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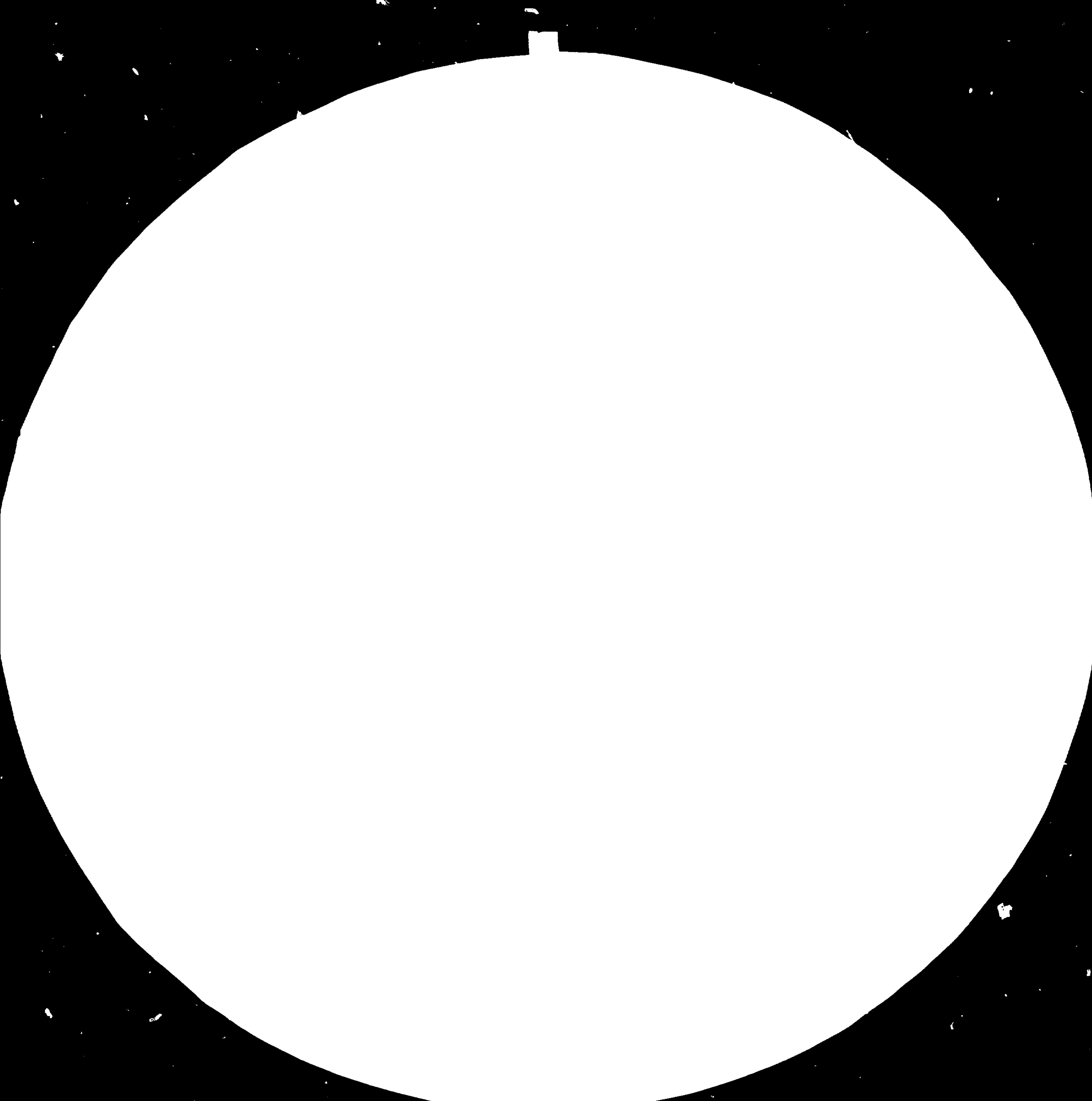

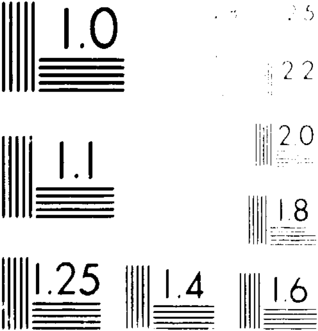
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Date: January 1983

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Project in Metal Cutting Technology
DP/CPR/79/021/11-02/31.9.B

China

INVESTIGATION INTO THE TESTING OF CUTTING TOOLS IN THE PEOPLE'S REPUBLIC OF CHINA

Terminal Report

by
C.J.Turpin
Expert of the United Nations Industrial Development Organisation acting as Executing Agency for the United Nations Development Programme.

ABSTRACT

This a brief summary of my report to the Chengdu Tool Research Institute as a contribution to the Chinese Peoples Republic Development DP/CPR/79/021/11-02/31.9.B to strengthen its cutting tool industry.

The work on cutting tool testing at the Tool Research Institute within an eight week period 24 August 1982 to 22 October 1982. The main objects were to appraise their test procedure and equipment, and to recommend improvements where necessary.

The main conclusions are that the present level of cutting tool testing requires more care in application and more detailed checking of carbide inserts before use. Also that there are serious limitations in instrumentation and capital test equipment. It is recommended to the Ministry of Machine Building that top priority be given to the capital investment required to purchase as soon as possible one C.N.C. test lathe with instrumentation equipment such as wattmeters and surface measuring equipment, followed by the purchase of a test milling machine and a gear shaping machine with appropriate instrumentation.

It is also recommended that further U.N.I.D.O. technical assistance be given towards the training of engineers at the Institute to give technical assistance to industry.

INDEX

INTRODUCTION

The project was instigated to help the Peoples Republic of China to strengthen its machinery building industry by improving quality of the tooling used to manufacture both machines and equipment. This necessitated visits to manufacturing industries in the instrument, machine tool and power generation machine companies to answer specific problems on the machining of components within the factories.

The purpose of this project also was to improve the setting up, organisation and operation of a machinability laboratory including the type of machine used for the tests and the instrumentation required to obtain results on the cutting tools tested. This required improvements in the equipment and methods used in the laboratory in addition to the requirements of more modern machines used for testing purposes.

Comparisons were made of the level of theoretical knowledge within the Institute, of cutting tool mathematical models from Australia America and Europe, and also of the latest developments in carbide coatings. Also talks were given on developments in other types of cutting tool areas such as Cubic Boron Nitride and Composite Diamonds.

Local personnel were included in the lectures and discussions also during the tests in the laboratory and for the necessary inspections made upon inserts before the tests commenced.

Lectures were given at the Institute on cutting tool theory and practice in addition to a seminar on current gear cutting techniques in the Western hemisphere.

Visits were made to various manufacturing companies including an instrument manufacturing company, a machine tool manufacturing

works and a factory engaged in the manufacture of hydraulic pumps and electric motors. Discussions were held subsequent to the visits where technical queries were answered and practical advice given. There was however one big problem in the technical advice given, in that a longer period ought to be spent within each company visited to gain more relavent facts and to obtain results on feedback to the technical advice given.
The second problem met with the advisory post was the language barrier. The Institute did marvellous work in supplying translators but it was often difficult to get technical points explained well from both sides.

A visit to U.K. was suggested in order to see how research and educational establishments operated in England (see Appendix C).

A list of personnel contacted can be seen in Appendix G.

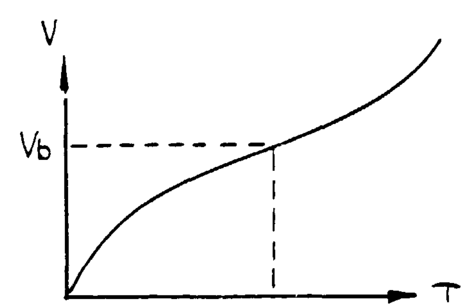
I. REPORT ON VISIT TO CHENGDU CUTTING TOOL RESEARCH INSTITUTE

A. Cutting Tool Test Procedure.

A test programme for at least six months into the future should be planned including all areas of testing (turning,hobbing,milling,copy turning). This means working through the list of materials currently in use in China and finding out the areas where tests are required,bearing in mind that some figures may be available from other sources. It is correct procedure to use inserts from a single source of supply as a standard from which all other inserts can be compared. This also means that Chinese inserts can be compared with each other and also with American and European types. This will also compare improvements in design and manufacture. These sort of tests should be done at regular intervals of a few months or whenever a change in manufacture occurs or the issue of a new grade of carbide.

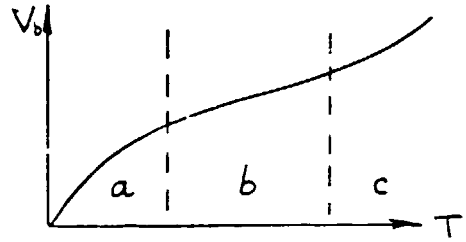
B. Tool Life Testing(carbide inserts).

I saw very few records of tests taken at the Institute,and the one test that I did watch gave reasonable values for the Taylor constant C and n when the test figures were used in Taylors formulae. I checked these figures and obtained similar values (see appendix A page 32&34). However I felt that the figure of Vb=0.3mm wear land was treated as a maximum figure and not as a mean. By this I suggest values should be taken well above 0.3mm so as the selected values of V1 T1 to V4 T4 used in Taylors criteria,obtained from the intersection of the Vb=0.3mm line, will be on the straight part of the graph e.g.



Also I would have prefered to have seen many more points plotted for wear land below the 0.3 intersection which would show the primary(a), secondary(b),and tietiary(c) wear of the insert under test,as shown on page 7

Vb = wear land, V= velocity, T= time.



This would also allow you to select various wear lands as your criteria depending upon the type of industrial use that the insert will be involved in.

For instance in Europe the values of wear land are plotted for four velocities with a standard insert SPUN 1203 12 and a selected standard feed and depth of cut. A wear time diagram is usually plotted for the different speeds and the wear criteria established at Vb=0.2mm finishing.

Vb=0.4mm roughing.

Kt=50um or 100um depending on operation.

A horizontal line on this graph then determines the wear criteria, and at the intersection of the velocity graphs, values of V1 T1 to V4 T4 are taken in the normal way. This system means that any wear criteria can be used to suit any Company or application and in this case the Taylor relationship is based on a 20 minute tool life rather than a 1 minute tool life which is sometimes used. The reason for this is that industrial users of carbide inserts are more concerned with a longer value of tool life where the tools may last for one shift or half a shift when all tools can be changed at the same time. Of course the number of minutes that the inserts are actually cutting may be only a small percentage of the total cycle time. There is also a further point with reference to your method of testing. In the particular test that I witnessed about 60% of the insert corners failed by chipping which suggests three things (1)job vibration (2) tool vibration or (3)wrong grade of carbide. I would not have used these figures until I had reduced the number of failures by some means. For instance the workpiece vibration was reduced by moving the tailstock as close as possible to the testpiece thus reducing the amount of overhang. The tightness of the chuck jaws were also checked. Again the tool vibration was reduced by limiting the number of packing pieces over and under the tool to one piece. This should have been the correct size to begin with.

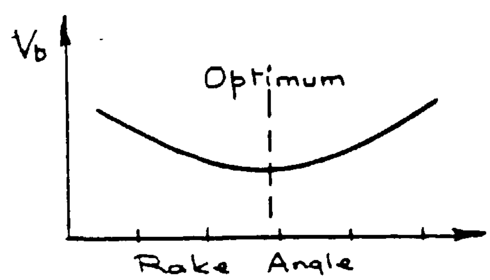
(Kt = crater depth)

The practice of having a deeper shank toolholder and dipensing with the packing altogether is even better practice. Also the toolholder should have minimum overhang even if it means using a right angle screwdriver to undo the insert clamp screw. The tool clamping screws in the tool turret were spaced too far apart allowing only half of the clamp screw to clamp the end of the toolholder. I suggested that as this was bad practice and a further screw should be placed midway between these two to facilitate better clamping and reduce vibration.
Finally I was not satified that the correct grade of carbide was being used as failure by chipping was high. As previously mentioned I would have rerun the test by either reducing the 4 velocities from 140,125,112,100 to 125,112,100 and 89mpmin because at 140mpmin there were 3 inserts chipped and only one at 100mpmin. However as there were still 3 chipped inserts(page 30) at 112mpmin which could not be explained so easily, I would suggest that the grade of carbide was too brittle. Now in ISO 513-1975 the various grades of carbide are listed and the ones used in the test was P15 and I would suggest selecting another grade which is tougher, say P20 or P25 at the original velocities of 100 to 140 m/min. It may be found that it is possible with the altered grade that the speeds can be increased to 157, 140,125 and 112. Conversely if the wear on the insert in the test had been too excessive then perhaps a harder grade (P10) could have been tried.

I cannot emphasize too strongly that vibration can ruin a test and checking of the shim and clamp condition is imperative. I could easily get a 0.05mm feeler gauge between the shim and the shim seat. This is bad practice. However I agree basically with your test and test sheet layout but I have included my sequence and layout for reference if required (Appendix A pages 24 - 35). I also feel that the checking of the insert before the test is of paramount importance. The slightest chip or malformed radius on the insert will give premature failure as will uneven surfaces on the insert seat. An incorrect nose radius will also influence the results. The first check on nine of your local made inserts resulted in four inserts having one fault,two inserts with two faults, and one insert had three faults. There was only one insert, that in my opinion, should have been used. I have designed a chart(Appendix A pages 26&27)that can be used for checking all the important dimensions of the tips and it is essential that all dimensions are within tolerance before the insert can be used. I also suggest that all four corners should be correct before each insert is used otherwise one reject corner, inadvertently used can ruin a whole test. The Japanese made inserts used for the one practical test that I saw, were quite reasonable. I did notice that the shape of your chipbreaker standard in China seemed to differ from western standards and I suggest that you take an epoxy resin replica to check the shape of these grooves.

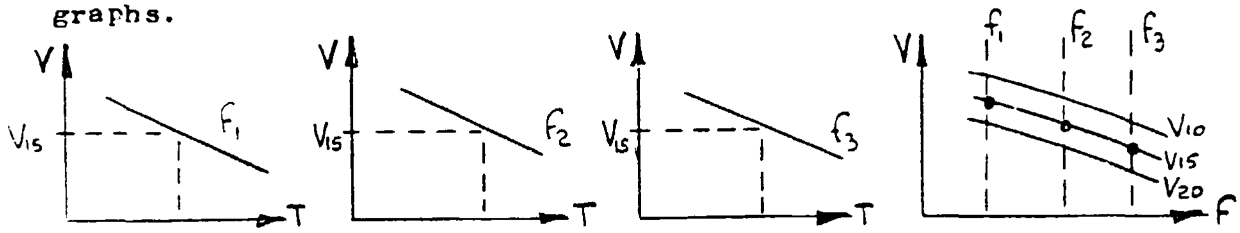
C. Other Tool Tests.

So far in this report only tungsten carbide inserts have been discussed but other tests on carbide brazed tips or High Speed Steel tools may be envisaged. Basically the procedure for checking the tool will be similar to checking an insert except perhaps a deeper look into thermal cracking in the case of brazed tipped tools and burned edges from grinding in the case of High Speed Steel (H.S.S.) tools. The first criterion is usually a test for optimum rake angle where an average speed is selected for the material and four tests can be run with four (or five) different cutting rakes. The tests are run for a predetermined length of time and the wear land values are then checked and a graph drawn to show the optimum value of the rake angle. Once this has been established the remainder of the tests can be run in the normal way with the exception that the value of Vb for H.S.S. should be about 0.60mm.



D. Taylor Equation Modifications.

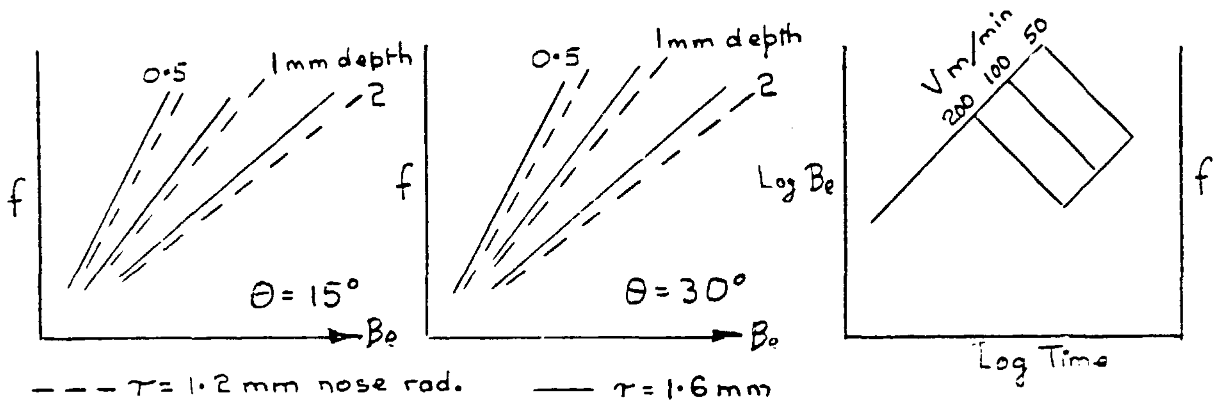
If the tests had continued I would have repeated the tests for two more feed rates, one above and one below the selected feed (f) and adjusted the constant values and drawn the appropriate graphs.



It should be understood that conditions in tests vary so much & Vb may be quite high before the linear part of the Vb versus time graph occurs or alternatively the linear portion may reach zero, but however this cannot be guessed. Sufficient values must be taken to ascertain this linear part and the mean level of the flank wear should therefor be greater than this. However the value of flank wear may have to be modified due to reasons of surface finish or tolerance requirements, so obviously with differing values of Vb, Taylors constant will vary. Also non linear Taylor plots can occur when machining thermal resistant materials or when machining at very **high** metal removal rates or exceptionally high tool life values, so care has to be excercised in extrapolating here. There are formulae (Kronenburg) for curve straightening in such cases, and also for the inclusion of feed and depth of cut to give the Extended Taylor equation $T=C_3 \,/\, V^{1/a} S^{1/b} d^{1/\gamma}$ where C_3, a, b, and γ are constants and S and d are feed and depth respectively, but unfortunately 15 tests are required to determine the constants. Perhaps the best known extension to Taylors equation is the $VT^n\,Be^m = \lambda$ where Be is the Equivalent Chip Thickness (not to be confused with the chip equivalent which is $1/_{Be}$). n, m and λ are constants. The term Be includes four parameters e.g. depth of cut (d), feed (f), approach angle (θ), and nose radius (r) and where

$$Be = \frac{fd}{\frac{d}{\cos\theta} - \frac{r\tan(90-\theta)}{2} + \frac{(90-\theta)\,r}{180}}$$

The proof of this in Appendix L. I feel that this is too comprehensive and time consuming to use at this stage although I am aware of one Company (De Beers Industrial Diamond Co.) in U.K. who closely follow this system. However the system explained simply is to evaluate tool lives for various equivalent chip thicknesses by varying feed rate and at various cutting speeds to enable the tool life equations to be represented in the form of a log Be/logT diagram.



See the paper by Yellowley.I. and Barrow.G. Fertigung No1 1971.

E. <u>Surface Finish and Power Tests</u>

Besides testing for tool life there are other parameters which are important to the cutting tool user. This depends upon the type of work produced by the industrial user and can include surface finish and specific power figures. I think these are important. The reduction in finish due to increase in the wear land of the cutting tool can be a criterion to tool removal in some cases. Alternatively for a given tool life T the velocity can be modified to give the required finish. Also specific power consumption is important because many shop floor machines in U.K. have been changed from High Speed Steel to carbide tooling without sufficient regard to rigidity, speeds,feeds and have underrated power for the use of carbide. This means that the machines are either running too slow or have irregular rotation, all of which is detrimental to the tool life.

F. Company Questionair and Liaison.

With reference to the type of information regarding the incorrect running of machines in your factories I was hoping to highlight by sending out questionair forms. I do realise that these forms are complicated and if sent by post there would be a certain reluctance to complete them due to the length of time required. However I do think that at least two staff should be employed to liaise with industry on these type of improvements. I have designed sheets for this purpose both for turning and milling (see Appendix F pages 46-50).If personnel employed for this work were engineers with many years practical shop floor experience behind them, I am sure improvements could be made if such consultative visits are attempted. This is a similar system to that which P.E.R.A. in U.K. employs in their Technical Assistance Department and the payment in their case is on a basis of project time spent with a Company. Also economic machining can be investigated whilst in a manufacturing Company either by the theoretical extension of the Taylors equation where optimum velocity

$V = C\left[\frac{H}{J}\left(\frac{n}{n-1}\right)\right]^{n}$ or optimum machining cost $H = \left(\frac{1-n}{n}\right) J \left(\frac{V}{C}\right)^{1/n}$

where V-velocity (m/min), H=machining cost per minute, J=tooling cost per minute (changing and grinding), C & n = Taylors constants, (see Appendix H). Alternatively practical tests can be run within the manufacturing company where variation of speeds and tool changing frequencies combined with factory costs applicable to the machine and labour can give the optimum speed at which to run the machine. (See layout in Appendix H).

G. Factory Visits.

The type of assistance that your industry requires was very noticeable when I visited some of your manufacturing companies. The reports are in Appendix B and it was quite clear that there are questions directly related to machining that the Institute could be involved in. For example some problems from Dong Fung

Electrical Machinery works at De Yang county.

(1) H.S.S. reamer design to efficiently ream split holes.

(2) Changeover from brazed tipped cutting tools to carbide inserts with relevant tests for efficiency and life.

(3) Tapping of bolt holes using collapsable taps.

(4) Tests on carbide bladed reamers (life comparison, economics, speeds, etc).

(5) The boring of water entry ducts in stainless steel, selection of correct feed, speed and grade of carbide to complete the machining of the duct without a tool change e.g. time of cut about 20 hours. A very difficult problem.

I have also attached a questionair(Appendix F page 50)to be sent to manufacturing companies asking for their views on the formation of various committees and their desire for seminars on specialised subjects and "in house" lectures on cutting technology.

H. Test Personnel.

The practical running of the cutting tool test was not to European standard. We do not use the same number of personnel. There were eight assistants on the workshop floor during your tests and I could not identify their function. All that is required for a test are a test leader and a technical assistant. The test leader's function is to direct the test, checking that insert material, speeds, feeds, depths and instrumentation are correct, and to take the values of the readings of power, tool forces, r.p.m., chip shape, surface finish and tool wear figures. The tool wear values can be made on site with a portable microscope with a measuring graticule and the surface finish readings by a portable instrument which has a hand held probe or a probe which can be placed onto the stationary surface of the test piece and oscillated mechanically over the surface.

The technical assistant will operate the machine tool and time the length of cut. The assistant should be protected from the flying swarf with overalls and safety glasses and it would be much safer to have a transparent shatterproof screen attached to the machine. The test leader would also be responsible for the results calculation and graphs, whereas the assistant's main duty is machine and cut supervision.

I. Test Sequence and Times.

Working on the assumption that a test piece is ϕ200x600mm long and that four tests are required at four different velocities. Each velocity will require a figure of at least 5,10,15,20 minutes and if run as separate inserts, the total cutting time will be $(5+10+15+20)\times 4 = 3.3$hrs. Now assuming 16 stops for checking at say 3/4 hour and 2 hours for setting up, clearing away by the assistant and for calculations by the test leader, each test should take 17.3 hours. Considering a 7 hour working day, each test would take 2.5 days to complete. Alternatively however, working on the assumption that the 4 figures e.g. 5+10+15+20 minutes are cumulative, the total cutting time for 4 tests are

20 minutes x 4 = 80 minutes = 1.33 hours. Assuming all the other times are identical the total time for each test should be 1.33 + 16x3/4+2 = 15.33 which for a 7 hour day = 2.2 days. Your test programme will include testing of some of the 600 different material specifications used in your country. These are divided into 30 groups of 20. If I assume that there are 15 main groups that you are immediately interested in and you would, on a average, test 7 specifications from each group then the total number of tests would be 105. This would take (based on a 6 day working week):

$\frac{105}{6}$ x2.5 days = 43.75 weeks; or $\frac{105}{6}$ x2.2 days = 38.5 weeks

to complete. (3/4 year)

The choice of which specification to test is difficult, there are 2 ways to approach this. Firstly find out from manufacturing sources the main ferrous materials used in their machining areas. Secondly obtain figures of sales from ferrous material supplies which indicate the highest bar stock sales to industry.

If however the decision has to come from the Institute about which ferrous materials to test, then a reasonable sequence based upon U.K. usage is as follows:

1) Low C; steels
2) Medium C; steels
3) High C; steels
4) Low alloy steels - alloying elements $< 5\%$
5) High alloy steel - alloying elements $> 5\%$
6) Extra hard steels;
7) Stainless steels;
8) Malleable cast iron;
9) Grey cast iron;
10) Heat resistant steels.

and then possibly commence on the non-ferrous groups such as Aluminium and Copper Alloys.

A suggestion on how to manually file the data until a computorised data storage system can be utilised is shown in Appendix E.

J. Comments on Theoretical Work.

During the discussion with the staff of the Institute I found the theoretical approach to cutting tool theory was in no way inferior to the level expected in Europe. They were well aware of Western expertise and of local requirements in China. I was impressed with the level of work on Aluminium High Speed Steel metallurgy for cutting tools and also on the amount of work that was involved in the publication "TO COMPARE AND INVESTIGATE THE PROPERTIES OF FOREIGN AND CHINESE INDEXABLE INSERTS" where the properties, shapes and performance of Chinese, German and Swedish tips were compared. This comparison has to be made at frequent intervals to determine the improvements in Chinese manufacture and compare with other countries products and improved techniques. Also they are well aware (as we are in the Western world) of the work of Oxley and Palmer, Lee and Schaffer, G.Burrow (UMIST) and possibly more aquainted than us with some of the Russian technical papers (Zollif). I was impressed also with the work on notch wear and feel that this knowledge should produce technical papers for international seminars worldwide. The system is to send a summary of a paper before hand for a proposed seminar and then one is notified of its acceptance or not. I would have been quite ᵗ ᐨy to have given a demonstration of the practical proof of Mᶜ Analysis in the laboratory but I do appreciate that there ·ner more demanding work to be done. It does not take long in our laboratory as we have a computer programme to determine the unknown forces and angles and shortly we hope to add to our practical tests of theoretical models. (Merchants Analysis Appendix K)

K. Workshop and Laboratory Comments.

I was impressed with the workshop area and its cleanliness and also with some of the test machines. (see Appendix J.)

1. Test Lathe.

This machine is an old model but in quite good condition.

The motor is reasonably powerful for tests and has an infinitely variable speed. There is no instrumentation on the machine and the wattmeter and rev-counter did not work too well. The power was taken from one leg of the three phase supply which is bad practice as the three phases can have different power values, also the tong test ampmeter needle was not damped making it difficult to read. It is important to obtain a wattmeter where the current and voltage in the three legs are read every second and the output averaged before the power is computed. A quotation in England for such an instrument should be about 2000/5000Yuan. The power can also be obtained from a dynamometer and serves as a check but a wattmeter included in a machine is very easy and convenient to use.

I agree with the system of calibrating a strain gauge type lathe dynamometer and the only point I would make here is to calibrate the instrument with the same cutting tool as is used in the lathe because tool shank material and section can vary. I have already mentioned guarding and rigidity of the machine. I also feel that this lathe could be replaced with a modern lathe and the decision has to be made wether to purchase a production lathe or a laboratory lathe. If tests are to be run in conjunction with industrial projects for manufacturing companies using their components with a view to confirming tool layouts, tool lives, economic machining conditions in addition to the normal cutting tool tests, then the ideal machine is a production lathe similar to the NDM40 made by George Fisher Ltd, Schaffhousen, Switzerland. Quote No. G953-55 of September 1982. This a numerically controlled machine with a multi tool turret where tests can be programmed with six tools in the indexable turret so as once the programme has finished six figures of wear land can be checked for six different speeds over a certain predetermined time. If the six inserts are then changed and the programme is set to a different time schedule then the 2nd test is being performed during the time of checking the first set of insert wear lands. This saves time but suffers from the fact that times and wear figures are not taken from the

(3.3 Yuan = £1)

same insert. Conversely, six different time schedules can be set on the six turret stations at one speed to give the values for the first time v wear land graph. I would advise keeping the older machine for a period in case some extra tests have to be made while the new production machine is being used. Also check upon the electrical capacity and floor loading in the workshop. Also make sure of the correct demonstration procedure from the company before hand.

Breakdown of quotation for George Fisher lathes, quotation No. 6953-55 of 15 September 1982.

Item	NDM16	NDM25	NDM40
1-maximum dia mm	160	250	400
2-turning length mm	500	500	500
		1000	1000
		1500	1500
3-main power Kw	20	30*	50*
		22	30
4-speed range R.P.M.	15 to	45 to	45 to
	4000	3200*	3200
		160 to	10 to
		4000	2500*
5-tool shank section mm	20x20	25x25	25x32
6-bearing size i/d mm	100	130*	
		110	
7-R.P.M. stability	± 2%	± 2%	± 2%
8-coolant flow 1/min	15	15	15

C.N.C. Siemens sinumeric 6T or G.E. Mark Century 105HL with canned cycles and tool radius offsets. There is no need for N.C. positions tailstock or hydraulic chucking.

* denotes the heavy duty spindle which should be considered.

N.B. Ascertain that the power input to the workshop is adequate and that the floor loading can accept 12000 Kg. Also state clearly your voltage and phase for the electric motors.

Lathe NDM40 is the best choice.

Costs of quotation for George Fisher lathe, quotation No. 6953-55 of 15 September 1982.

Item	Cost Sw franks	Y
1) 1-053-21 NDM40/100 NC lathe	390 000	
2) 1-128-38 tailstock	24 500	
3) 1-132-60 coolant	2 150	
4) 1-153-24 tailstock centre	260	
5) 1-169-35 height setting gauge	760	
6) 1-S713-58 Valenite power monitor	10 500	
7) 1-F042-15 basic version Sinumeric 6T with options	58 400	
8) 1-170-81 programme typer	47 950	
9) 1-F-170-021&022 recommended equipment	2 290	
10) 1-F742-22/70 spare parts)		
11) 1-F742-67 " ")	29 340	
12) 1-F742-64 " ")		
13) Seaworthy packing	7 100	
Transport	4 300	
	577 590	

However if you do not expect to run any production type tests or simulate industrial conditions then a laboratory turning lathe such as a Boehringer DM550 with a constant cutting speed facility will be suitable. A similar machine to this is used by De Beers Diamond Co. and a quotation has been requested from Boehringer. The important points to consider when applying for a quotation are:-

1) Headstock centre height from bed 300mm+
2) Main motor capacity 25Kw+
3) Electric power 3 Phase 380 volts
   lighting 1 Phase 220 volts
4) Main drive to headstock to be infinitely variable
5) Speed reading on headstock output (tachometer)
6) Kilowatt meter to register input power
7) C.N.C. added to allow programming of test runs

If this type of machine is purchased then it can completely replace this existing test lathe. A quotation was obtained from Dean Smith & Grace for a lathe similar to the machine used at Kingston Polytechnic for laboratiry tests but apparently this model (type 18) has been discontinued and model 2415 (quote No. HC/JE/T27305 of 30 September 1982) does not have the infinitely variable speed facility and therefor is not suitable.

2. <u>Test Milling Machine</u>.

The milling machine in the workshop has a sufficient large capacity motor (11kw) to conduct single blade or double blade milling tests. It is not necessary when using an inserted blade or indexable throw away tip cutter to completely fill each blade slot as the wear land characteristics can be identified on just one blade (or two blades for equal balancing purposes). The feed rate must be adjusted so as the feed per tooth on one blade is the same as that which would be on the remainder,if all the cutter blades were inserted. So for example if a 20 bladed cutter were to be used with a feed per tooth of 0.25mm, then with all blades inserted would be 20x0.25=5mm per revolution and with only one blade inserted would be 1x0.25mm per revolution,. or with two blades it would be 2x025mm=0.5/rev. The wear land and notch wear will be identical for the one tooth as for a 20 tooth cutter but the power used will be within the range of the existing machine. Also a cutter body can be made in the workshop with just one seat for cheapness and quickness. I feel that the need for another milling machine is of second importance to that of a lathe and need not be considered until at least 12 months later.

The Kistler dynaometer No. 9257A and charge amplifyer 5006 is an excellent choice and we use their equipment regularly. This can be used for calculating power requirements from the milling forces bearing in mind that a model will have to be made to convert the single (or double) insert forces into a figure representative of a completely bladed cutter. When a new machine is considered the inclusion of C.N.C. is not so important as tests can not be programmed in the same way as turning. Also bear in mind that workshop tests can always be confirmed by taking further tests in the factory under production conditions. I will send information on a suitable machine if requested.

3. Test Copy Lathe.

This machine can only be used effectively for specialised copying inserts tests and thus is rather limited in application. However, it is worth keeping if there is a possibility of development work on the proving of templates for specialised components.

4. Test Hobbing Machines.

This is an excellent machine for testing the hob life on HSS and carbide hobs, especially as it has a hob shift device incorporated into the head.

Hob shift mechanisms are fitted as standard in U.K. to even out hob wear and the standard figure used on con inuous hob shift is 0.0005mm per revolution of hob. Standard wear land figure in U.K. automative industry for HSS hobs is 0.75mm. (Seminar App. D.)

5. Test Gear Shaping Machine.

There is no suitable gear shaper in the test laboratory and I feel such a machine should be considered in the long term. Factory tests in U.K. are based upon using the highest speed for the cutter oscillation to give a 4 hour or 8 hour life e.g. one shift or half a shift. There is also development work upon single cut finishing, which means a set of roughing and finishing teeth each on half the cutter and the component is completed in one revolution of the cutter.

Considering workshop and laboratory equipment:

Short term purchase:

Test lathe, wattmeter, portable surface finish testing equipment:

Long term purchase:

Test milling machine, test gear shaping machine.

II APPENDICES

Appendix A.

Test procedure for turning tools

1. Establish the conditions required in the test and enter onto the test data sheet
2. Inspect the insert for condition and dimensional accuracy and complete the tip data sheet.
3. Check toolholder for flatness of the insert seat(shim) within 0.01mm and for cleanliness.Also check toolholder for flatness under the shank within 0.1mm.Also make sure that the shim is not damaged especially on the working corner.The insert,when fitted,should not protrude more than 0.3mm over the support face. Keep the tool overhang to a minimum.
4. Check the machine for cleanliness and good condition.also check the lubricating oil levels and correct clutch operation.make certain that the wattmeter,tachometer and dynamometer (if required) are fitted and working.Attach guard to machine to prevent damage by flying chips.
5. Place billet of test material to be machined between the chuck the tailstock making sure that there is no runout at the chuck end which may cause vibration.
6. Take a roughing cut across the billet of test material with a spare tool to remove the scale.
7. Set the spindle speed comensurate with the selected velocity. Set the depth of cut and feed per revolution .Start the spindle and check the wattmeter and tachometer readings.Also check the zero settings on the dynamometer (if it is connected). Enter these readings onto the test data sheet.
8. Start the clock and commence cutting.Check wattmeter reading and enter into test data sheet.
9. Remove cut whilst running at about halfway along the billet and stop the machine and the clock.Check the wearland on the insert and enter onto the test data sheet,also time of cutting and the value of the surface finish reading.
10. Replace the insert and restart cut and the clock.Continne to the end of the billet.Stop machine and clock.Check insert wear land value again and also surface finish value and enter onto the test data sheet.
11. Repeat 7,8,9 & 10 until a wearland of 0.3mm or over is reached. Note that at each new diameter the speed of the spindle must be

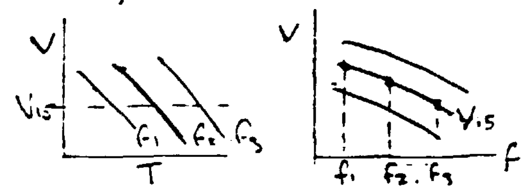
in the ratio of 1;1.12:1.25: and 1.4 and adjusted to give the designed velocity as in 7.Again note the reduction in surface finish.

12.Repeat the previous tests 7,8,9,10 & 11,endeavouring to get tool life figure between 5mins and 20mins although this is not too important.Four tests are required.Values onto test data sheet.

13.Draw a graph of wear (y) versus time (x)for the four velocities and draw a horizontal line at y=0.3mm wearland (or other pre-determined figure).

14.Select values of $V_1 T_1$, $V_2 T_2$, $V_3 T_3$, $V_4 T_4$ (and more if required) from this graph and enter these in the chart on the test data sheet.From the expression logV+nlogT = logC,find the straight law by linear regression or by graphical means and deduce values of "n" and"C".Put these values in the test data sheet,for evaluating tool lives.

15.If there is suficient time take VT figures at 3 different feed rates and plot feed comparison charts;- or evaluate the equivalent chip thickness (Be) and draw V-T-Be diagrams.



16.From the nett power figures and the value of the metal rem--oval rate in mm^3/sec,calculate the specific power consumption and to the test data sheet,add this figure.

17.From the surface finish values found at the various speed ranges,plot graph of surface finish (y) versus time (x) for V_1 , V_2 , V_3 & V_4 .Also plot the value of the theoretical optimum surface finish value (osfv).If the feed/rev $\leq$ 2rTanψ then osfv=f^2/8r where f=feed/rev.ψ= clearance angle.r=nose rad(mm)

18.It will assist the evaluation of different metallurgical specimens if one set of standard conditions(feed,depth,approach, noseradius,etc)is established as a basis to compare machinability. A suitable standard could be--feed 0.25mm/rev,depth 1.0mm,gradeP30. Insert code SNGA 15 06 and wear criteria 0.2mm finishing,0. 4mm roughing.The test is conducted asnormal test procedure.

Insert data check sheet.

Test no. ____________ Date ______________ File ______________

Insert code-

Grade -

check dimension	size	tol.	method	tip no.				
				1	2	3	4	5
1.Tolerance on inscribed circle diameter (width)-two sides."d"			project. or micr.					
2.Circle tangent to nose radius -four corners."m"			project- -or.					
3.Thickness "s".			micro- meter.					
4.Nose radius."r" -four corners.		∓0.1	project. microsc.					
5.Radius blend four corners.		< 5°	project.					
6.Angle tolerance four corners.		∓0.5°	project.					
7.Flatness tolerance		0.004	sur.fin. measure.					
8.Surface examination 10 magnification.Acceptability on all faces.			microsc- -ope.					
Overall acceptance.All factors must be yes.								

Yes=1 No=0

Signed. ______________ Date. ______________

INSERT DATA CHECK SHEET

Test No 1 Date 15 Sept 82 File ________

Insert code SNUB-12-04-08 JAPAN DIJET

Grade SRT (P15)

Check Dimension	Size	Tol.	Method	Tip No 1	2	3	4	5	6	7	8	9	10
1) Tolerance on inscribed circle diameter (width)--two sides. "d"	12.7	±0.13	project. or micr.	1	1	1	1						
2) Circle tangent to nose radius--all corners. "m"	2.6314	±0.2	projector	1	1	1	1						
3) Thickness "s"	4.76	±0.12	micro-meter	0	0	0	0						
4) Nose radius "r" --four corners	0.8	±0.1	project. or micr.	1	1	1	1						
5) Radius blend four corners		<5°	projector	1	1	1	1						
6) Angle tolerance four corners	90°	±0.5°	[illegible] ~~projector~~	^	1	1	1						
7) Flatness tolerance		0.004	DTI or ~~sup. fin measure.~~	1	Y	1	1						
8) Surface examination 10 magnification. Acceptability on all faces.			micros-ope	1	1	0	1						
Overall acceptance. All factors must be yes.													

Yes=1 No=0

Signed *[signature]* Date 15 September 1982

Test data check sheet.

Test no. ____________ Date. ____________ File. ____________

Material.

specification-

hardness-

Machine name-

Tool

maker- tradename-

type.HSS- carbide- ceramic- diamond-

blank.solid- butweld- brazed- insert-

coolant.yes- no-

finish.hand ground- machine ground- diamond lap-

chip br. groove angle- width- depth-

insert code-

HSS tool angle rake- clearance- approach-

Conditions.

depth(mm) feed/rev(mm/r) nose rad(mm).

Calculations-

velocity of cutting(V)= $\pi \times d(mm) \times rpm/1000$

specific power=power from cutting($p_2 - p_1$)/metal removal rate(mm^3/sec)

metal removal rate(mm^3/s) =feed(mm/rev) x depth(mm) x V x 1000/60

power from cutting(watts)=($p_2 - p_1$) or $\pi \times d \times f_c \times rpm/2000 \times 60$ (watts)

where d(mm)=uncut or original diameter

f_c(newtons)=dynamometer vertical force

watts = $\sqrt{3}$ VI x 0.78 power factor.

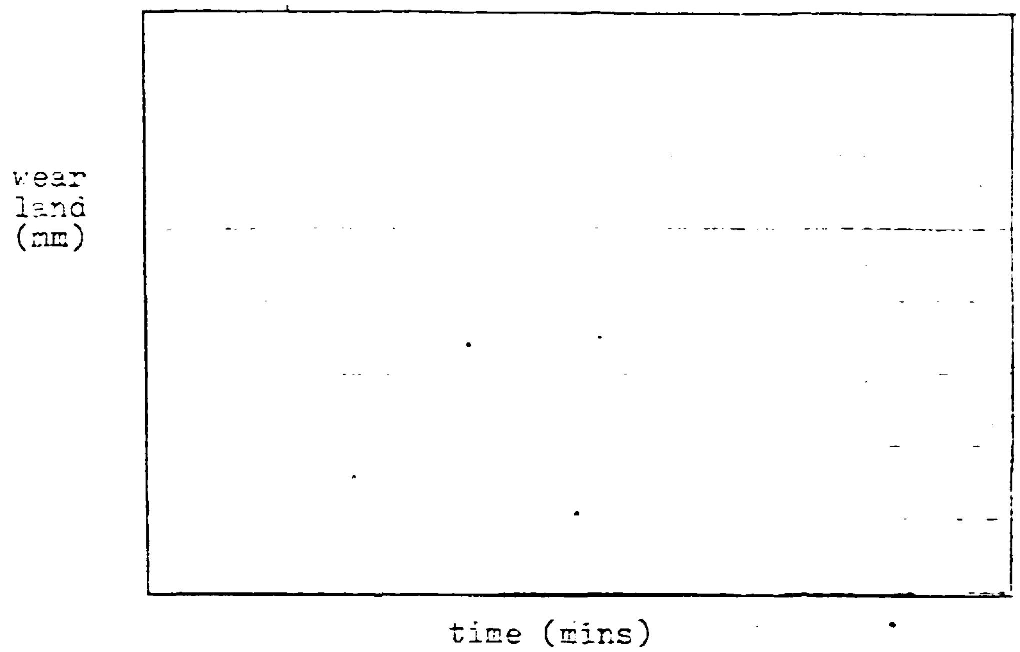
Test data check sheet

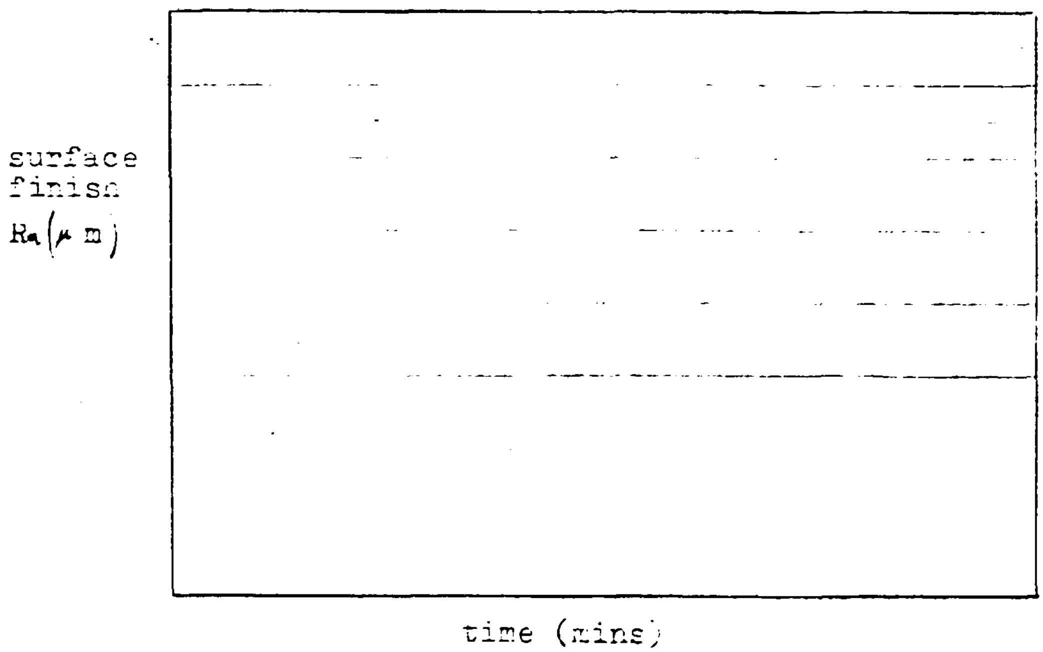
cut no.		cutting time (mins)	wear land (mm)	surface finish μ m	dynamo-meter reading newtons	total power P_2 during cutting	power from cutting $P_2 - P_1$	specific power watts/mm³/sec
V_1	1							
vel=	2							
rpm=	3							
mmr=	4							
nett	5							
power	6							
P_1 =	7							
	8							
V_2	1							
vel=	2							
rpm=	3							
mmr=	4							
nett	5							
power	6							
P_1 =	7							
	8							
V_3	1							
vel=	2							
rpm=	3							
mmr=	4							
nett	5							
power	6							
P_1 =	7							
	8							
V_4	1							
vel=	2							
rpm=	3							
mmr=	4							
nett	5							
power	6							
P_1 =	7							
	8							

Test data check sheet

cut no.		cutting time (mins)	wear land (mm)	surface finish μm	dynamo-meter reading newtons	total power P_2 during cutting	power from cutting $P_2 - P_1$	specific power watts/mm³/sec
V1	1	9.82	.324					
vel=140	2	9.03	Chipped			6839	895	0.693
rpm=	3	9.50	Chipped					
mmr=1400	4	8.07	Chipped					
nett	5							
power	6							
P_1 = 5944	7							
	8							
V2	1	15.00	.294			7288	637	0.637
vel=100	2	20.00	.329			7289	638	0.638
rpm=	3	40.00	.200	ignore		6533	118	0.118
mmr=1000	4	1.82	Chipped					
nett	5							
power	6							
P_1 = 6651	7							
ave	8							
V3	1	15.00	.321			7113	362	0.323
vel=112	2	16.50	Chipped			7569	818	0.730
rpm=	3	18.00	Chipped					
mmr=1120	4	15.00	Chipped					
nett	5							
power	6							
P_1 = 6751	7							
ave	8							
V4	1	14.07	.383			8032	277	0.225
vel=125	2	1.05	.299					
rpm=	3	12.08	Chipped					
mmr=1230	4	3.57	Chipped					
nett	5							
power	6							
P_1 = 7478	7							
	8							

Test data test check sheet.

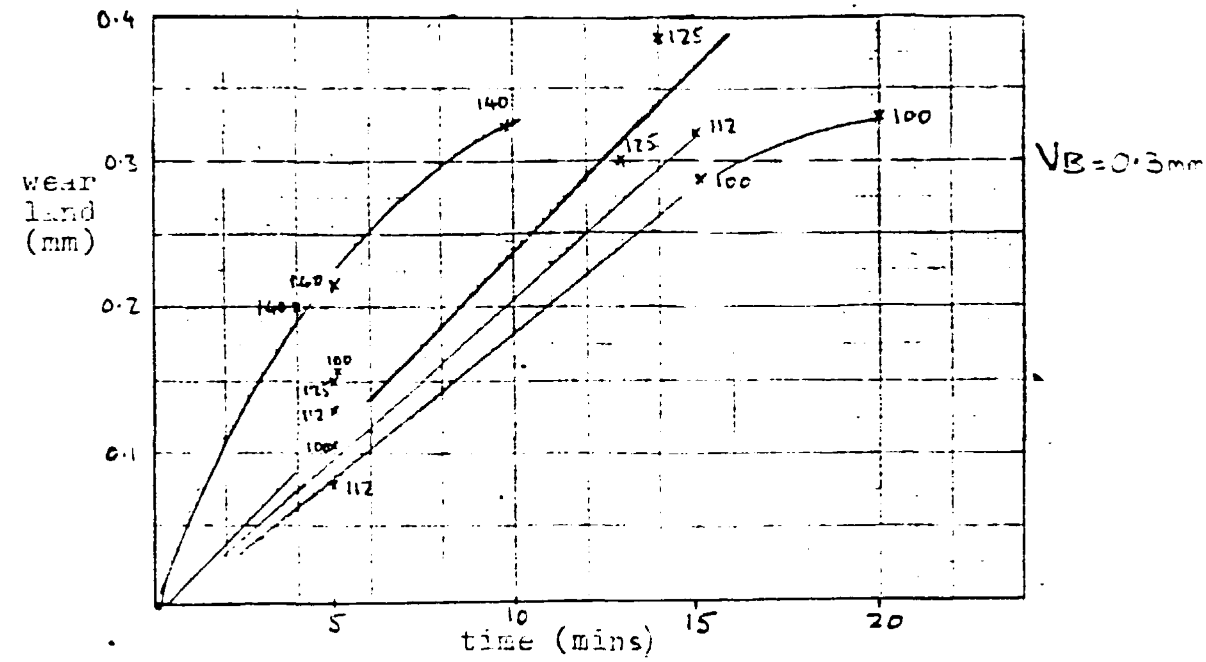


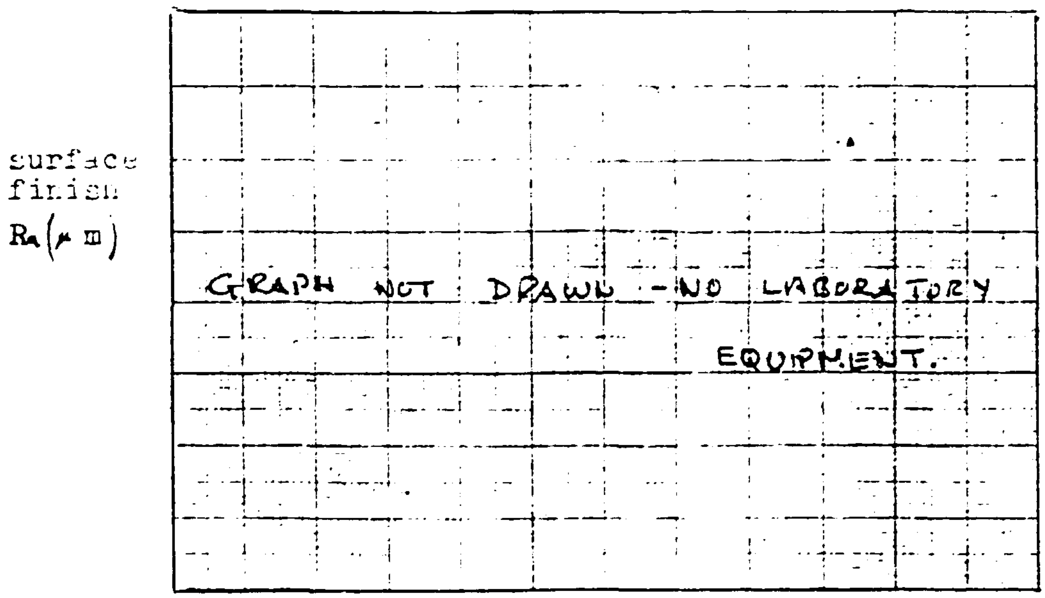


Theoretical optimum surface finish value=$f^2/8r$ (tosfv)
where f=feed/rev, r=nose radius(mm), ψ = clearance angle
and where the feed/rev $\leq 2r\tan\psi$.

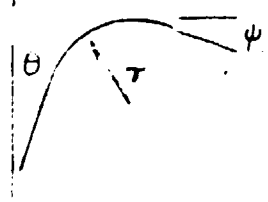
In inserts, approach=clearance.
For other tip forms the tosfv
must be recalculated.

Test data test check sheet





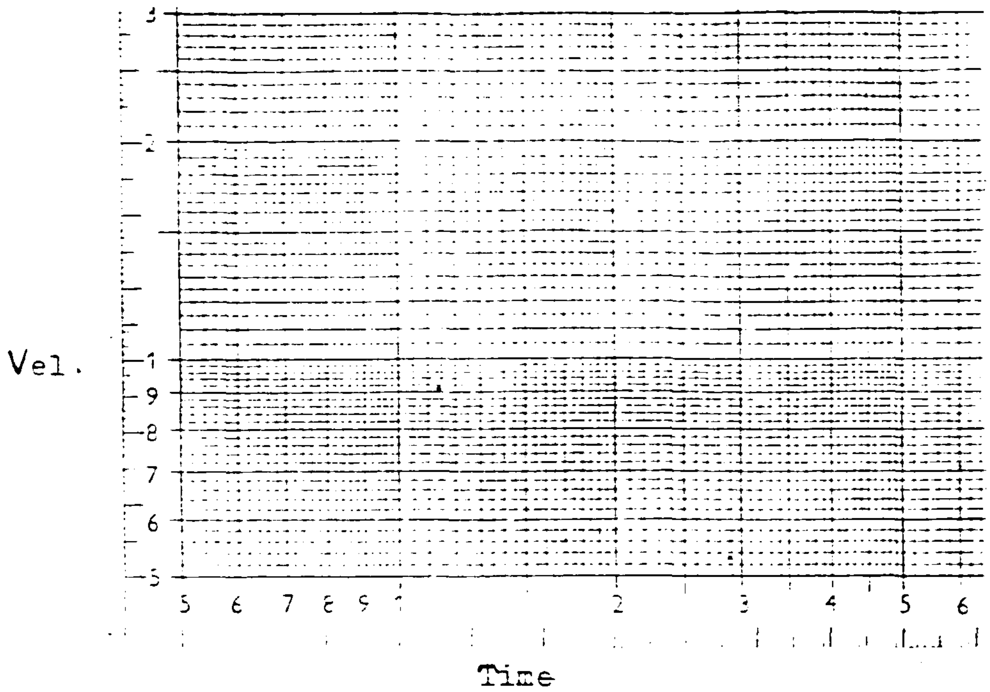
Theoretical optimum surface finish value $= f^2/8r$ (tosfv)
where f=feed/rev, r=nose radius(mm), ψ = clearance angle
and where the feed/rev < 2r tan ψ .



In inserts, approach=clearance.
For other tip forms the tosfv
must be recalculated.

$VT^n = C$

Test data check sheet.



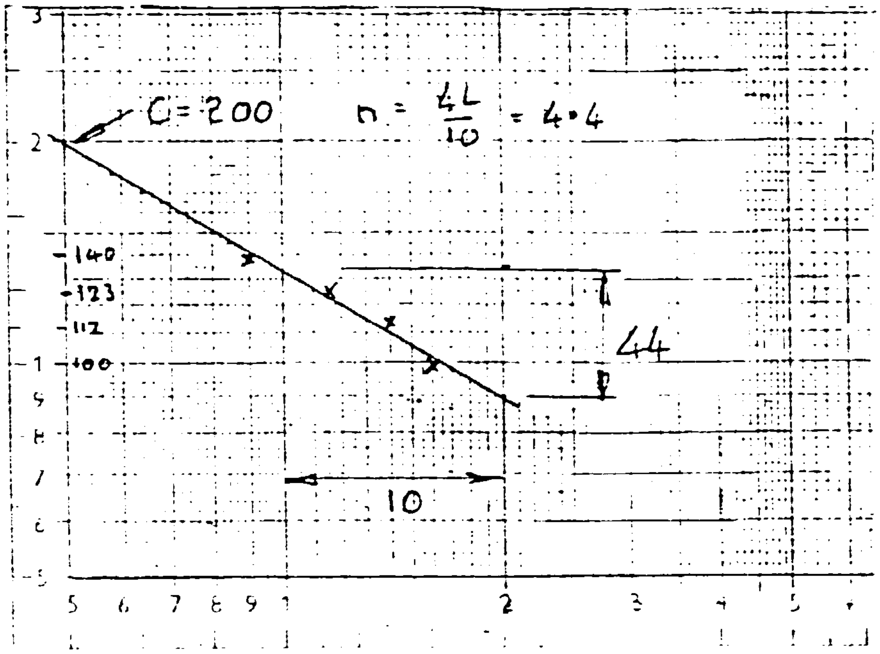
	V (m/min)	T (min)		
V_1 T_1				
V_2 T_2				
V_3 T_3				
V_4 T_4				
V_5 T_5				
V_6 T_6				
V_7 T_7				

Constants n = C =

$VT^n = C$

Test data check sheet.

V. 1.



Time

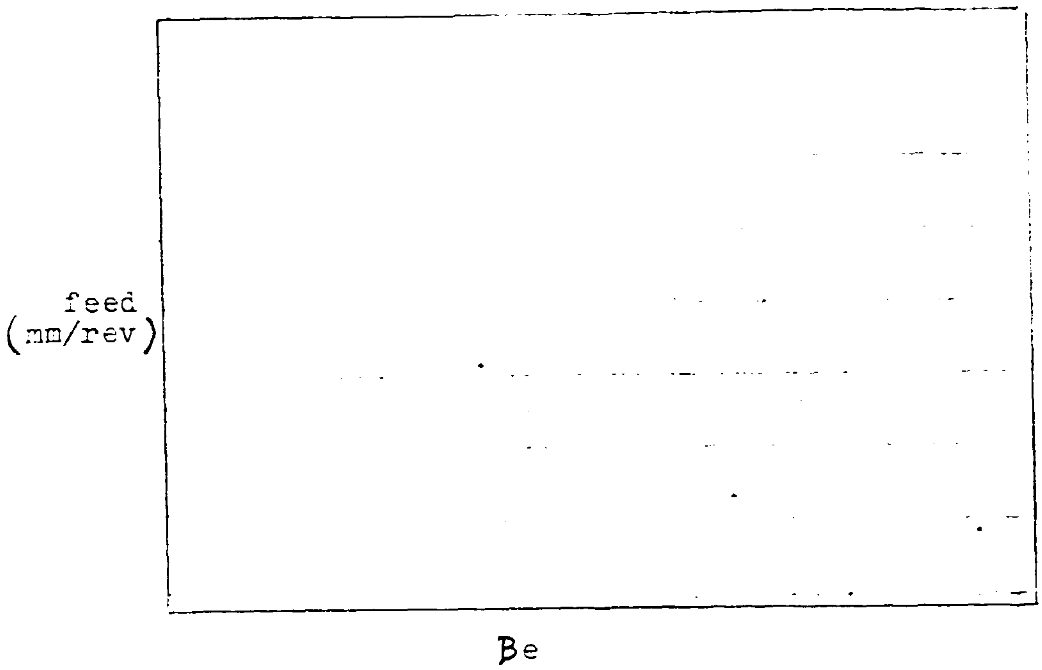
	V (m/min)	T (min)	VB.	
V_1 T_1	140	9	0·3	
V_2 T_2	125	12·2	0·3	
V_3 T_3	112	14	0·3	
V_4 T_4	100	16	0·3	
V_5 T_5				
V_6 T_6				
V_7 T_7				

Constants n = 4·4   C = 200

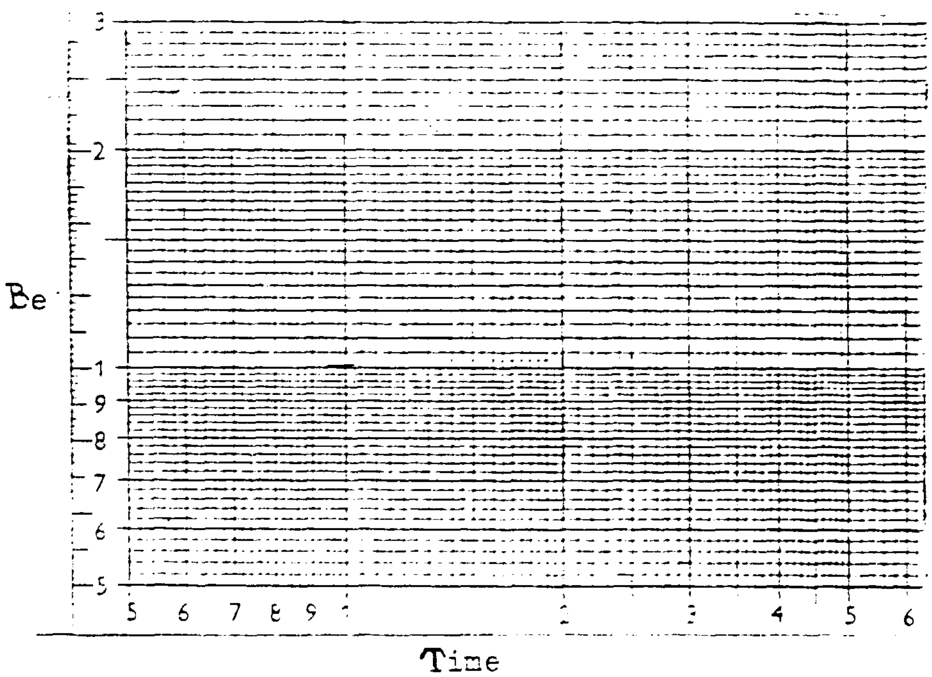
Institute calculations n = 4·3, C = 233

Test data test check sheet.

Feed-Be diagram



T-V-Be diagram



Corner radius-   Approach angle-

Chip equivalent thickness 'Be=

$$Be = \frac{fd}{\frac{d}{\cos\epsilon} - r\tan\frac{(90-\epsilon)}{2} + \pi r\frac{(90-\epsilon)}{180}}$$

Appendix B.

Report on a visit to Chuan Brand Instrument Company on 4 September 1982.

We arrived at 9.00am and were introduced to Mr. PAN DAUBEI Vice Director of factory, Mr. LI-YAGI head of administrive office and Mr. LUI-GUA-DING Director of measuring instrument research.

The factory was built in 1956 for the manufacture of drills (0.25mm to 60mm), dies, taps, milling cutters, reamers in High Speed Steel. The factory was in the same complex as the tool research institute and is responsible for the research institute's efficiency. Gauges, verniers, dial test indicators, slip gauges and electronic gauges are also made at the company. There is about 5,300 workforce and exports are made for France, U.S.A., Australia and S.E. Asia. They have been developing new products since 1979. The company uses university graduates where possible and have "in house" training schemes and special internal colleges.

The machines used are mainly Chinese, some being over twenty years old, but a replacement plan is in hand. The Government five year plan is to double output and purchase all equipment internally. The factory is now autonomous so better working conditions and more profit are expected.

When asked to comment I mentioned that up to date machines ought to be purchased to improve output and quality but more important was the need to improve handling time between machines and have continuous conveyor systems for the high volume lines, and a selective conveyor for the batch production. I suggested palletising with coded pallets that could be programmed to go to each machine relative to its machining requirements and be mechanically loaded to the machine. This a forerunner to a flexible machining system (F.M.G.) which is now new technology. I also mentioned the safety requirements needed on their press tools and that automatic press feeders on some of their press tools would assist both labour and safety.

We thanked our hosts for their hospitality and left at 12.00.

Report on a visit to Dong Fung Electrical Machinery Works at De Yang County on 10 October 1982.

Mr. Hofvenstam and I arrived at the factory ay 10.30am and were welcomed by ZHANG JIWU Vice Director and Vice Chief Engineer.
GUAN DUANXIN Vice Chief Engineer.
WAN GUILING Deputy Director of technological dept.
QIN ZEJUN Engineer.

The Company manufactures four classes of products:-
Hydroelectric generators 10 000 to 320 000 Kw.
Steam turbines.
AC and DC generators.

The Company has 6900 employees including 790 technicians. In manufacturing at this moment are 320 000 and 100 000 Kw hydro-electric plant. There are some seventeen workshops although we only had time to visit two of these. The workshops visited were well equiped with 15m diameter table vertical boring machines and 2mx15m lathes in the heavy duty machine shop and conventional machines in the medium duty machine shop. We discussed some of their machining problems such as the reaming of split holes, half in mild steel and half in stainless steel and suggested that the reamer blade design could be improved by increasing the entry angle to 45^{o} as the original angle could cause rubbing and work hardening of the stainless steel. The accuracy of the lands should be within 0.003mm concentricity with the outside diameter. The High Speed Steel specification for reamer manufacture used in England was also mentioned.

The cutting tools in use during machining were of the brazed type, well made, on the Company's premises and we mentioned that inserts could be used to advantage in some cases. We also commented that the finish on the carbide tip from the diamond impregnated grinding wheel was not fine enough. The final grinding was with 180 grit wheel and we finish with a 240 to 360 grit. Also in Europe we have a centralised grinding and regrinding area where specialised technicians manufacture and finish the tools. There is also a distribution and collection system throughout our factories. The cutting conditions could be improved, we feel, but without the knowledge of your feeds and speeds and carbide grades a precise evaluation is difficult. We understand that figures are to be forwarded.

We also saw an inserted blade milling cutter used for the slotting of the rotor. This cutter had alternate blades for cutting each side of the slot. The rake at the cutting point seemed excessive and on closer investigation seemed to be about 20° negative. I would not have thought such an excessive land would have been conductive to good cutting conditions.

The turning of the pivot at each end of the water entry blades presented a problem as the diameters had to be in line and the unsupported weight of the blade made this difficult. However with a fine finishing cut this problem was reduced but not overcome. I believe one Company in U.K. puts the component in a cradle which supports the mass centrally on rollers. I will have to confirm this. Another problem was the boring of water entry ducts where a taper or wedge was formed due to tool wear before cut completion. This was removed by grinding. The problem should be tackled first by looking at carbide grades, feeds and speeds to try and cut one pass without a tool change. Cutting tool velocities appeared to be a little on the low side which could cause carbide tools to abraid and wear. However a limit must be placed upon speed with such large revolving masses. A dearth of C.N.C. machines was noticed within the Company. I suggest that the end plate cooling tube holes could be produced more efficiently on a co-ordinate table or a point to point drilling machine.

Another problem we met was the tapping of the bolt holes with solid H.S.S. taps. With large taps in the 100-150mm range it is usual to have collapsible teeth which retract at the completion of the thread. This is economic on withdrawal time and replacement of teeth. I will find some information on this subject.

Thread spec.-100-150mmx4-6mm pitchx6H.

Mr. Hofvenstam and I had a final discussion in the factory office on some of these points including the design of reamer holders. A good floating holder is difficult to find and most companies depend upon some float in the spindle due, to wear, to give line-ability and a figure of 0.5xdrilling speed and 2xdrilling feed is a rough guide to use.

We thanked the Company for their hospitality and departed at 16.00 hrs.

Report on a visit to Ningjiang Machine Tool Works in Guanxian on 16 October 1982.

Mr. Hofvenstam and I arrived at 10.30am and were welcomed by their Director and Chief Engineer Mr. CHEN SHUN YANG. This Company manufactures automatic lathes, gear cutting machines, jig boring and grinding machines and polishing machines. They employ a total of 3500 people of which 250 are technicians and engineers. Within the Company they have a technical school, a training centre and a hospital. Most of the machines manufactured are for the watch-making industries in China although some 13% are exported all over the world. This Company also operates a worker-management participation scheme which I commented upon as being an ideal situation where the workforce would feel that they are making a contribution which benefits both the Company and themselves. We were very impressed with the layout of the Company's manufacturing plant and thought that it compared favourably with some European factories and that the quality of manufacture was very high.

After a short tour of the factory we returned to the office where our impressions of the factory were discussed and one or two technical questions were put to us. The questions ranged from the feeds and speeds of gear cutting where I mentioned the high speed hobbing techniques used in U.K. to the eliminating of the burrs from the hob grinding process. I mentioned that there was no easy solution to this problem but that the grinding wheel used could be changed to a softer grade and perhaps a more open structure to alleviate the pressure on the work. The recommendation of Metcut Research Associates, for a grinding wheel for this application is, A 100 LV. A=aluminium oxide 100=grit size and L=grit hardness.

We thanked the Company for their hospitality and left at 12.30 hrs.

Report on visit to Gearcutting Section of Chengdu Tool Research Institute on 18 October 1982.

The visit to the gear cutting section was to explain the developments that the Institute had made in the finishing of hardened gears by means of carbide hobs. The gear in production was from the winch of a crane which showed excessive distortion in the teeth after hardening. The development machining was to successfully finish cut the teeth, after hardening to Rc 50, with a carbide tipped hob.

The conditions of machining were;-

Number of teeth in gear = 60
Diameter of gear = 143mm
Feed = 1.5mm/rev of work
Velocity of hob 120mm dia. and 200 rpm = 70m/min
Depth of finish cut = 0.8mm
Accuracy between class 4 and 6
Hob Vb = 0.15mm after cutting 20 to 30 gears
Hobbing time = 30 mins

$$\text{Savings} = \frac{\text{cost of grinding}}{5} = \frac{\text{time of grinding}}{8}$$

Appendix C.

Suggested Visit to U.K.

At a meeting in the Chengdu Tool Reasearch Institute on the 14 October 1982 with Mr.MA CHUANG RONG,Head of Department No.9, Mr.XU ZHU DE,engineer,and Mr.WEN XIAO LI,interpreter, I suggested that a visit could be made to U.K. in September 1983. The duration of stay suggested was about 3 weeks with the main purpose of discussions and visits.

The main areas for the visits were P.E.R.A., M.I.T.R.A., Vauxhall, Ford, British Leyland machining plants, Sheffield Twist Drill Co., Sandvik, University of UMIST, University of Aston(Prof.E.M.Trent) and Cranfield Institute of Technology.

I suggested that a letter is written to Mr.YU XIYUAN at the Institute during December 1982 with an invite to this suggested programme.

I have written to Mr.A.Sissingh to ask him to contact UNIDO about this visit. UNIDO should then,I understand,contact the British Council in London.

Appendix D.

Report on a Gearcutting Seminar held on Sunday 17 October 1982 in the Chengdu Tool Research Institute.

The discussion centred around the use of carbide hobs in U.K. and Europe and whether any development had been made in the coating of such hobs. Questions were also asked as to whether carbide hobs were used for finishing hard gears as in the Institute. In U.K. the gears are always finished prior to hardening so the problem does not arise. I could not say whether there were any finishing techniques for internal hardened gears as I had never met the problem. The feeds and speeds for high speed steel hobs were also discussed and I mentioned the U.K. practice of high speed hobbing and the increase in the strength needed in the machine. The land wear allowed for high speed hobbing of about 0.75mm was mentioned as this is the figure used by General Motors in U.K. Other topics discussed were the current techniques used on gear cutting such as the single cut rough/finish cutters used on gear shaping and other types of finishing used in U.K. such as shaving and the allowances and accuracy achieved.

I agreed to send Mr. YIN-JIE-HUA of the Chengdu Tool Research Institute some information on use of carbide shaping cutters used in U.K. and the speeds at which they are used.

Appendix E.

A Suggestion for a Manual Data File.

It may be helpful to obtain certain information quickly and the most important problem that industry will probably ask of a tool research institute is how can they machine a certain material. They would also want to know what sort of tool life they would expect from a certain cutting tool material and what feeds and speeds to use. Therefore a certain filing order may be helpful such as, material, tool material, feed, depth, nose radius, approach and wearland. A code can be set up to classify the various combinations as follows:-

Materials		**Approach**	
Low Carbon Steel	01	15(75)°	01
Medium carbon	02	0(90)°	02
H.C. Steel	03	10(80)°	03
Tool Material		**Nose Radius**	
HSS	01	0.2 mm	01
Carbide	02	0.4	02
Ceramic	03	0.6	03
Diamond	04	0.8	04
Feed		**Wear Land**	
0.12 mm/rev	01	0.2 mm	01
0.25	02	0.4	02
0.50	03	0.6	03
0.00	04	0.8	04
		0.3	05
Depth			
05 mm	01		
1.0	02		
1.5	03		

So the standard No. for a carbide cutting tool, cutting a low carbon steel with a 15° approach angle, 1mm depth of cut, 0.8mm nose radius, 0.25 feed/rev and a roughing wear land of 0.4mm would be 01-02-02-02-01-04-02. This could be filed then in numerical order in a conventional filing system.

The code makes provision for 99 sections under each heading

Appendix F.

LATHE TOOLS

THE CHENGDU TOOL RESEARCH INSTITUTE.

Service to Industry Qestionair.

This form is to enable your cutting conditions to be improved .Please complete the forms including column 1 and return to above address. we will then recommend improved cutting conditions in column 2and return it to you. Will you then complete column 3,putting in your nearest changed con--ditions and return it to us.One set of sheets per tool.Please only answer questions ringed ◯

Material

(1) specification.

(2) hardness. brinell- vickers- rockwell-

(3) delivered. bar- forging- cast-

machine

(4) name- (5) age-

(6) motor kw- (7) machine size-

no.7 means the largest work size that can be machined

Tool. (8) maker- (9) tradename-

(10) type. hss- carbide- ceramic- diamond-

(11) blank. solid- buttweld- brazed- insert-

(12) tool overhang- (13) coolant type-

(14) finnish. hand ground- machine ground- diamond lapped-

(15) holder or shank size. width- depth- approach angle-

(16) hss tool angles. rake- clearance- approach ang-

(17) carbide insert code-

(18) if 17 unknown or brazed tip used,give shape- size- pos/neg rake- no. of corners- nose radius- chipbreaker yes/no- thickness -

(19) surface roughness of component. good- fair- bad-

(20) are there interupted cutting conditions?yes- no-

Costs

(21) labour cost per minute

(22) production machine cost per min.(labour+overheads)

col. 1 | col. 2 | col. 3

LATHE TOOLS

(23) tool or insert cost

(24) no.ofregrinds per tool

(25) no. of edges per insert

(26) no.compts.made per tool change or edge

27 tool cost per component
cost(23)/no.(24)x no.(26)
or cost(23)/no.(25)x no.(26)

(28) time to change(+regrind)tool tip(min)

29 toolchange costs.time(28)xcost(21)

(30) machine production time (mins).

31 machine production cost.time(30)x cost(22)

(32) load,unload,downtime(mins)

33 downtime costs.load(32)xcost(22)

34 total manufacturing cost per compt.
cost(27)+cost(29)+cost(31)+cost(33)

(35) diameter of cut(mm)(precut dia.)

(36) depth of cut(mm)

(37) feed per revolution(mm)

(38) speed (rpm)

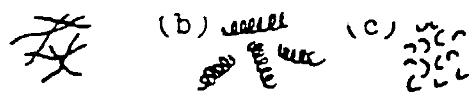
39 feed rate mm/min.=feed(37)x rpm(38)

40 material removal rate(mm^3/sec)
πx dia(35)x depth(36)xfeed(37)x rpm(38)/60

41 specific power consumption for material
is mm^3/watt/sec

42 power required=sp.pow.con.(41)xm.m.r.(40)

(43) chip type- (a) (b) (c)



44 proportion of production time(30)
that tool or edge is cutting(%)

45 tool life in mins
no.(26)x time(30)x prop(44)

(46) grade of carbide used

47 velocity of cutting (meters/min)
=rpm(38)x πx dia.(35)/1000

48 tangential wear land value (mm)

49 log vel.(47)+n.log life(45)=log

figures not ringed are for institute use only

50. log vel.(47) + n log life (45) + m log Be = log λ.

where Be = feed(37) x depth(36) ÷ d(36)/Cos a.a.(16) − rad(18) $\tan\left(\frac{90-a.a(16)}{2}\right)$ + (90−a.a(16)) π rad(18)/180

MILLING CUTTER

THE CHENGDU TOOL RESEARCH INSTITUTE

Service to industry questionair

This form is to enable your cutting conditions to be improved.please complete the forms including column 1 and return to above address.We will then recommend improved cutting conditions in column 2 and return it to you.will you then complete column 3, putting in your nearest changed con--ditions and return it to us.one set of sheets per cutter.
Please only answer questions ringed○

Material

(1) specification.
(2) hardness. brinell- vickers- rockwell-
(3) delivered. bar- forging- cast-

Machine

(4) name- (5) age-
(6) motor Kw- (7) machine size-

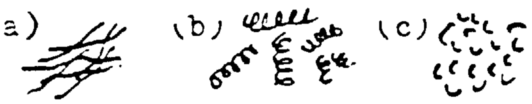
no. 7 means the largest work size that can be machined.

Tool

(8) maker- (9) trade name-
(10) type of body.solid- inserted blade- other-
(11) type of tooth.hss- carbide- ceramic- diamond-
(12) if inserted tooth,type.taper wedge- insert- other-
(13) finish.handground- machineground- diamond lap-
(14) cutter effective dia- mm
(15) number of teeth in cutter-
(16) rake angles.axial- ° radial- ° approach- °
(17) if insert code is-
(18) length x width of milled face- mm X mm
(19) surface roughness of component,good- fair- bad-
(20) are there interupted cutting conditions?yes- no-

Costs

(21) labour cost per minute-
(22) production machine cost per minute.(labour+overheads)

MILLING CUTTERS	col. 1	col 2	col 3
23 complete cutter or reblade cost.rebl·decost =(blade cost x no.blades in cutter)+body cost x machine production time/120000			
24 no.regrinds solid cutter			
25 no.edges per insert			
26 no. components made per cutter(inserts)change			
27 tool cost per component cost(23)/no.(24)x no.(26) or or cost(23)/no.(25)x no.(26)			
28 time to change(+regrind)tool tip(mins)			
29 tool change costs.time(28)x cost(21)			
30 machine production time(mins)			
31 machine production cost.time(30)x cost(22)			
32 load,unload,down time(mins)			
33 downtime costs.load(32)x cost(22)			
34 total manufacturing cost per compt. cost(27)+cost(29)+cost(31)+cost(33)			
35 feed per tooth feed(37)/15			
36 depth of cut (mm)			
37 feed per revolution of cutter(mm)			
38 speed(rpm)			
39 feed rate(mm/min) feed(37)x rpm(38)			
40 material removal rate (mm^3/sec) feedrate(39)x depth(36)x facewidth(18)			
41 specific power consumption(mm^3/watt/sec)			
42 power required=sp.pow.con.(41)x m.m.r.(40)			
43 chip type- (a) (b) (c) 			
44 proportion of face width(18)/cutter diameter(14) as a percentage(%)			
45 tool life(mins).no.(26)x time(30)x (44)			
46 grade of carbide used			
47 velocity of cutting (meters/min) =rpm(38) x π x dia(14)/1000			

48 tangential wear land value(mm)

49 log vel.(47)+n.log life(45)=logC

figures not ringed are for institute useonly

50. log.vel.(47) + n.log.life(45) + m log Be = log λ

where B_e = feed(37) × depth(36) ÷ d(36)/Cos a.a.(16) − rad(18) Tan $\frac{(90 - a.a.(16))}{2}$ + (90 − c.c.(16)) π rad(18)/180

THE CHENGDU TOOL RESEARCH INSTITUTE

Sevice to Industry Questionair

1.0 Are you interested in forming a committee to discuss standards, techniques or problems. yes-   no-

2.0 If yes, upon which subjects-

2.1 materials-

2.2 machine tools-

2.3 cutting tools-

3.0 Are you interested in lectures upon engineering subjects either at the institute or at your company about the subjects mentioned above.

4.0 Are you interested in the formation of an association with this institute on the basis of a small subscription based upon your company's annual turnover, where, your company recieves in return-

4.1 Short term answers to queries (within hours)

4.2 Long term problem solving projects (weeks, months)

4.3 Consultancy service by experts at your company.

4.4 Monthly issue of a free periodical containing-

4.4.1 Developments of new techniques in industry.

4.4.2 List of engineering or tooling abstracts available as free photocopies.

4.4.3 List of periodicals or books available free on loan from the institute library.

4.4.4 list of reports available on institute research work (unless secret), test results etc, as free printed pamphlets.

Interested-   Not interested-

Appendix G.

Personnel Contacted from the Chengdu Tool Research Institute and Ministry of Machine Building in Chengdu.

Director	Fan Zengren
Vice Director	Song Yunhong
Chief Engineer	Yu Xiynan
Head of Department No.1	Wu Yuanchang
Head of Department No.2	Yun Jiehua
Head of Department No.3	Ma Baocheng
Head of Department No.4	Fu Songjun
Head of Department No.5	Yu Yunjun
Head of Department No.6	Sheng Zhuangxing
Head of Department No.7	Wang Zhengyu
Head of Department No.8	Chang Xingnan
Head of Department No.9	Ma Chuang rong
Head of Administrative Office	Ma De xing
Vice Director of factory and Chief Engineer	Pan Daubei
Head of Administrative Office	LiYaqi
Director of Measuring Instrument Research	Lui Guo Ding
Interpreter (1)	Wen-Xiao-Li
Interpreter (2)	Lui-Ming-De
Engineer	Xu-Zhu-De

Appendix H.

MACHINING COSTS

The total cost of any machining operation consists of

1) TOOLING COST eg Cost of tooling per hour or per component. If a tool has 6 cutting faces then obviously it is the cost per cutting edge that is important. Conversely if a milling cutter has 40 inserted teeth then it is the cost of each insert x 40. In the case of a solid cutter (or tool) the tooling cost between tool changes = $\frac{\text{The Total Tool Cost.}}{\text{Number of Regrinds}}$

Once this has been established the cost for each component will be

$$= \frac{\text{Tool Cost For Each New Ground Tool Or Edge}}{\text{No Components Produced Between Tool Changes}}$$

Now suppose a 6 sided insert costs £3.00 (eg £0.50/edge)

so that at speeds of	300	400	500	600	700	800 rpm
the No. of pieces per tool change might be	15	10	7	5	4	3
then the tooling cost per component would be (£)	·033	·050	·071	·100	·125	·166

2) CUTTING COSTS eg The cost of running the machine during its cutting cycle time. = Rate Per Minute x Cutting Time (or Cycle Time)

3) TOOL CHANGING COSTS eg The cost of changing over from a worn tool (or edge) to a resharpened tool (or a new edge on an insert)

$$= \frac{\text{Cost Of Tool Change (Time x Shop Rate)}}{\text{No. Pieces Produced Per Tool Change}}$$

4) LOAD & IDLE COSTS eg The cost of loading and unloading a component from the machine. = Time to Load & Unload x Shop Cost or Rate.

NOTE The above costs ((2), 3) & 4)) all depend on the shop rate (or machine rate) for the particular machine being used and can vary from a low rate for an old centre lathe to a high rate for a new machining centre. These are assembled as follows:-

OVERALL MACHINE COST

Machine Rate	£ 4.00	per hr.	
Labour Rate	£ 4.00	" "	
Direct Overheads	£ 2.00	" "	(rates, power, etc.)
Indirect Overheads	£ 2.00	" "	(inspectors, F'men)
	£12.00	" "	or £0.2 per min

/Cont'd...

Now load/unload (M/C idle costs) = 0.5 min (say) x £0.2

= £0.1

and cost per tool change = 0.4 min (say) x £0.2

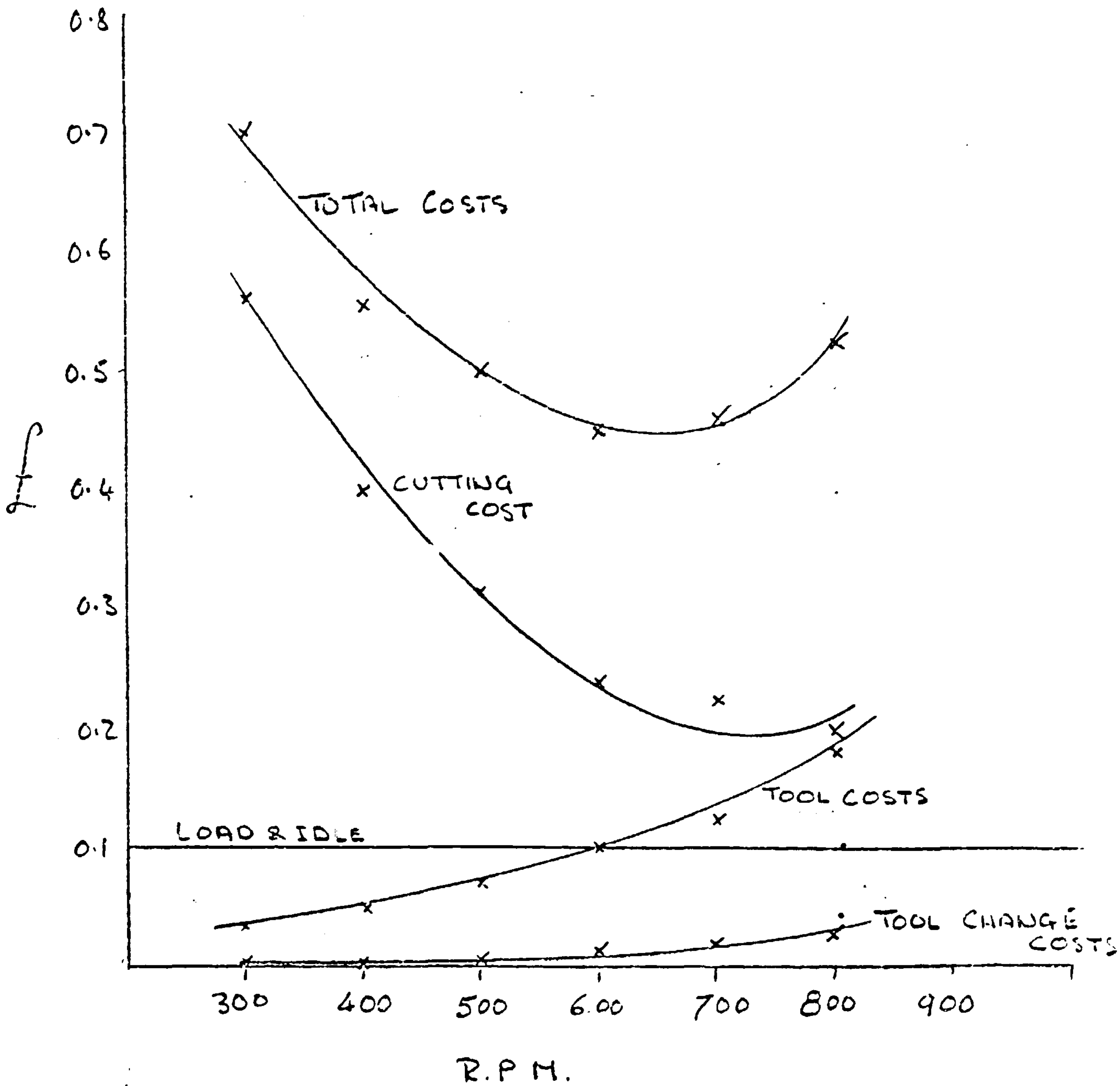
= £0.08

To analyse these costs on an automatic lathe we can put up the speed to reduce the cycle time and get more pieces off at the end of the day. BUT will our costs per component be reduced? Let us run the machine at 300, 400, 500, 600, 700 & 800 r.p.m. and note that the pieces/tool change are 15, 10, 7, 5, 4 & 3 as mentioned previously. In chart form we have:-

Speed r.p.m.	300	400	500	600	700	800
Pieces/Tool Change	15	10	7	5	4	3
Cutting Time (Mins/Piece)	2.8	2.0	1.57	1.2	1.13	1.0
Cutting Costs (Rate/Min x Cutting Time)	.560	.400	.314	.240	.226	.200
Tool Costs (Cost/Edge / Pieces/Tool Change)	.033	.050	.071	.100	.125	.166
Tool Change Costs (Cost/Tool Change / Pieces/Tool Change)	.005	.008	.011	.016	.020	.026
Load and Idle Costs	.100	.100	.100	.100	.100	.100
Total	.698	.558	.496	.456	.471	.492

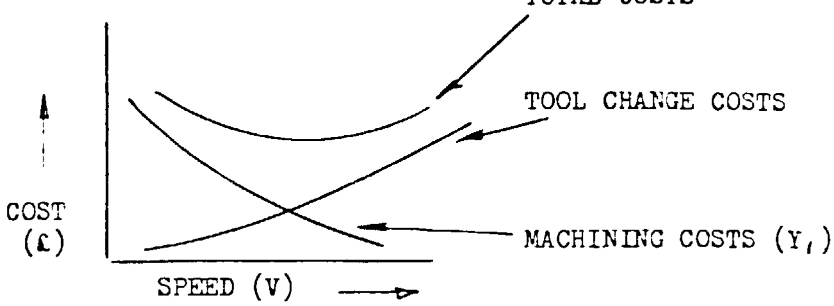
So it is a fact that there is an optimum set of conditions for a machine, and in this case it is at a speed of 600 r.p.m. This can be shown by a graph:-

GRAPH OF CUTTING TOOL ECONOMICS
(MINIMUM TOTAL COSTS ABOUT 600/650 r.p.m.)



OPTIMUM TOOL COSTS FROM $VT^n = C$

It has been shown that as the speed V increases the tool life decreases. As this occurs the frequency of tool changing increases. This is costly and cancels any decrease in costs due to higher production. Graphically it is



Time to m/c unit volume (mins) $= \frac{1}{dfV} = \frac{K}{V}$

Cost of machining a unit volume $= \frac{HK}{V} = Y_1$

No of tool changes in $\frac{K}{V}$ mins. $= \frac{K}{TV}$

Cost of tool changes in a unit volume

$$= \frac{JK}{TV} = Y_2$$

But $T = \left(\frac{C}{V}\right)^{\frac{1}{n}}$ from $VT^n = C$, so $Y_2 = \frac{JK}{\left(\frac{C}{V}\right)^{\frac{1}{n}} V}$

$$= \frac{JK}{C^{1/n} V^{-1/n} V^1} = \frac{JK V^{-(1-1/n)}}{C^{1/n}} = \frac{JKV^{(1/n - 1)}}{C^{1/n}}$$

$$= \frac{JKV^{\left(\frac{1-n}{n}\right)}}{C^{1/n}}$$

where :-

d = cut depth
f = feed mm/rev
V = velocity
Y_1 = machining cost of a unit volume
H = machining cost per min.
T = tool life (mins)
J = tooling costs (changing & grinding.)
Y_2 = cost of servicing the cutting tools
Y = total costs ($Y_1 + Y_2$)
K, C and n = constants

And $Y = Y_1 + Y_2$ $= \frac{HK}{V} + \frac{JKV^{\left(\frac{1-n}{n}\right)}}{C^{1/n}}$ and differentiating w.r.t. V

$$\frac{dY}{dV} = -\frac{HK}{V^2} + \left(\frac{1-n}{n}\right) \frac{JKV^{\left(\frac{1-n}{n} - 1\right)}}{C^{1/n}} = -\frac{HK}{V^2} + \left(\frac{1-n}{n}\right) \frac{JKV^{\left(\frac{1-n}{n} - \frac{n}{n}\right)}}{C^{1/n}}$$

$$= -\frac{HK}{V^2} + \left(\frac{1-n}{n}\right) \frac{JKV^{\left(\frac{1-2n}{n}\right)}}{C^{1/n}}$$

For minimum conditions $\frac{dY}{dV} = 0$ so $\frac{HK}{V^2} = \left(\frac{1-n}{n}\right) \frac{JK}{C^{1/n}} V^{\frac{1-2n}{n}}$

and $H = \left(\frac{1-n}{n}\right) \frac{J}{C^{1/n}} V^{\frac{1}{n}}$ or $\left(\frac{1-n}{n}\right) J \left(\frac{V}{C}\right)^{\frac{1}{n}}$

Optimum velocity $V = C\left[\frac{H}{J}\left(\frac{n}{n-1}\right)\right]^n$ and ratio of machining cost to tooling cost $\frac{H}{J} = \left(\frac{1-n}{n}\right)\left(\frac{V}{C}\right)^{\frac{1}{n}}$

Appendix J.

Workshop Capacity.

	LATHE	MILL	COPY LATHE	HOBBING M/C
Motor power Kwatts	22	11	n/a	n/a
Length between centres mm	900		1000	450
Length between table & head mm		350		
Maximum diameter mm	280		400	800
Spindle taper morse taper	4			
Maximum speed	750	1400	1400	
Minimum speed	14	18	22	
No. of changes	18	20		
Maximum feed mm/min	2.65	1250	infinite	
Minimum feed	0.05	0	"	
No. of changes		16		
Maximum module cut				10
Minimum module cut				1
Maximum hob diameter mm				180
Maximum hob length				500
Hob shift				yes

Lathe manufacturer Shanghai Heavy M/C Tool Works model C630

Mill manufacturer Shanghai No.4 M/C Tool Works model X53T

Copy lathe manufacturer Great wall M/C tools model CE7120

Hobbing M/C manufacturer Chong Ching M/C Tool Works model Y3180H

n/a means not applicable

Appendix K.

Merchant's Analysis of the mechanics of metal cutting.

Requirements.

4 HSS tools 20x25 mm shank size. Rake angle $5^\circ, 10^\circ, 20^\circ, 30^\circ$.

Mild steel tube 50 mm o/d, 42mm i/d.

Tool dynamometer measuring Fc cutting force & Ft feed force.

Calibration chart.

Wattmeter.

Lathe conditions.

Feed rate 0.1 mm/rev

Surface speed 24 m/min.

Spindle speed at 46mm mean dia.= $\frac{24 \times 1000}{46 \times \pi}$ = 166rpm

Calculations

Mean circumference = $46 \times \pi$ =144.51mm.

Chip thickness ratio(r)=t_1/t_2=$\frac{\text{deformed chip length}(l_2)}{\text{undeformed chip length}(l_1)}$

r= $l_2/144.51$

Shear angle $\phi = \mathrm{Tan}^{-1} r\mathrm{Cos}\alpha/(1-r\mathrm{Sin}\alpha)$

Merchant sugests that 'r' is the measure of cutting efficiency and equals 1 when $C=45^\circ$ which is the limiting value of shear angle and ideal cutting force conditions.

Theoretical cutting power=work done(cutting)+work done(feed)

=Fc x velocity + Ft x feed velocity

=Fc(newtons) x $\frac{24(m/min)}{60}$ + Ft(newtons) x $\frac{0.1}{1000} \times \frac{166}{60}$

Shear force(Fs)=$F_c\mathrm{Cos}\phi - F_t\mathrm{Sin}\phi$

Normal force(Fn)= $F_t\mathrm{Sin}\phi + F_t\mathrm{Cos}\phi$

Friction force(F)=$F_c\mathrm{Sin}\phi + F_t\mathrm{Cos}\phi$

Normal force(N) = $F_c\mathrm{Cos}\alpha - F_t\mathrm{Sin}\alpha$

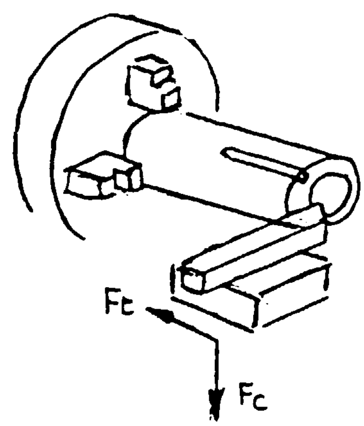
Coeficient of friction(μ)= F/N

Friction angle(β)= Tan^{-1} (F/N)

Merchants machinability constant(C)=$2\phi + \beta - \alpha$ .which according to merchant equals 45° for optimum shear angle at minimum energy conditions.

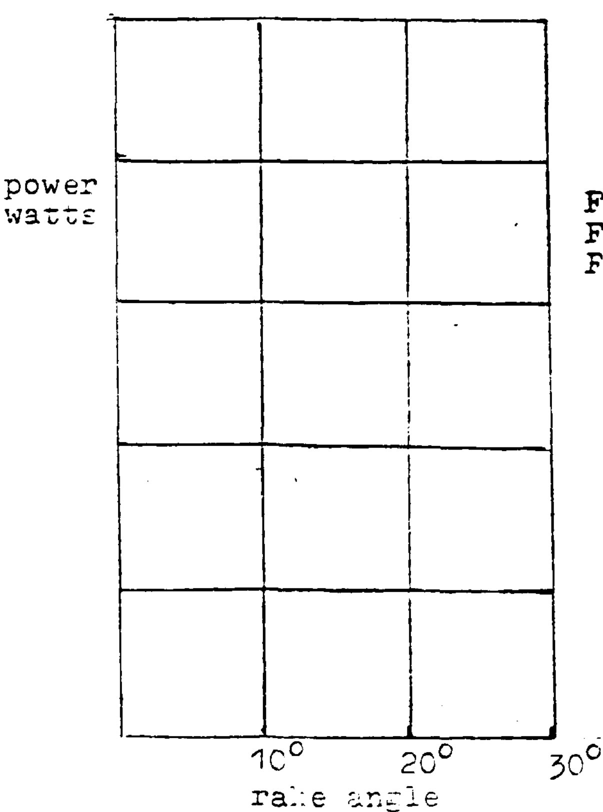
Power=540xI(watts)

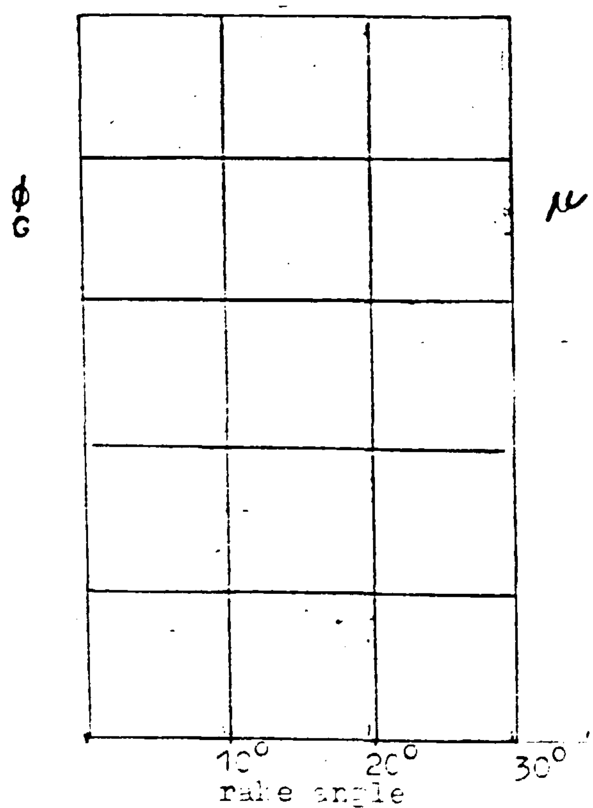
Rake angle= α



Rake angle(α)	30°	20°	10°	5°
Total power(watts)				
Running idle power(watts)				
Cutting power(watts)				
Theoretical cutting power(watts)				
Cutting force(Fc) (newtons)				
Feed force(Ft) (newtons)				
Actual chip length(l_2)				
Chip thickness ratio(r)				
Shear angle(ϕ)				
Shear force(calculated) (Fs)				
Normal force(calculated) (Fn)				
Friction force(calculated) (F)				
Normal force(calculated) (N)				
Coeficient of friction(μ)				
Friction angle(β)				
merchant machinability constant(C)				

Graphs;- Fc/rake;Ft/rake;cutting power/rake;shear angle/rake;
shear force/rake;friction/rake;machinability const/rake:





Appendix L.

Equivalent Chip Thickness.

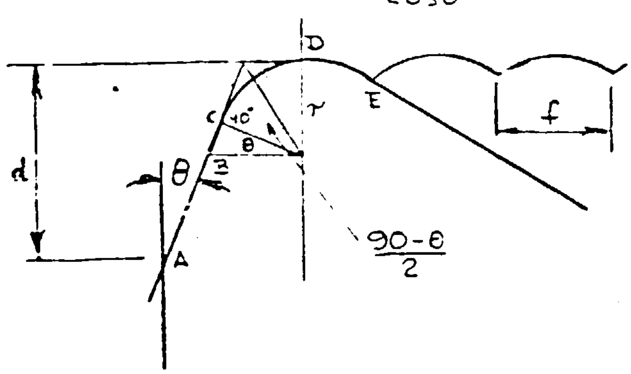
It could be said that tool life is also equal to change in feed (f) depth of cut (d) nose radius (r) and tool approach angle θ thus Taylor's equation becomes extended and is now $VT^n g(f,d,r,\theta) = C$ where g is a function of feed depth, nose and approach values. As such an equation would be unwieldy , Brewer and Rueda sought a relationship between these parameters (A simplified approach to the optimum selection of machining parameters, September 1963, Engineering Digest 24.9)

They reasoned that tool life was a function of the cutting edge temperature (x), and steady state temperature depends on a balance between heat generated and heat removed from cutting edge

i.e. Heat generated/heat removed. = x

Provided the depth of cut exceeds r and ignoring length DE the cutting edge, length equals

$$\frac{d}{\cos\theta} - r\tan\left(\frac{90-\theta}{2}\right) + \frac{(90-\theta)}{(180)}\pi r$$



Cutting Length = ABCD

$$ABC = \frac{d}{\cos\theta} - r\tan\left(\frac{90-\theta}{2}\right)$$

$$CD = \frac{\pi r(90-\theta)}{180}$$

$$ABCD = \frac{d}{\cos\theta} - r\tan\left(\frac{90-\theta}{2}\right) + \frac{\pi r(90-\theta)}{180}$$

Hence $x = \dfrac{fd}{\frac{d}{\cos\theta} - r\tan\left(\frac{90-\theta}{2}\right) + \frac{(90-\theta)}{(180)}\pi r}$ = 'be'

'be' is known as the equivalent chip thickness and includes the four variables d, f, r, & θ. This enables a generalised tool life equation to be written as follows:

$VT^n be^n = \lambda$ (λ = constant for the material)

The constant m appears to be dependent only upon the material being cut. Brewer suggested a value of 0.45 for cast iron and PERA report no. 163 indicates a value of 0.37 for steel.