

Chapter 8

CHAPTER 8

PARTIAL EXPERIMENTAL VALIDATION OF MODEL

8.1 Introduction

A number of experimental studies have been carried out in the past to evaluate the machining parameters in orthogonal cutting and to identify the variables affecting the process. In thirties and forties, such investigations were mostly undertaken to set up empirical equations for cutting and thrust forces and tool life in terms of such variables as speed, feed and depth of cut (Kronenberg[37], Colding[22], Woxen[6], Rubenstein[56], Taylor[4]). After fifties, however, attention was mostly directed towards having a deeper understanding of the mechanics of the process and to compare experimentally observed results with those predicted by theory. Experimental flow fields to observe the nature of deformation in the primary and secondary shear zones have been presented by Roth et al.[47] and Childs[52]. The nature of pressure distribution in the natural contact length has also been studied by a number of investigators as discussed in chapter -I (Childs et al.[74], Barrow et al.[62], Kato et al.[48], Kapoor et al.[33] and others). An exhaustive volume of experimental data of tangential cutting force, thrust force, contact length and cutting ratio for orthogonal cutting are given by Eggleston et al.[23] and Ponshe[35] for different non-zero rake angles and for different work materials like mild steel, aluminium and copper. Some of the above reported results have been compared with the present theoretical models in the previous chapters.

In the present experimental investigation tangential cutting force, thrust force, cutting ratio and contact length were measured for orthogonal cutting using a turning

tool having rake angle equal to zero degree. Mild steel and aluminium were taken as work materials. The cutting tool was made from high speed steel with 10% cobalt. Cutting tests were performed on round bars using three different feeds and at three different cutting speeds. The experimental procedure and the results are discussed in the following sections.

8.2 Apparatus

A turning tool dynamometer (syscon make) with digital strain indicator was used for measuring the cutting forces. A heavy-duty HMT copying lathe with automatic feed drive system was used for the turning operation. The chip-thickness was measured with a Screw thread micrometer with pointed anvils having a least count of 0.0254mm. The natural contact length was measured using a large tool maker's microscope with digital display. The least count of the display was .0001mm.

The specifications of the measuring instruments and the cutting tool were as follows:-

specification of digital indicator for dynamometer

- 01 No of displays : Three , one each for Tangential , Radial and Feed force

- 02 Full Scale Indication : 1999 counts

- 03 Least Count : 1 kgf

- 04 Excitation Supply to
Bridges : 5 volts DC
- 05 Initial Zero Setting : Panel mounted ten turn Potentiometer
- 06 DC Output
(For Recording) : 200mV full scale for indication of 1999
on the display i.e. , 0.1mV / count of display
- 07 Operating Temperature: 10⁰ C to 50⁰ C
- 08 AC Supply Voltage : 230 volts ± 10 % AC Mains 50 HZ
- 09 Dimensions (Indicator): 483mm width × 133 mm height ×300 mm depth

Dynamometer specification

Shank Size	=	30mm
Tool receptacle size	=	16 × 16 mm
Maximum overhang	=	20mm
Maximum tool length	=	60mm

Cutting tool specifications

Length of cutting tool = 60mm

Cross section of tool = 15 × 15 mm

Orthogonal rake angle (γ_o) = 0.0°

Inclination angle (λ) = 0.0°

Principal Cutting Edge Angle (ϕ_P) = 90°

8.3 Experimental Procedure

The orthogonal turning operation was carried out on an HMT copying lathe with automatic feed system. Round bars of mild steel and aluminum were used as work-pieces. These bars were supported by a three jaw self-centering chuck at one end and by a revolving center at the other end (Fig.8.1). The specimen was first given a skin pass to remove any eccentricity in the work-piece before actually carrying out the test. A cutting tool of zero degree orthogonal rake angle having zero degree inclination angle of approximately 60mm length was mounted in the tool receptacle of the dynamometer. The maximum overhang of the tool was restricted to 20mm. After mounting the dynamometer on the tool post, the tool-tip was adjusted such that it touched the

diametral plane of the bar. The tests were carried out at three different feeds (.05 mm / revolution, .07 mm / revolution and 0.1 mm / revolution) and at different cutting speeds. The maximum cutting speed for machining was limited to 60 m / min for steel whereas, for aluminum, it was limited to 226 m / min. The chip produced was continuous in nature. Since the tool approach angle (Principal cutting edge angle) was 90° and the inclination angle (λ_o) was zero, only two forces i.e. the tangential cutting force and the feed force were read, the radial force being almost zero. The forces were normalised using the procedure presented in Appendix C. The chip-thickness was measured using a screw thread micrometer with pointed anvils and the natural contact length was measured using a large tool maker's microscope from the adhesion mark left by the chip on the tool face Fig.8.2. Some of the cutting tools used in the experiments along with some chip samples for different cutting variables are indicated in Fig.8.3 and 8.4 respectively.

8.4 Results and discussion

The results from the present experimental investigations are shown in Fig.8.5 - 8.8 for steel and aluminium. The cutting forces reported in the above figures are the mean of three values which were recorded after the cutting process stabilised. Similarly, the chip thickness used for calculation of the cutting ratio and the shear plane angle β was obtained from the mean of five readings taken at five different locations of the chip produced. For aluminium the tests were performed at cutting speeds of 226m/min, 183m/min and 140 m/min. For steel the tests were conducted at 33m/min, 49.7m/min and 60.9m/min. These speeds were arrived at after taking into account the diameter of the workpieces and the rpms available in the lathe. Higher cutting speed could not be used for steel as the

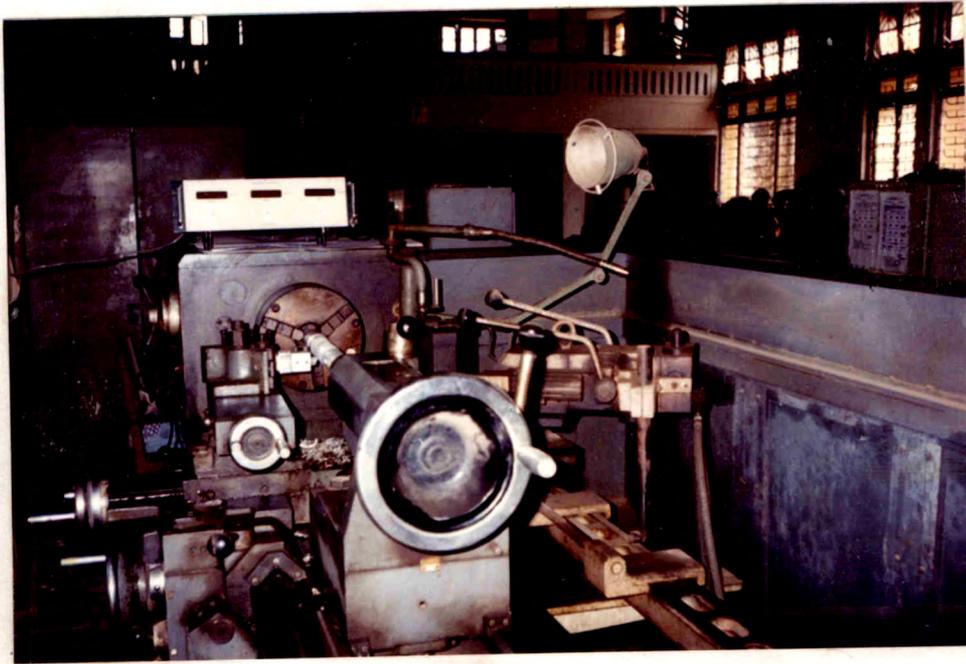


FIG.8.1 EXPERIMENTAL SETUP FOR MEASURING CUTTING TESTS

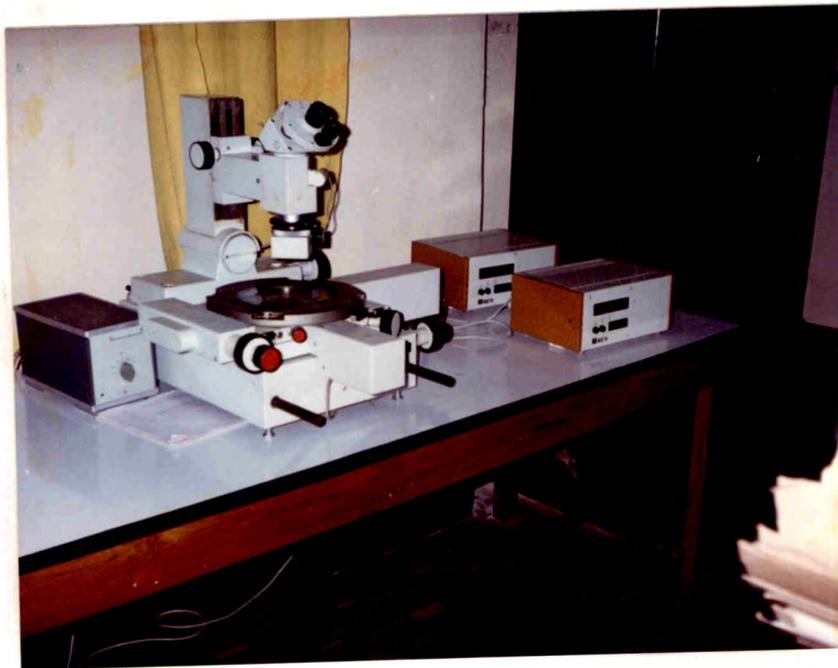


FIG.8.2 EXPERIMENTAL SET-UP FOR MEASURING CONTACT LENGTH

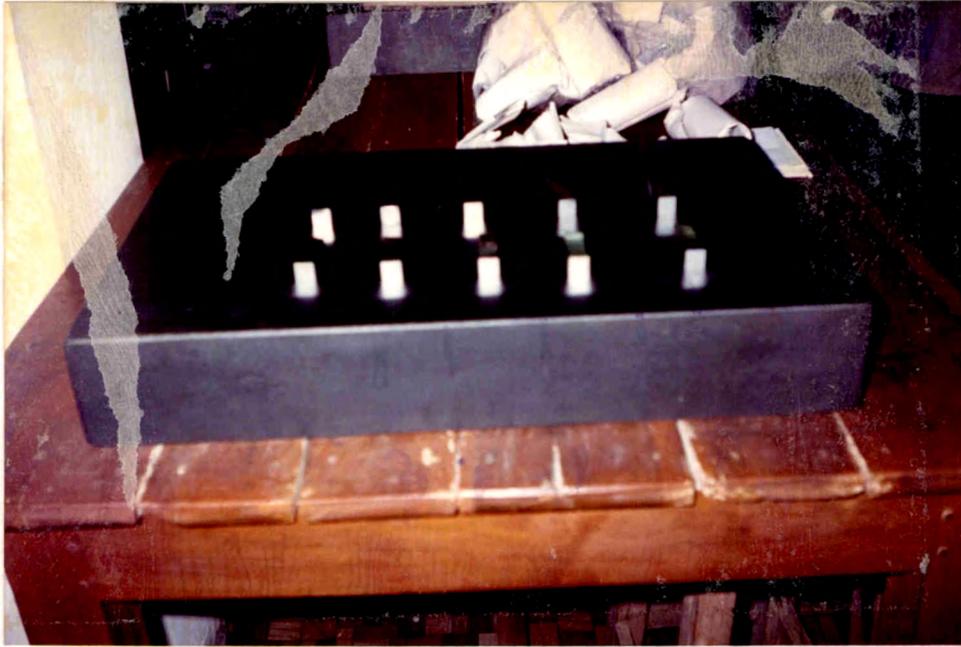


FIG.8.3 CUTTING TOOLS USED IN THE EXPERIMENT

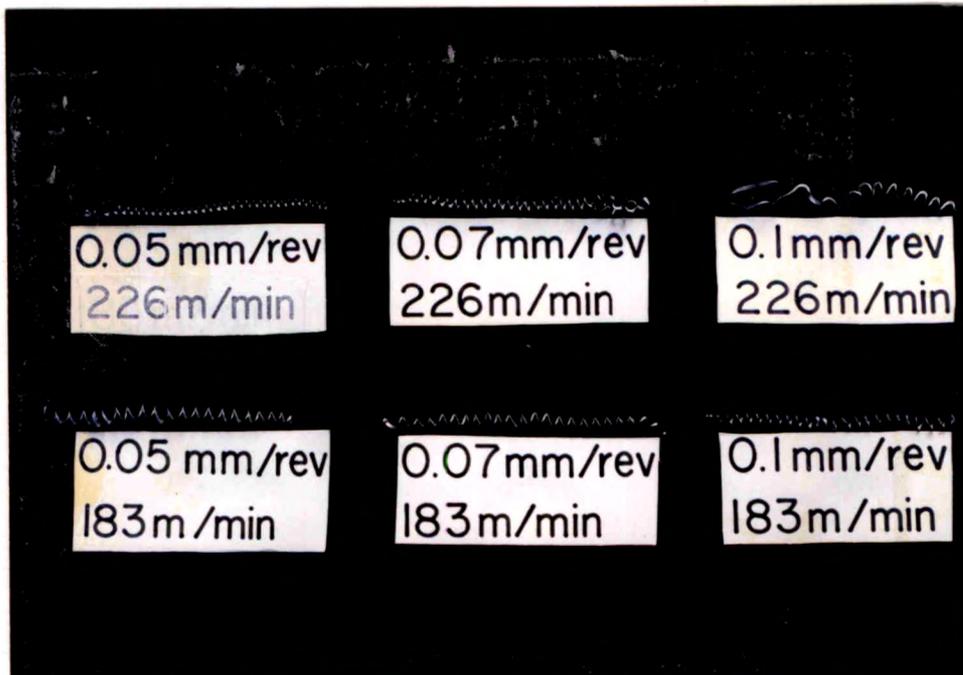


FIG.8.4 CHIP SAMPLES

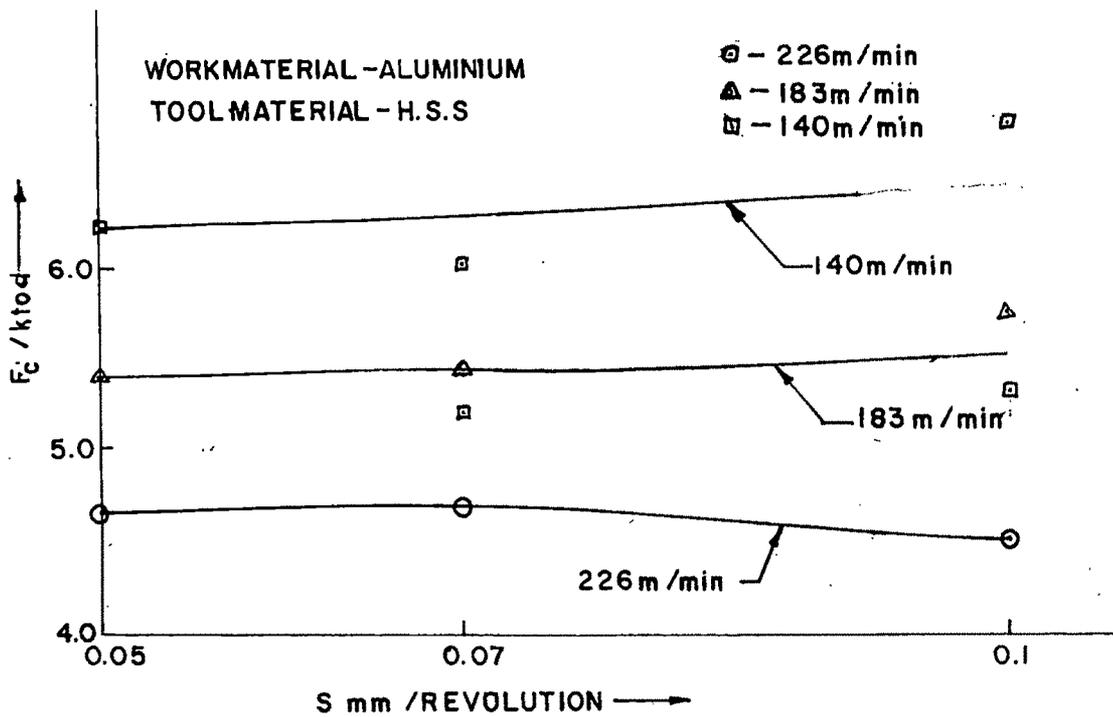


FIG.8.5 VARIATION OF CUTTING FORCE WITH FEED (ALUMINIUM)

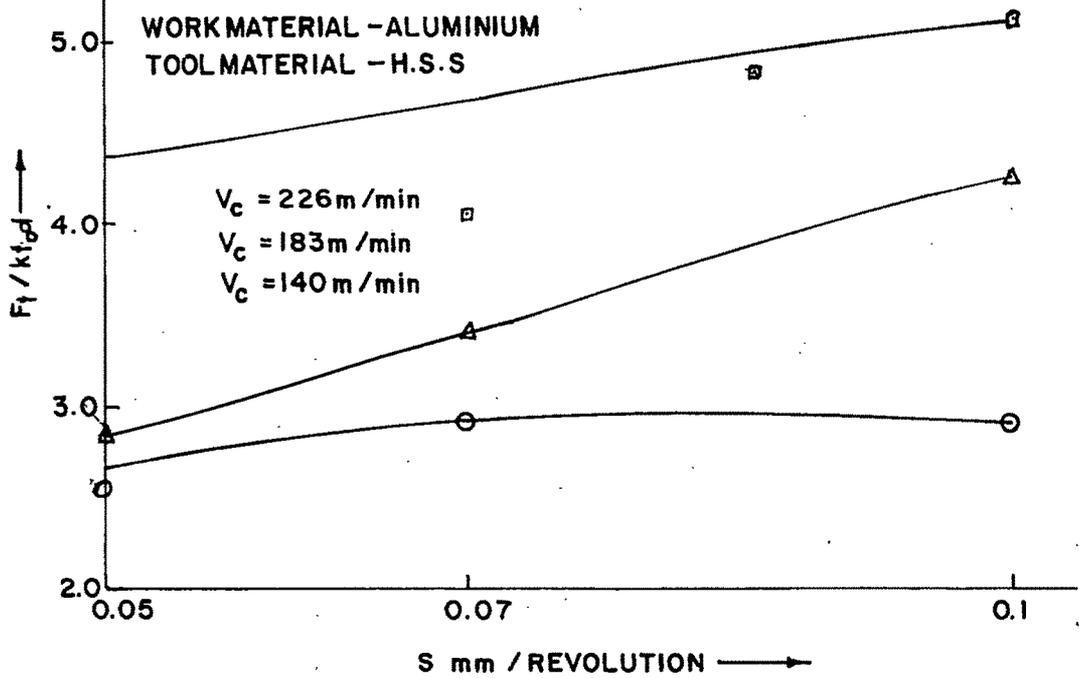


FIG.8.6 VARIATION OF THRUST FORCE WITH FEED (ALUMINIUM)

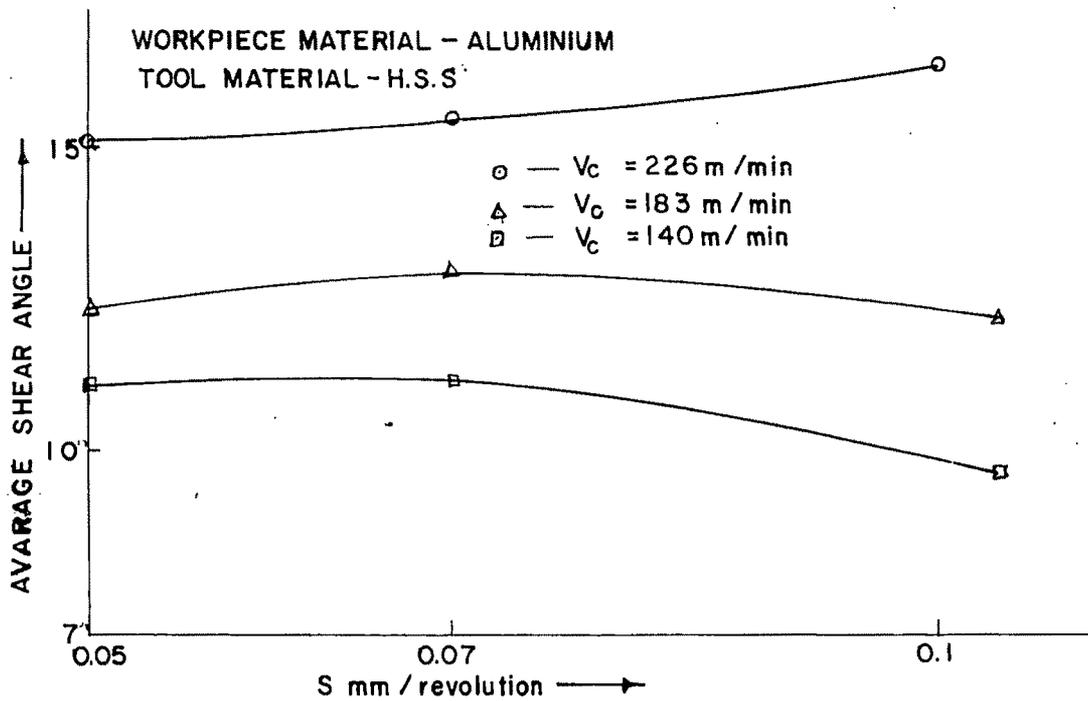


FIG. 8.7 VARIATION OF AVERAGE SHEAR ANGLE WITH FEED (ALUMINIUM)

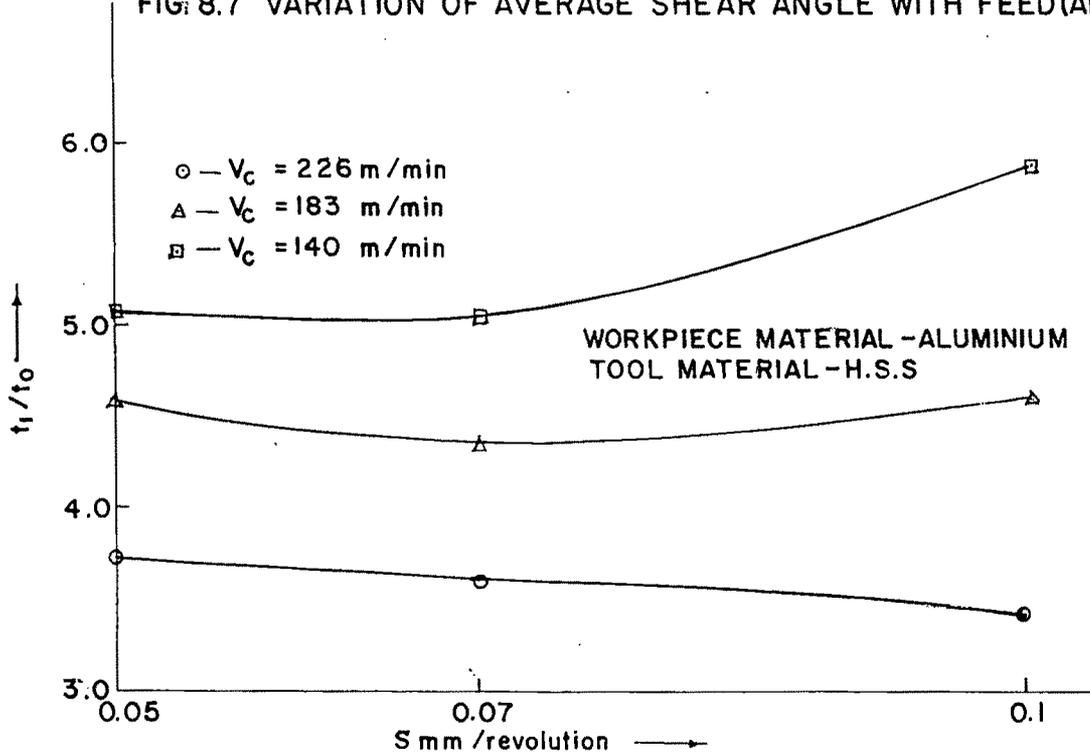


FIG. 8.8 VARIATION OF CUTTING RATIO WITH FEED (ALUMINIUM)

WORKPIECE MATERIAL - MILD STEEL
 TOOL MATERIAL - H.S.S'

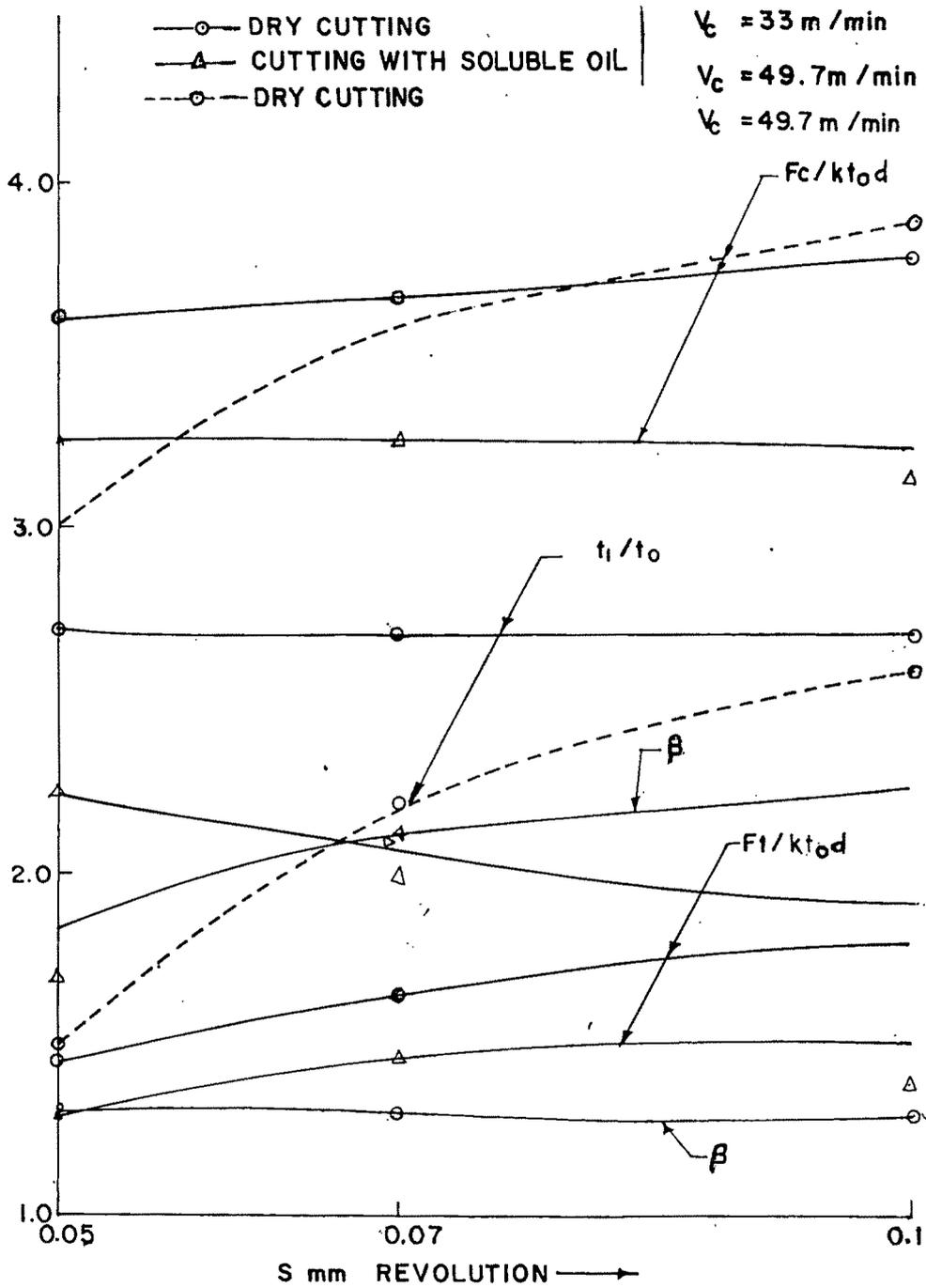


FIG.8.9 VARIATION OF MACHINING PARAMETERS WITH FEED

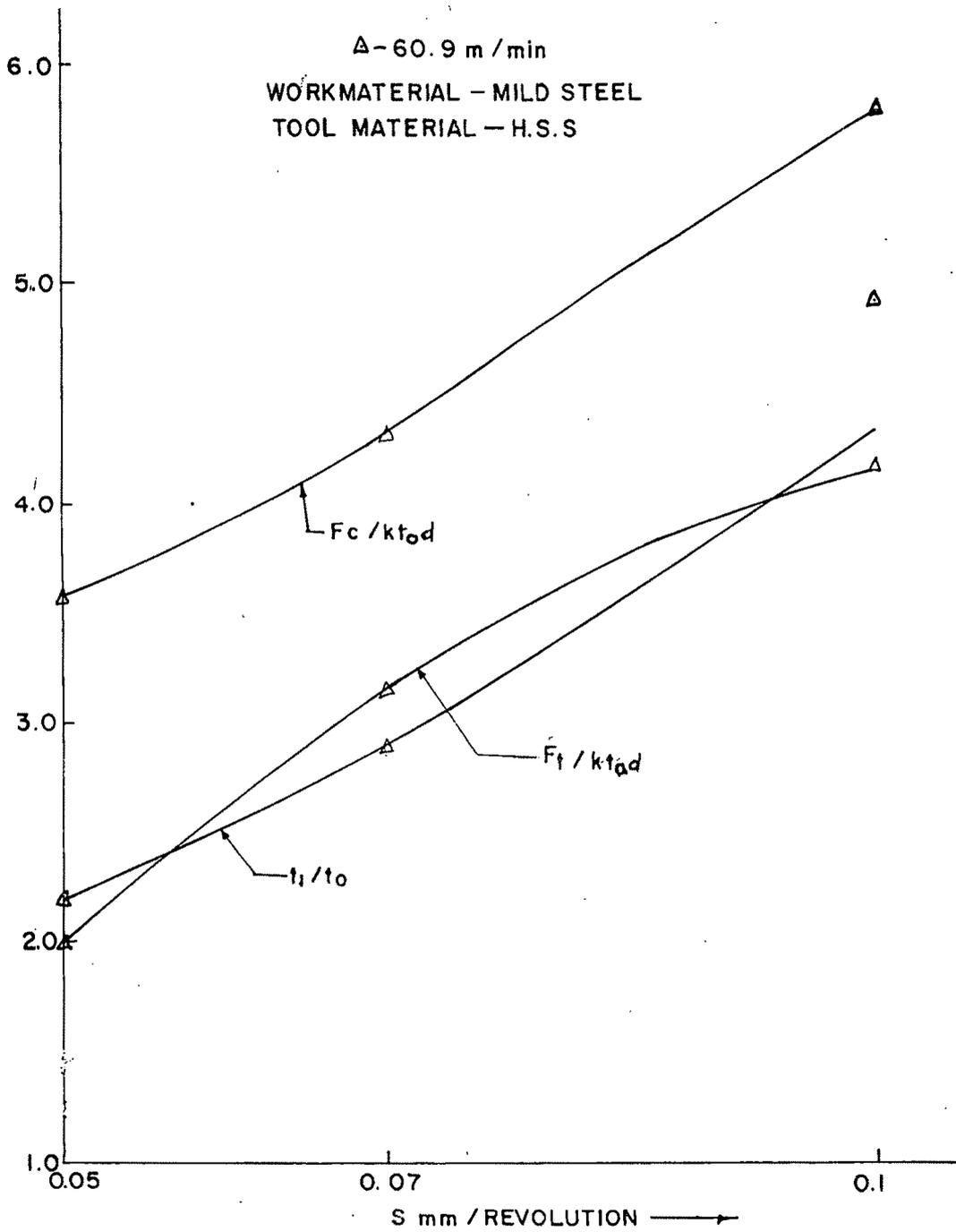


FIG.8.10 VARIATION OF MACHINING PARAMETERS WITH FEED

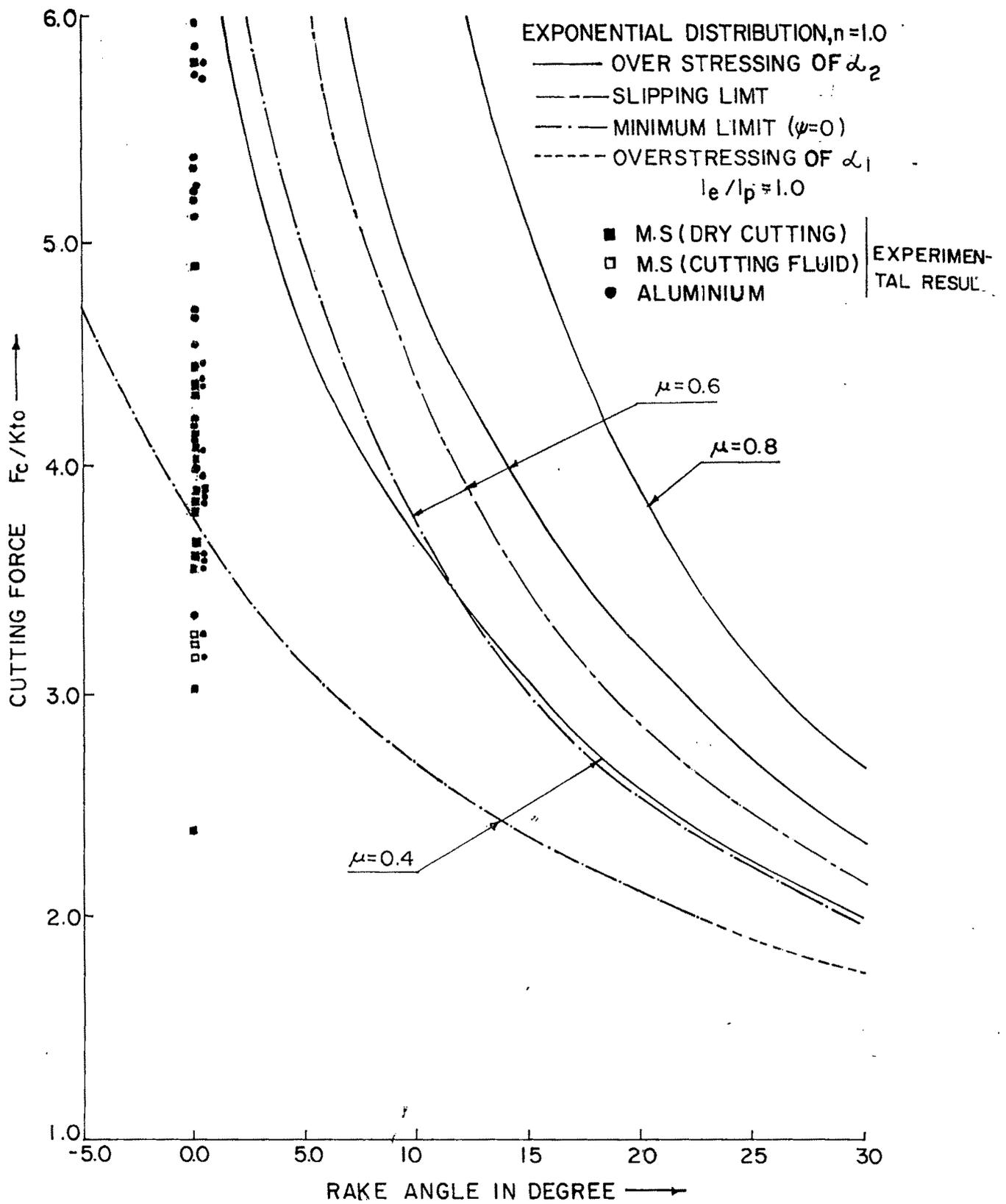


FIG.8.II COMPARISON BETWEEN EXPERIMENTAL AND COMPUTED RESULTS OF CUTTING FORCE

tool got burnt out at these speeds. For steel the tests were conducted dry (without coolant) and also in the presence of a coolant. Aluminium was machined with intermittent application of kerosene oil in the form of drops at the cutting zone to avoid seizure of the chips to the tool.

Referring to Fig. 8.5, Fig.8.6 and Fig.8.9, it may be seen that the normalised cutting force (F_c / kt_0) and thrust force (F_t / kt_0) decrease as cutting speed increases. The cutting ratio also decreases with increase in cutting speed (Fig.8.8). Average shear plane angle, however, is found to increase with increase in cutting speed. Cutting in the presence of a coolant significantly reduces the cutting forces as may be seen with reference to Fig.8.9. A reverse trend, however, was observed in cutting tests for steel performed at 60.9m/min (Fig.8.10).

It may be mentioned here that there is considerable scatter in the experimental results and this is due to the non-unique nature of the machining process. But the experimental results do lie within the limits predicted by slipline field solutions presented in chapter -VI (Fig.8.11- 8.13).

In Fig. 8.14 the experimentally measured contact lengths are compared with those computed from the theoretical analysis. The comparison in this case however is not found to be very satisfactory. This is because the contact length measurement from the adhesion mark left by the chip was extremely difficult and measurement could be made only in very limited number of cases.

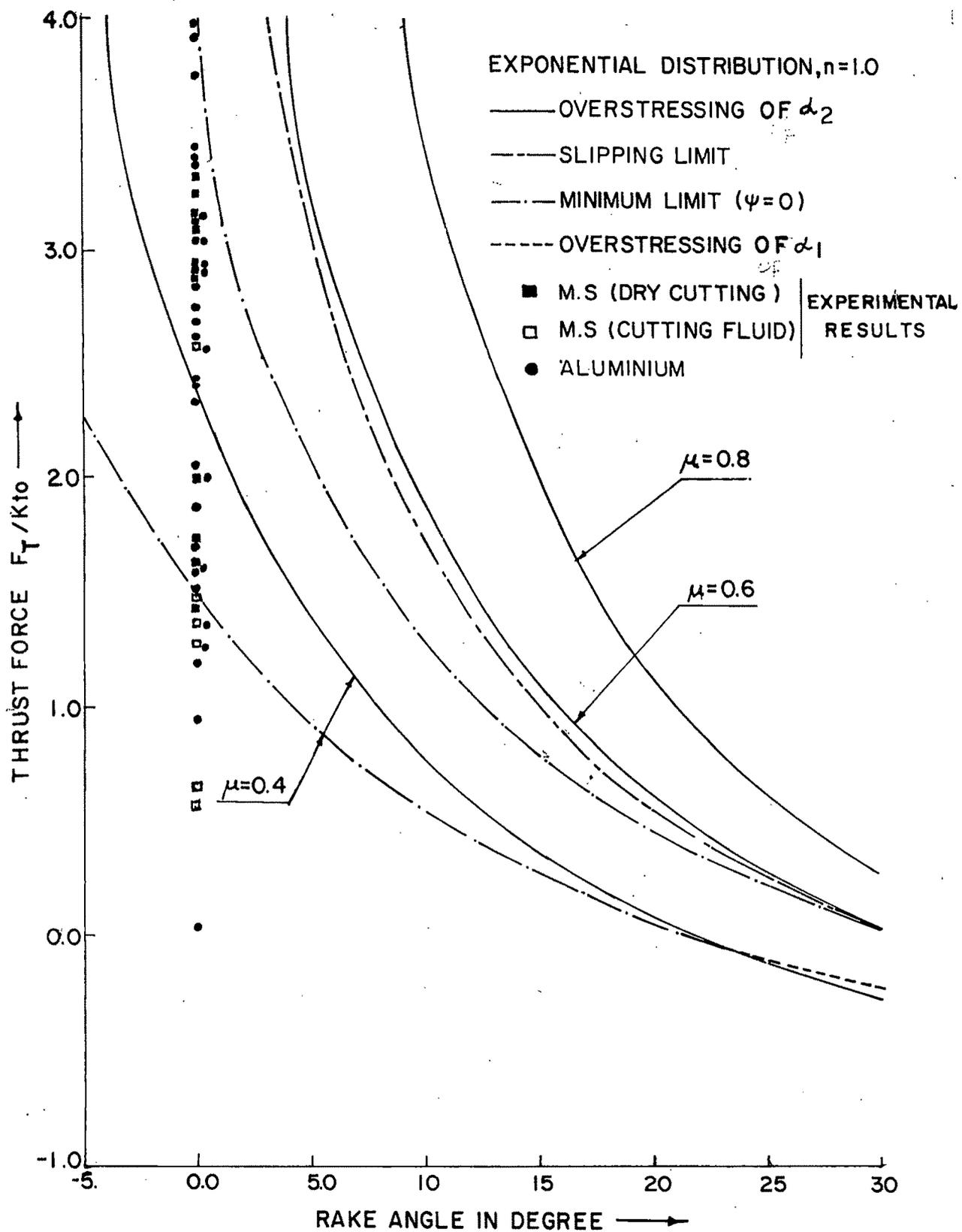


FIG.8.12 COMPARISON BETWEEN EXPERIMENTAL AND COMPUTED RESULTS OF THRUST FORCE

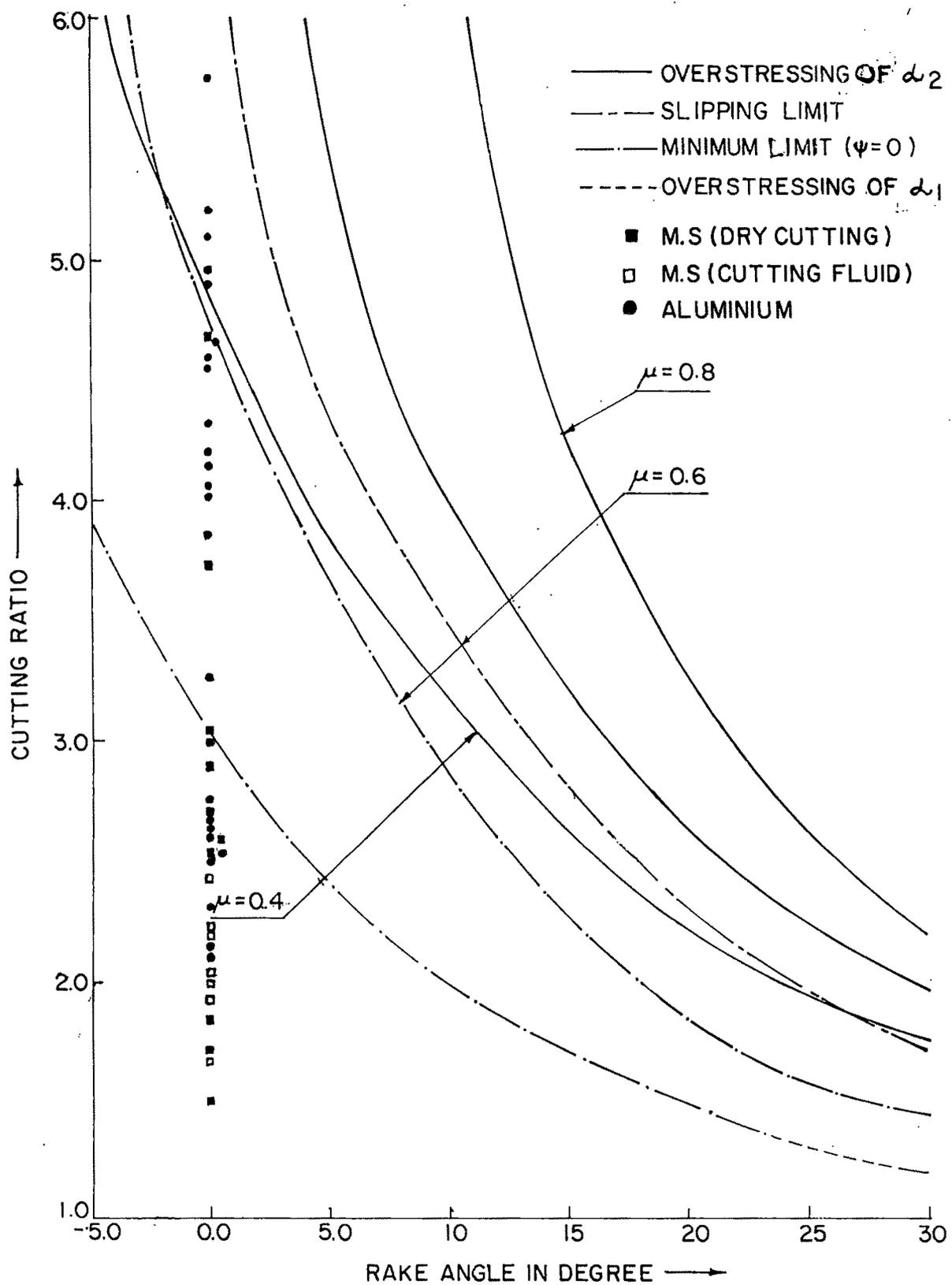


FIG. 8.13 COMPARISON BETWEEN EXPERIMENTAL AND COMPUTED RESULTS OF CUTTING RATIO

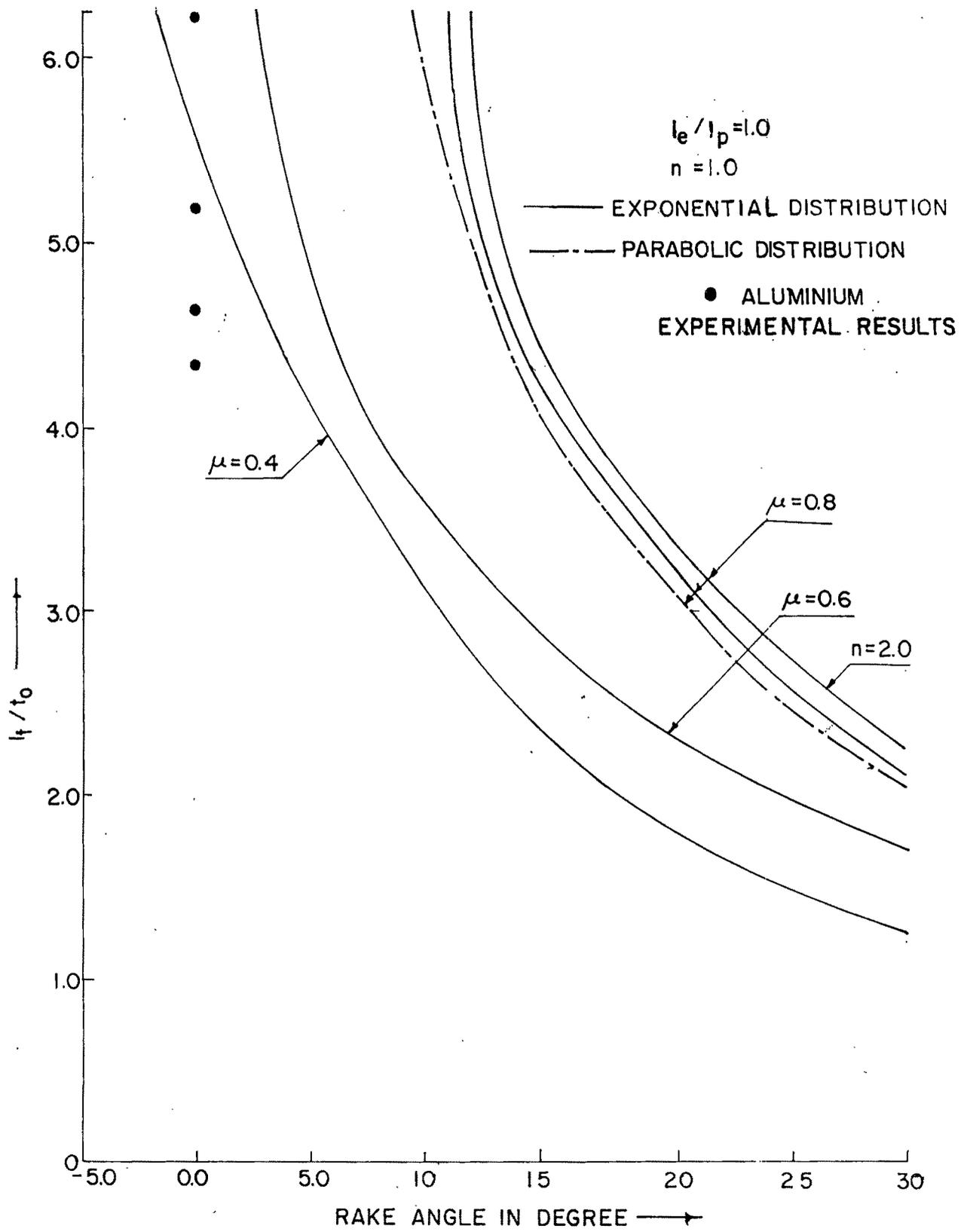


FIG.8.14 COMPARISON BETWEEN EXPERIMENTAL AND COMPUTED RESULTS OF CONTACT LENGTH.

8.5 Conclusion

The non-dimensional cutting force, thrust force and cutting ratio obtained from the experimental investigations lie within the limits computed from the slipline field solutions in Fig.6.1 and Fig.6.2 for μ values between 0.4 and 0.6. The agreement in respect of the contact length is not found to be good.

