22
	3- Reference surface block.....	25
	4- Contacting elements.....	26
18-		
	5- The tilting-rig for the assessment of angle of friction.....	29
19-		
	6- Principle for the assessment of the angle of friction.....	31
	7- Relations between coefficient of friction and initial asperity angle for different machining processes.....	36
20-		
21-	8- The effect of the initial asperity angle on the junction plastic deformation.....	39

35-				Page
	2	22-	A sample of scatter in the relation between initial asperity angle and coefficient of friction for shaped and milled surfaces.....	67
36-				
37-	2			
38-		23-	A sample of scatter in the relation between the standard deviation of peaks distribution and coefficient of friction for milled and lapped surfaces.....	68
39-				
40-	3			
		24-	A sample of scatter in the relation between the depth of smoothness and coefficient of friction for milled and lapped surfaces.....	69
	3	25-	A sample of scatter in relation between the specific process parameter and the coefficient of friction for milled and lapped surfaces.....	70
	3	26-	A sample of scatter in the relation between the specific process parameter and the asperity angle.....	71
	3	27-	The scatter in the relations between the static coefficient of friction and centre-to-average val. for ground and polished surfaces.....	72

INTRODUCTION

Although the problem of dry friction has occupied the minds of many previous investigators, yet only recently the nature and mechanism of dry contact could be adequately explained. J.A. Greenwood and J.B.P. Williamson stated that dry friction may be explained by the shapes of the peaks and their distribution through the upper decile of the texture. J. Halling, T. Tsukizoe, and T. Hisakado considered the plastic deformation of asperity junctions and the possibility of junction growth and derived theoretical formulae for the macroscopic coefficient of friction assuming pyramidal or conical asperities.

However no quantitative results were given for actual engineering surfaces. On account of the great importance of the dry friction assumes in many engineering situations, the need was felt for an experimental investigation of the relations between surface roughness and the static coefficient of friction.

Besides, the aim of designing a cheap and simple instrument utilizing any of such relations for the assessment of surface roughness was in view when planning the present work.

OBJECT AND SCOPE OF PRESENT WORK

OBJECT

This investigation has a double object:

- (1) Finding out the most significant parameters of surface roughness which affect the static coefficient of friction for steel surfaces and establishing their appropriate empirical relations.
- (2) Supplying adequate information for the design of a simple surface finish measuring instrument working on a functional basis for those surfaces which prove to have simple relations between their static frictional resistance and the usual standard parameters.

SCOPE OF WORK

The scope of work in this investigation covered the study of the comparative effect of the variation of the shape and standard deviation of the distribution of the peaks of surface roughness on the static coefficient of friction. The shape of the peaks was expressed in both the mean asperity angle and a 'smoothness index' in the form of the ratio between the smoothness depth of peaks (G) and the center-line-average value (CLA).