PERFORMANCE OF ULTRASONIC MACHINING WITH COMPLEX FORM TOOL

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ABSTRACT

At present many special materials such as heat resistant steels,geraminium ,quartz,... are utilised in modern engineering. Such materials are difficult to be machined by the conventional methods. Ultrasonic machining stands as one of the appropriate methods to handle such situation.

The scope of the present work is to study the performance of ultrasonic machining with form tools (three dimensional tools),where the process paramceters such as amplitude of tool vibration,static pressure and slurry circulation can be adversely influenced during tool penetration. A set of experimental work with different tool forms was carried out.Problems associated with form tool machining and different methods for inhancing the process were introduced.

INTRODUCTION

Ultrasonic machining is one of the appropriate means to produce complex form products.It offers solution for the production of fine delicate dies and electrodes of the non conducting materials for electro discharge machining .The performance of ultrasonic machining is primarily determined by the acoustic and slurry system,besides the product materials and tool form. For constant cross section tools,such parameters are independent or slightly changed during tool penetration. The effects of the slurry system can impose serious limitations on the tool penetration. When machining with tools of complex form,progressive changes in the process parameters for both the acoustic and slurry systems are expected. Such changes can prove harmful regarding the performance and adequate solutions are to be looked for. The process parameters which are liable to change are:-

1-Amplitude; The impact force acting on the workpiece during ultrasonicmachining is a function of the acoustic parameters,mainly amplitude. Pahlitzsch[1] analyzed the results of various investigators on different materials in Braunschweig Institute and found that the removal rate was exp-

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onentialy propertional to amplitude . Thus for constant frequency the removal rate can be assessed by using an empirical formula [2] in the form:

$$V = C.(A)^{x}.P_{st.}$$

where

V	is the removal rate in mm^3/min
A	is the amplitude in μm
$P_{st.}$	is the static pressure daN
C	is an ultrasonic machining factor
x	is the power exponent =1 for graphite material

A previous analysis carried out by Markov [3] on the experimental results of ENIMS yielded a wide range for the power exponent X ranging from 0.5 to 1.7 .

The same experimental results were reanalysed [4] and an adequate definition of the power exponent X had been reached . It attained a value of 1.2 for the lower range of amplitude.

Obviously increasing the amplitude leads to an increase in the particle velocity and therefore the impulsive force [5] .

For a constant cross section tool the amplitude and thus the impulsive force are constant regardless tool penetration .

For certain forms of tools (stepped cylindrical, exponential, conical and catenoidal) , the theoretical amplification factor , the resonance half - length, co-ordinate displacement node and the co-ordinate of stress antinode can be well defined.

Further for other complex form tools a programmable solution to find the amplitude distribution across the tool length , based on the finite eleme ent method and with reasonable assumptions, was introduced [6] .

The position of the antinode of a constant cross section tool plays no role during tool penetration , while for the form tool the position of the antinode determines the maximum permissable depth of tool penetration. Besides, for the form tool the axial component of the amplitude plays a harmful role in the ultrasonic performance as it decreases the removal rate and increases the side gap between tool and workpiece.

2- Static Pressure : The relation between static pressure and the removal rate is not well defined [7] .

Some [8] have suggested a proportional relation up to a certain limit (optimum load). For a constant cross section tool the applied static pressure remains constant independant of the tool penetration , while for the form tool , the static pressure changes during the tool penetration, especially for small size tools .

3- Slurry Circulation : The form tool leads to difficulty in slurry ciculation especially for tools with internal cavities ,thus the renewal of the abrasive and the evacuation of the debris are retarded and consequently the removal rate decreases and sometimes disintegration stops.

4- Uneven Tool Wear : The frontal wear of a constant cross section tool is much more significant as compared with side wear , since it leads to a drop in the amplitude of tool vibration . For the form tool the lateral areas represent active areas and thus subjected to side wear which is not uniform along the tool length and leads to significant dimensional and form errors .

EXPERIMENTAL WORK

The present work was carried out on an experimental machine with the following specifications:

. Machine

Generator : Branson Type -1120
Power : 1130 watts
Frequency : 20 kHz
Transiducer : Piezo electric
Amplifieres : Intermediate amplifires yielded a wide range of amplitudes up to 100 um
Feed System : Counter weight acting on acoustic head .

.Measuring Equipment

The tool penetration was measured and recorded by means of an optical pick-up type SPLEM Ref. MSA-554 ,recorder type Philipps Ref. T2Y .

The form error was measured by a three dimensional programmable ZEISS machine type VMB-850,(program CIRCLE).

.Tools

Two group of tools were desdgned

Frist Group: Simple form tools:

a- With an exterior conical surface
b- With an interior conical surface

Second Group: Complex form tools

.Test Conditions

The experimental work was carried out under the following conditions:

Amplitude : 20-100 um
Frequency : 20 kHz
St. Pressure : Up to 15 daN
Abrasive : B_4C,280,10%

EXPERIMENTAL RESULTS

I - The Removal Rate

With a set of exteriour conical tools (cone angle 90°-150°) ,the results showed that the removal rate was decreased 80 % for a tool with cone angle 90°and for a depth of tool penetration of 10 mm as compared with a flat end cylindrical tool , this can be explained by the decrease in the value of the effective normal component of amplitude , Its value is 50% that of the axial amplitude for a 90° cone angle tool. Besides ,the slurry circulation is retarded the abrasive renewal and debris removal is less effective.Fig. 1 .

However, for a form tool with interior cone 90°,the situation was less dificult as the drop in the removal rate was only 15% for a depth of tool penetration up to 20 mm Fig. 2. This can be explained by the fact that this improvement is mainly due to the cavitational efect which is inhanced in case of interior conical tool.

With a set of multi-form tool (L = 0-24 mm) the results showed that the removal rate was almost equal to that of the flat end tool (□ 30 mm) Fig .3 . inspite of the unfavourable conditions regarding slurry circulation and amplitude changes, this can be explained by the effect of the increase in tool perimeter,where the increase of the ratio P/S (P is the tool perimeter and S is tool frontal area) leads to an improvement in the slurry circulation . For a set of tools with the same frontal area but with different tool perimeters , an emperical relation had been introduced in the form :

$$V = \bar{a} \cdot P/S$$

where

$\underline{V}$ is the removal rate in mm^3/min
$\bar{a}$ is the constant of tool configuration

For a wide range of tools and under the test conditions $\bar{a}$ was founded to be 4.5 .

II-The Surface Integrity

a- Surface Roughness

The experimental results have shown that the tool form has no significant effect on the surface roughness where the granulometry of the abrasive is considered as the main factor,other factors have only a partial effect, the measured value of Ra for graphite product (Type Ellor -9) was 2.5-

3 um for all machined surface (Abrasive ,B4C,280,10%) Fig. 4 . .

b- Accuracy

The measurments of the machined parts with complex form tools have indicated that the induced lateral force resulted in an increase of the side gap

For the multi-form tool the results showed that the side gap for part A was 200 um and 100 um for part B Fig. 5 .

For complex form tools , machining does not occur simultaneously on the whole tool working surface.Hence tool wear will not be uniform and form error in the product is to be expected.

The form error of the rounded parts corresponding to multi form tool had been measured on the three dimensional, Zeiss WMB 850 programmable machine the results showed that the circularity for parts with delayed machining was much better than that for the preceding ones.Fig .6 .

c- Surface Defects

For complex form tools the difficulty of slurry circulation results in contamination of the fresh abrasive with the machining debris.

The debris of the graphite form a pasty layer and acts as a damper which hinders the ultrasonic impulsive action and thus limits the depth of tool penetration and causes blockage.
The complex shaped tools have shown severe cavitational effects that can result in marring the surface with numerous cavities. The position , distribution and concentration of such cavities depend on the tool shape Figs. 7 & 8 .

The local vibration of the abrasive results in marring the side surface with numerous and deep craters. This is especially so when machining with a non symmetrical tool,generating lateral vibrations.

RECOMMENDATION

In order to solve the problem of possible variations of the process parameters as well as slurry contamination and blockage for complex form tools, a feed back control system similar to that proposed in Fig. 9 . can be applied. Its objective would then be to readjust the working parameters in accordance to the input optimum parameters. Besides, it would lift up the tool at the onset of blockage to allow a temporary evacuation of harmful debris and thus maintain the fresh renewal of abrasive slurry.

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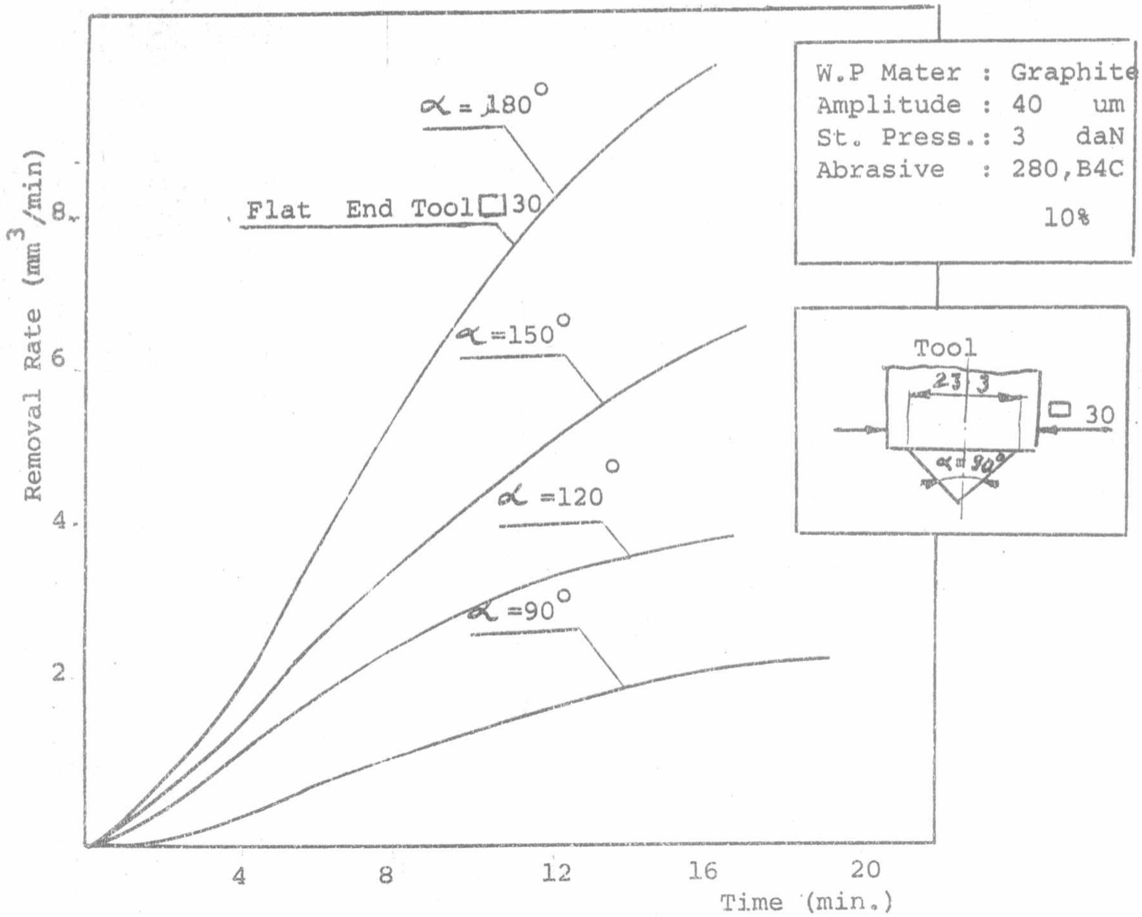


Fig.1. Removal rate as a function of time

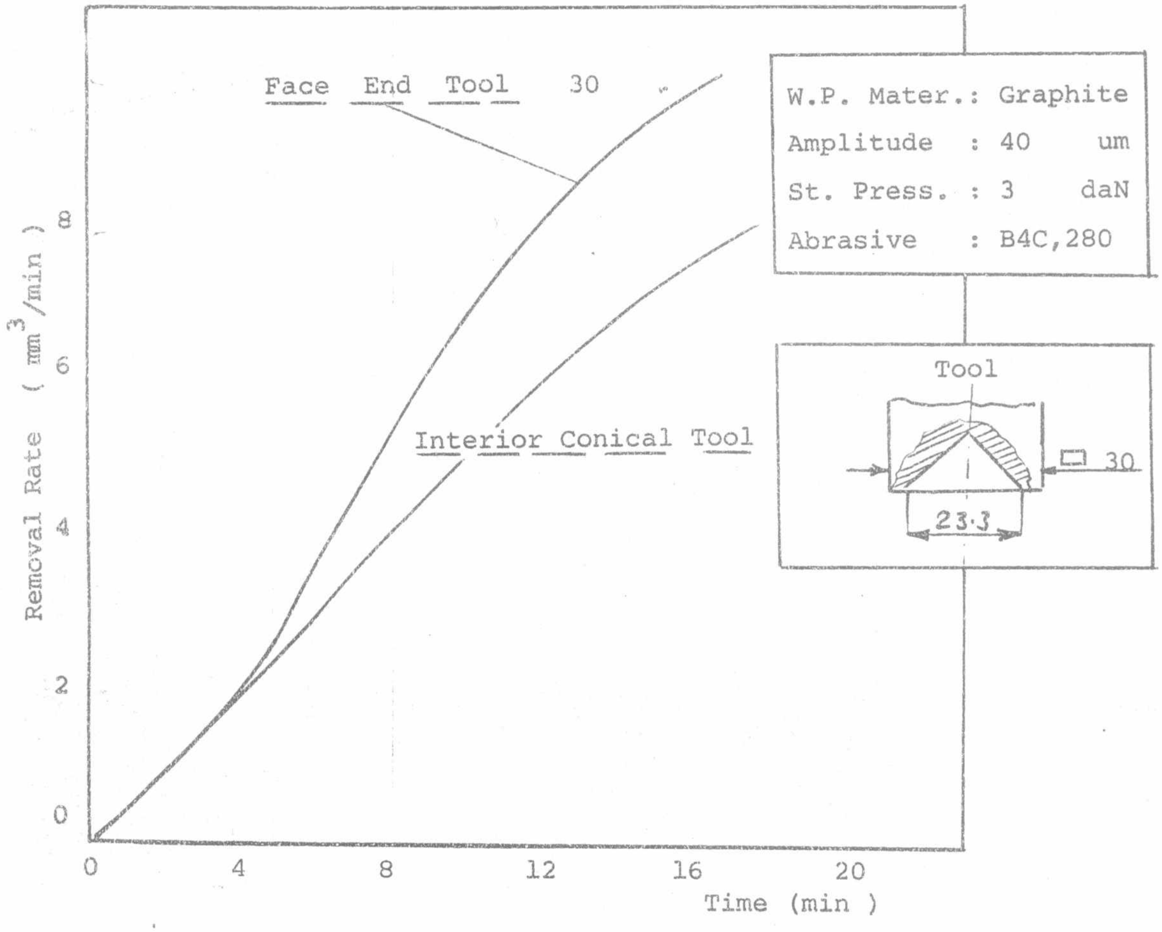


Fig:2. Removal rate as a function of time

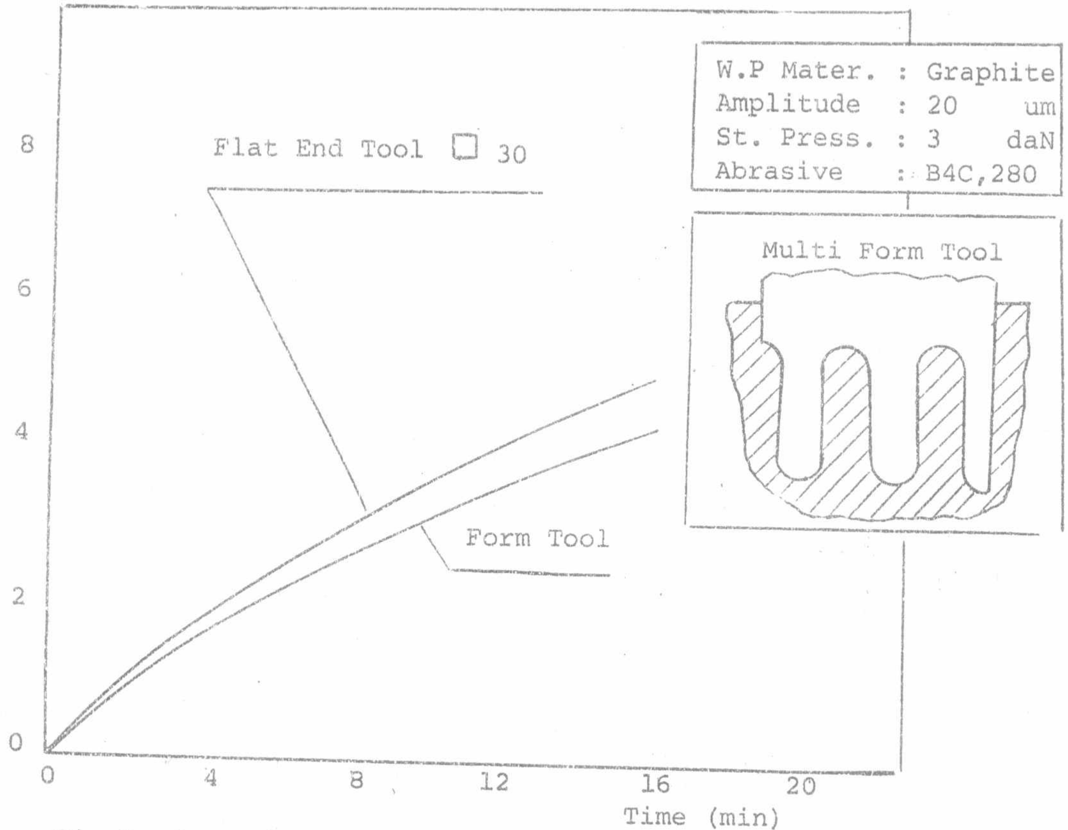
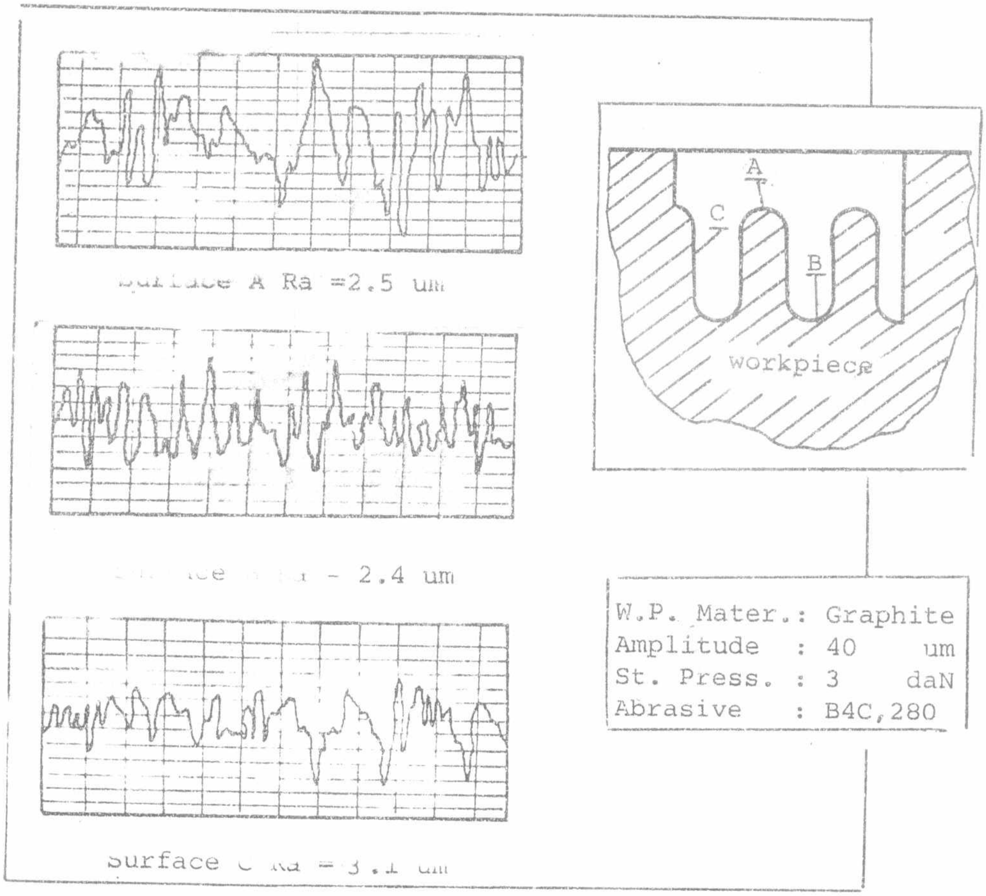


Fig.3. Removal rate as a function of time


Surface A Ra =2.5 um

Surface B Ra = 2.4 um

Surface C Ra = 3.1 um

Fig. 4. Surface roughness for form complex product

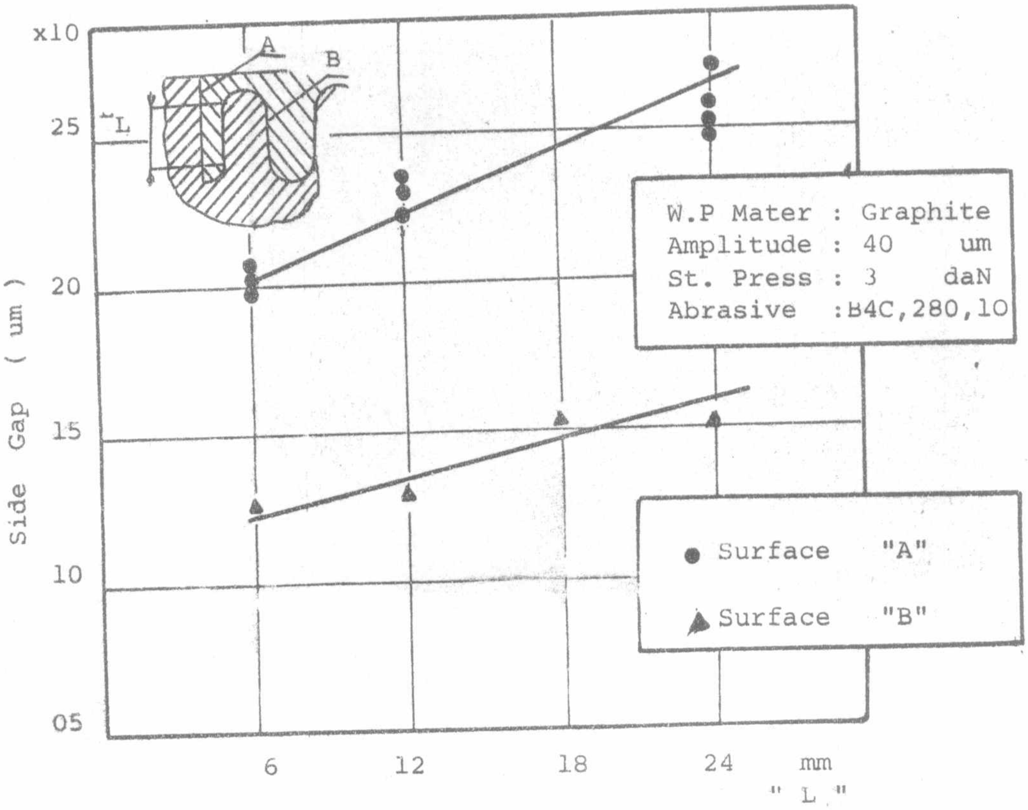


Fig.5. Uneven side wear and dimensional error

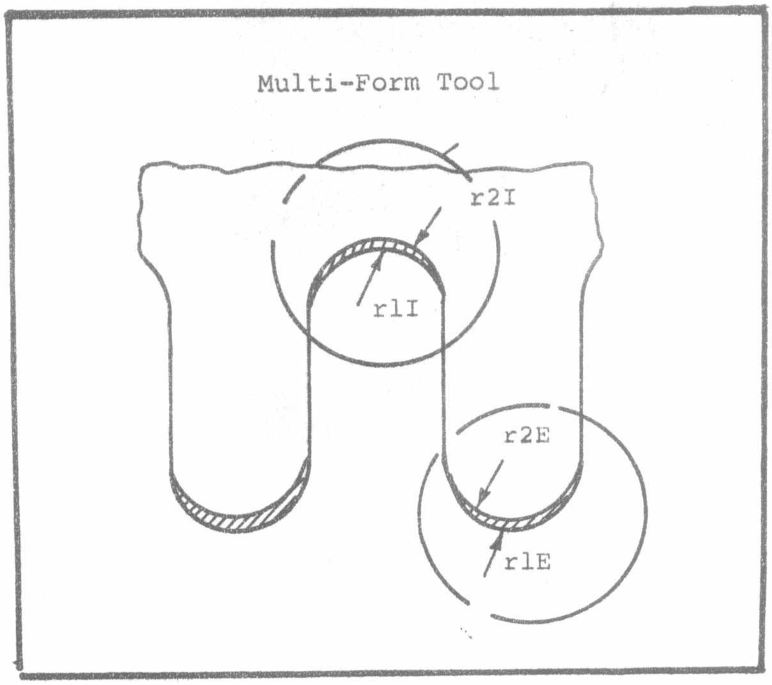


Fig.6 Uneven wear and circularity error

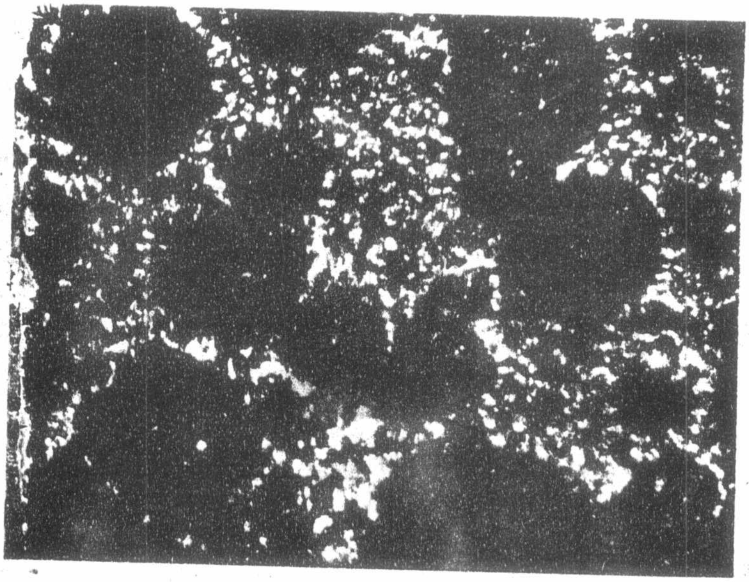


Fig. 7. Severe cavitational effect

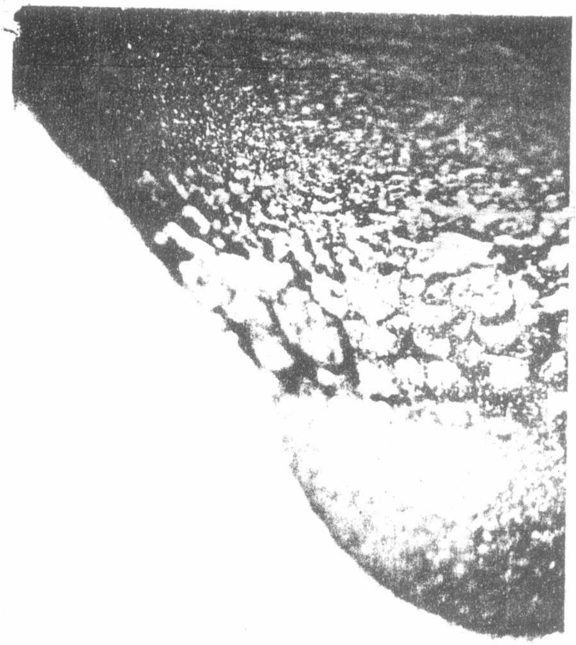


Fig.8. Blockage and form error

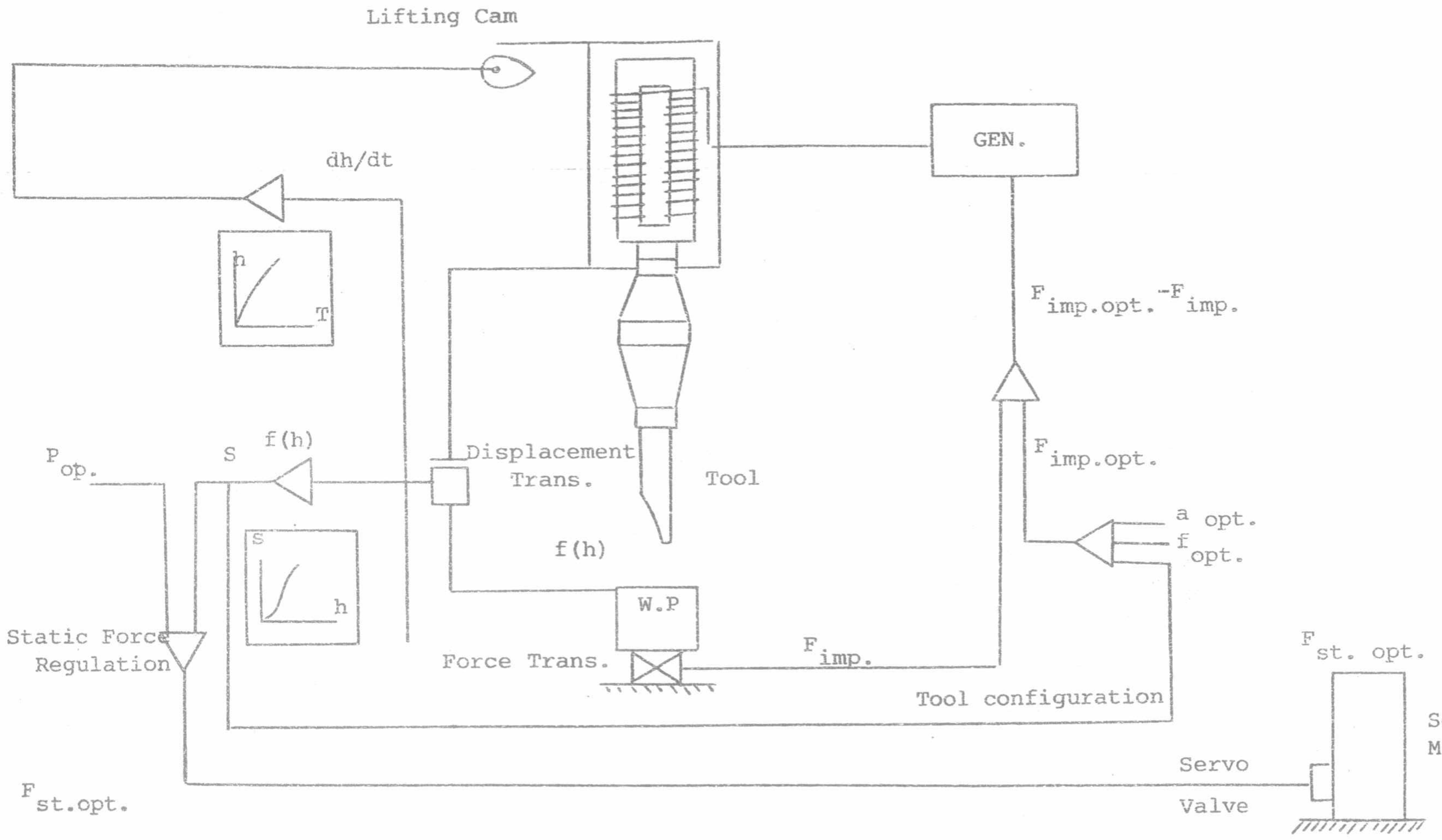


Fig. 9. Feed back control system for optimum working parameters