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SLIP LINE FIELD APPROACH FOR THE ASSESSMENT OF SCRAPING FORCES

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ABSTRACT

A slip line field technique is adapted to estimate scraping forces in the present research for conical tools scraping. Hencky's equations are applied assuming orthogonal slip line field to prevail while scraping. The contact pressures acting around half of the cone periphery are calculated assuming sticking conditions to exists along conical tools sides. In such a manner, the values of horizontal and vertical force components acting on the tool are predicted. The horizontal force are found to be functions of the workpiece material yield strength in shear and the contact area of the cone together with its half semi-cone angle. On the other hand, the vertical force components are found to be functions of the workpiece material yield strength in shear, the unit area of the cone which is in contact with the workpiece and half semi-cone angle. The apparent coefficient of friction can be also predicted via the proposed slip line field technique.

Such theoretical predictions are compared with a large amount of experimental data obtained for the dry scraping of sharp cones of high speed steel tools cuting free machining brass as well as commercially pure aluminium blocks.

Fair agreements between theory and experiments are noted. Reasons for discrepancies are discussed.

INTRODUCTION

Scraping utilizing three dimensional sliders has direct impact on sliding grinding and frictional asperities. Scrapers forms can simulate those of asperities during any tribological

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friction studies [1]. Such contact result in elastic to be subsequently produced by plastic deformation. While the elastic behaviour was not studied in the open litrature those of the plastic deformation merred speciale attention. Any study of that direction has to be connected with a force study where in the static or in the dynamic conditions. As entery of later study may be a force prediction treating the sliding situation as a quasi static case.

ANALYSIS

The analysis presented here is approximate assumes a slip line field which is not supparted by the principle of volume constancy. Abdel-Moneim and Scrutton [2] and Chandresikaran and Kapoor [3] applied a similar technique to the one adopted here.

The contact pressure, P, acting around half of the cone periphery (that facing the workpiece) may be assumed via Hencky's equations as follows;

$$P + 2\tau\Phi_m = \text{constant along an } \alpha \text{ slip line}$$

The major principle stress acting in the direction parallel to the surface is tensile and equals to $-\tau$. Then,

$$P = -\tau \; (1 + 2\Phi_m)$$

It may be seen (Fig. 1), assuming sticking friction conditions to prevail over the entire facing periphery, then,

$$P = \left|(2.571 - 2\alpha)\right|$$

Such stresses may be analysed in the horizontal plan to yield:

$$\delta F_{hp} \simeq (P \cos\alpha + \tau \sin\alpha) \,.\, \delta A$$

$$\simeq (2.571 \cos\alpha - 2\alpha \,.\, \cos\alpha + \sin\alpha) \,.\, \delta A$$

With δA being the unit surface area at the interface of the cone-workpiece and δF_{hp} is the elemental horizontal plan force. Such elemental forces would be acting around the conical interface as shown in Fig. 2.

That forces are further analyzed in the sliding (h) direction and normal direction such as the total horizontal force (F_h) will be;

$$F_h \simeq 2 \int_0^A \int_0^{\pi/2} \delta F_{hp} \cos\theta \,.\, \delta\theta \, \delta A$$

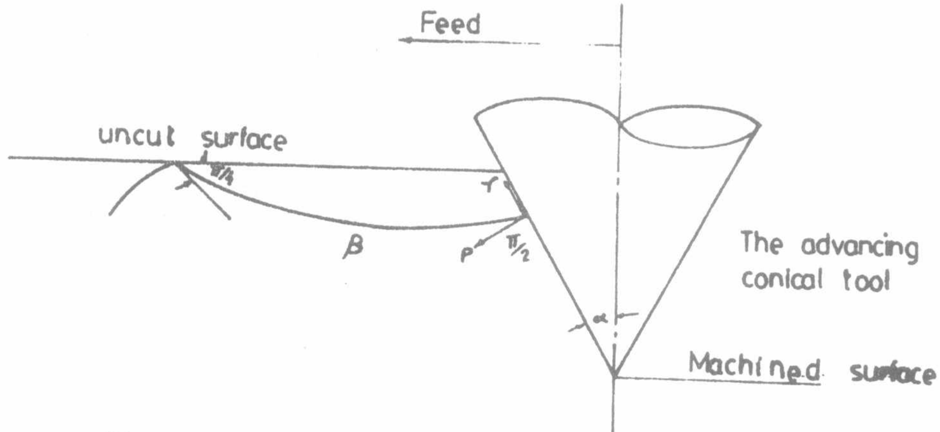

Fig. 1 Stresses acting on the frontal cone periphery.

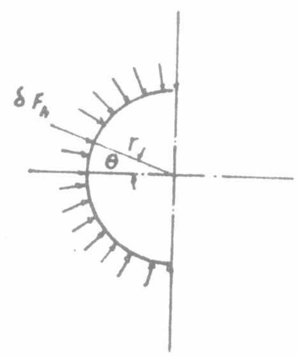

Fig. 2 Elemental force (δF_h) acting around the cone.

$$\simeq 2 A_c \tau \quad (2.571 \cos\alpha - 2\alpha\cos\alpha + \sin\alpha)$$

Where, A_c being the total interface area and equal to:

$$= 0.5 \pi R \sqrt{R^2 + t^2}$$

i.e $F_h / \tau = 2A_c . (2.571 \cos\alpha - 2\alpha \cos\alpha + \sin\alpha)$ (1)

With the maximum horizontal force at

$$= 0.5 \cot\alpha + 1.2855$$

Thus, the max. Forces will be as follows

$$\frac{d F_h}{d \alpha} = 2(-2.571 \sin\alpha - (2\cos\alpha - 2\alpha.\sin\alpha + \cos\alpha) = 0$$

$$= - 2.57L \sin\alpha - \cos\alpha + 2\alpha \sin\alpha = 0$$

$$= - 2.571 \tan\alpha - 1 + 2\alpha \tan\alpha = 0$$

Where,

$$2\alpha \tan\alpha = 1 + 2.571 \tan\alpha$$

$$= 0.5 \cot\alpha + 1.2855 \text{ (For max horizonal force)}$$

Then, vertical forces can be get as follows=

$$\frac{d\,F_v}{d\,\alpha} = (2.571 \cos\alpha - (2 \sin\alpha + 2\alpha .\cos\alpha) - \sin\alpha) = o$$

i.e $3 \sin\alpha + 2\alpha \cos\alpha = 2.571 \cos\alpha$

$$3 \tan\alpha + 2\alpha = 2.571$$

$$\alpha = 1.2855 - \frac{2}{3} \cot\alpha \quad \text{(for max. Vertical force).}$$

Similarly;

$$\delta F_{vp} \simeq (P \sin\alpha + \tau \cos\alpha).\delta A$$

$$\simeq \tau (2.571 \sin\alpha - 2\alpha \sin\alpha + \cos\alpha).\delta A$$

Such elemental forces would be acting tangential to such cross sectional areas as that shown in Fig. 2. Such forces may be seemed to yield the total vertical force (F_v) ,

$$F_v = \int_0^{Ac} \int_{-\pi/2}^{\pi/2} \delta F_{vp}\, \delta\theta = \pi . A_c . \tau (2.571 \sin - 2\alpha \sin_\alpha + \cos\alpha)$$

i.e.

$$\frac{F_v}{\tau} = \pi A (2.571 \sin\alpha - 2\alpha \sin\alpha + \cos\alpha) \qquad (2)$$

With the maximum vertical force at

$$\alpha = 1.2855 - 0.667 \cot\alpha \qquad (3)$$

The apparent coefficient of friction μ equal to;

$$\mu = \frac{F_h}{F_v} = \frac{2(2.571 \cos\alpha - 2\alpha \cos\alpha - \sin\alpha)}{\pi(2.571 \sin\alpha - 2\alpha \sin\alpha + \cos\alpha)} \qquad (4)$$

EXPERIMENTAL DETAILS

Sharp conical high speed tools of semi - apex angles ranging between 30° to 60° with steps of 5° were employed. Dry scroping cutting tests were performed for free machining brass (62% copper, 34% zinc, 4% lead) and comercially pure aluminium blockes (99.6%) of 15o x 40 x 10 mm.

The cutting tools were firmly held in a specially designed two components force dynamometer and mounted in a rigid milling machine utilized as a planer.

RESULTS AND DISCUSSION

The theoretical results of the yield shear stresses(τ) were found to be 26.5 kg/mm^2 and 19.3 kg/mm^2 for free machining brass and aluminium respectively.

Such values were obtained from standare tensile tests with the subsequent application of Von. Misses yield criterion ($\tau = Y / \sqrt{3}$). Figs. 3 and 4 indicate modes of horizontal forces (F_h) increase for higher values for cone apex semi-angles (α) for free machining brass and aluminium workpiece.

Figs. 5 and 6 indicate modes of vertical forces (F_v) increase for biger values of cone apex semi-angles (α) for free machining brass and aluminium workpieces.

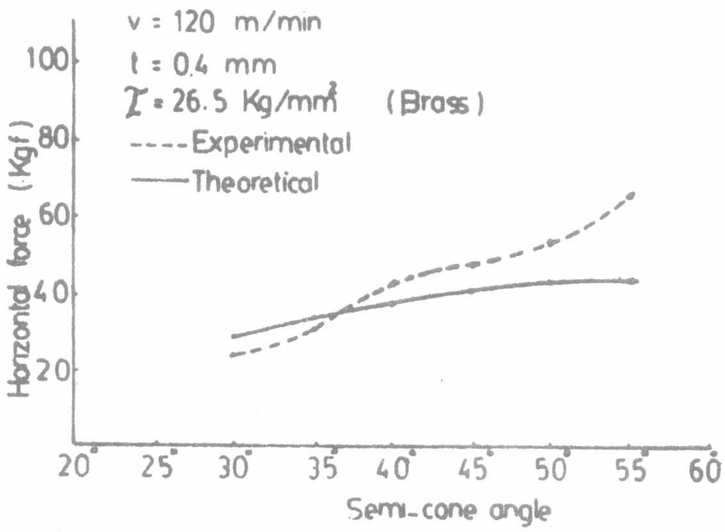

Fig. 3 Relationship between Semi-Cone angle (α) and horizontal force (F_h) for brass.

Figure (7) gives the variations of the apparent coefficient of friction (μ) with cone of multi - semi-angles (α) for the employed materials.

Figs. 3,4,5 and 6 indicated that the theoretical computed forces, utilizing the slip line field technique(S.L. F.T.) as a first approximation yield invariably higher values than the actual experimental values. Such differences are quite understandable which may be due namely to main reasons viz;

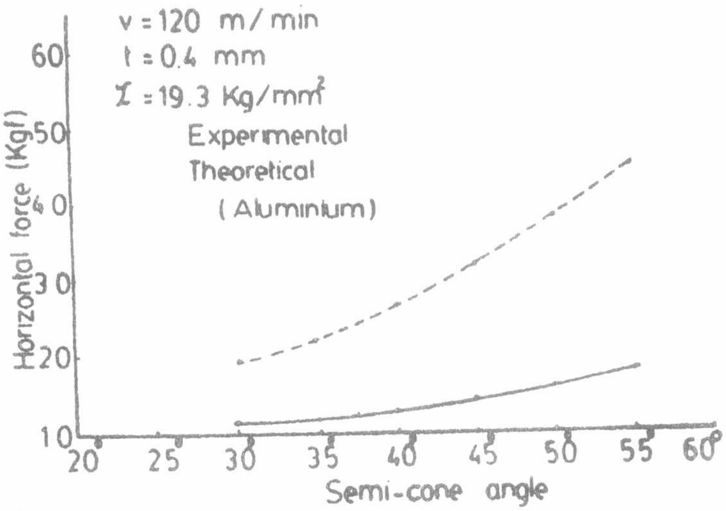

Fig 4 Relationshop between semi cone angle (α) and horizontal force (F_h) for aluminium.

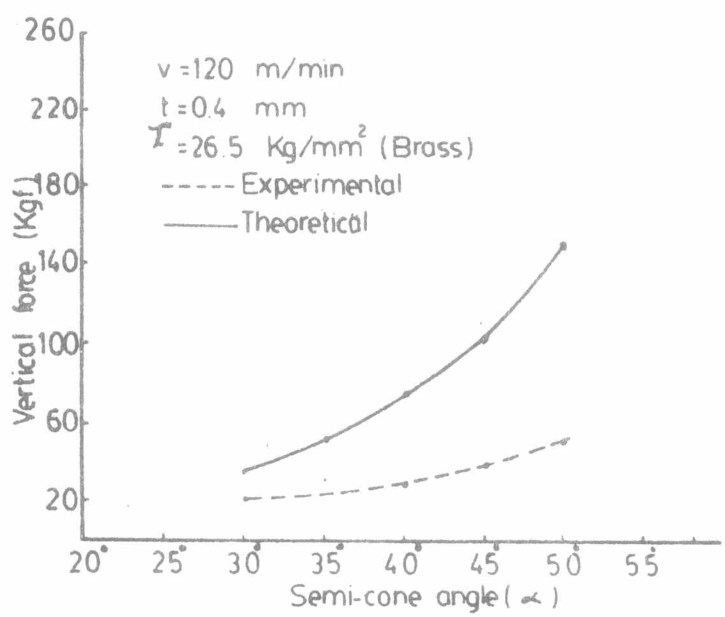

Fig. 5 Relationship between semi-cone angle (α) and vertical force (F_v) for brass

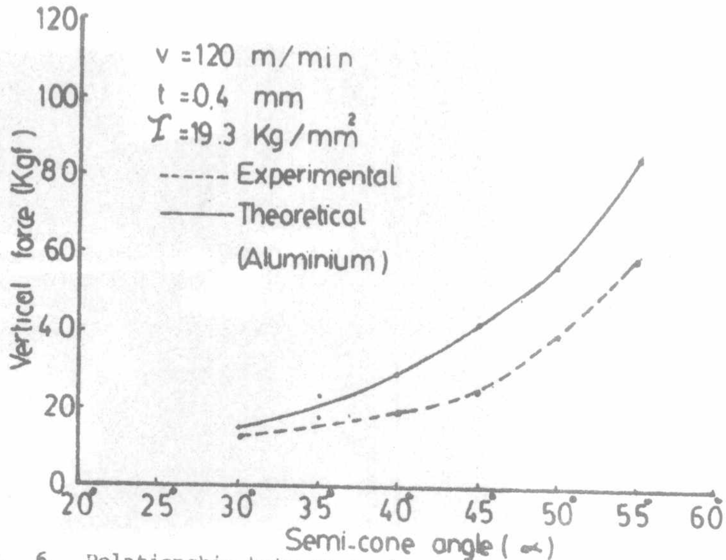

Fig. 6 Relationship between semi-cone angle (α) and vertical force (F_v) for aluminum .

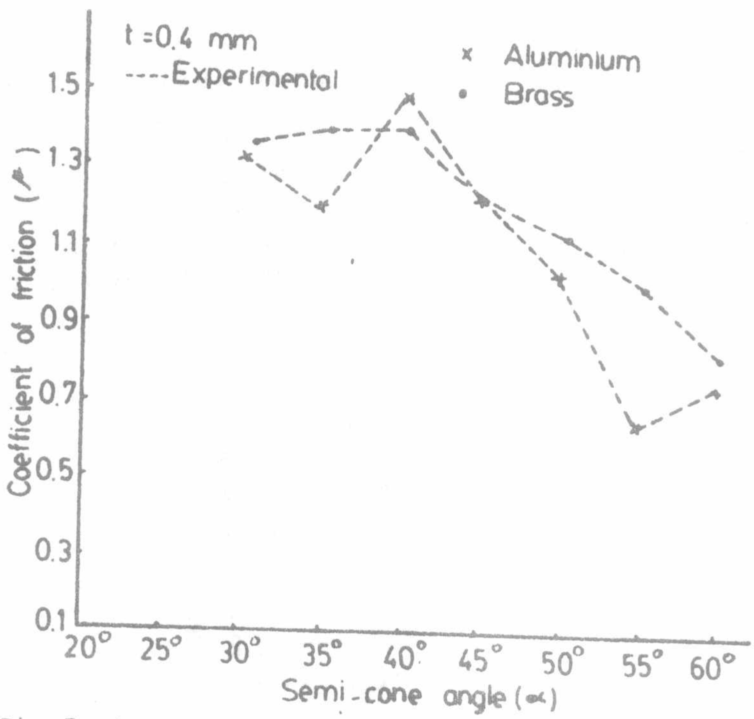

Fig. 7 The relationship between semi-cone (α) angle and the apparent coefficient of friction (μ).

The inevitable material flow past and arround the conical surfaces upon scraping. Such phenomena leads to ridge to existence of uncontrollable ridge formations. Such formations are inconsistent and yet depend on scraping conditions and inheomgenties in workpiece materials (Fig. 8).

That ridge height has been the object of investigations for some researches, e.g. Shield [4] and Tsukizoe and Sakamoto [5].

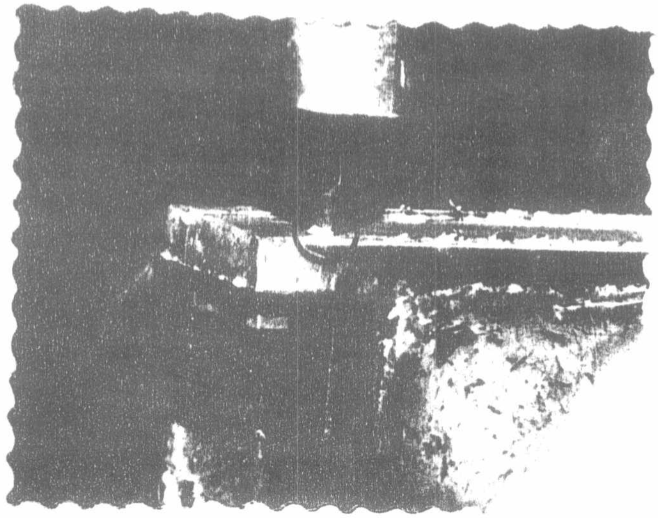

Fig. (8) The shape Of active built-up edge.

While Shield [4] confined this reaserch mainly to the configurations of such irregular shapes, Tsukizoe and Sakamoto [5] persued the matter further. In their papers [5] they employing Scanining Electron Micorsrope (SEM) to investigate this phenomena carefully (Fig. 9). Sakamoto and Tsukizoe [6] forwarded some mathematical deriviations to count for such phenomena in conical scraping forces than those computed with the lower values (Figs. 3,4,5 and 6).

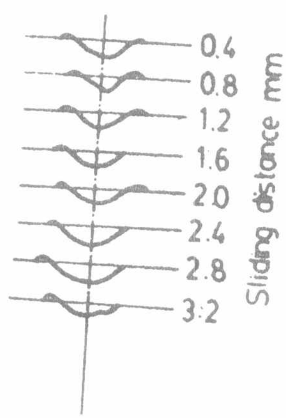

Fig. 9 Change in cross-section of groove formed by low carbon steel conical slider. (5)

Unstable built -up formations are unavoidable during aluminium cutting at low speeds. Therefore, the deviations between the theoretical and experimental values are to be greater for aluminium cutting than those for brasses cutting that was actually found.

CONCLUSION

1. The slip line field technique (S.L.F.T) can be utilized as a first approach for the compute of the scraping forces.

2. The ridge height has to has significance on the cutting forces.

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NOMENCLATURE

A	Unit orea of the cone which in contact with the work-piece	mm)
A_c	Contact area of the cone	(mm)
F_h	Horizontal force	(Kg F)
F_{hp}	Elemental horizontal plane surface	(Kg F)
F_v	Vertical force	(Kg F)
F_{vp}	Elemental vertical plane surface	(Kg F)
h	Horizontal direction	

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P	Contact pressure	(Kg/mm^2)
t	depth of cut	(mm)
V	Cutting speed	(m/min)
Y	Yield stress	(Kg/mm^2)
α	Half semi-cone angle	(degree)
β	Slip line field	
θ	See Fig. 2	
ϕ_m	Anticlockwise rotation of the slip. line	
τ	tensile stress	(Kg/mm^2)
μ	coefficient of friction	