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Process Parameters of Chemical Machining

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ABSTRACT: Non-traditional machining is a non-contact machining process. Non-traditional machining consists on many machining techniques. One of the techniques which we will be discussing will be is chemical machining. Chemical machining is one of the oldest non-traditional machining process. This process is dependable on various parameters. Some of the notable parameters are surface finish, material removal rate, accuracy, etchants. In this paper, we will be discussing about these parameters and how it affects this process.
KEYWORDS: Chemical machining, Surface finish, Material removal rate(MRR), Accuracy, Etchants.

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I. INTRODUCTION

Non-Traditional machining is a process which involves, a mechanism to machine a material without direct contact between workpiece and the tool. It uses various other sources of energy like chemical, thermal, electrochemical, light, sound to remove material from the surface. It is employed for machining of highly complexed parts in industries such as aerospace, automotive manufacturing etc. It is used for manufacturing of high precision parts such as deep internal cavities, fine quality components. [3][4]

Chemical machining is considered as one of the oldest machining method. In this process, the material is removed from the surface by chemical dissolution. The chemical can be of acidic or alkaline in nature. A special coating, can be also called as maskants are applied to protect areas from which metal is not to be removed.The mechanism of this process is to invoke a chemical reaction between workpiece material and a chemical reagent so that the products of the reaction can be removed easily.

The steps of this process can be classified as,

1) Workpiece preparation.
2) Coating with masking material.
3) Scribing of the mask.
4) Etching.
5) Cleaning masking material.

A typical setup of a chemical machining process is as the figure below. [6]

Fig 1

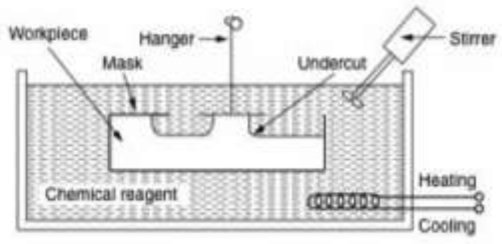


Fig. 1. Typical chemical machining set-up [6]

The rate of chemical machining is dependent on many factors like, the material of workpiece, the etchant concentration, the level of maskant applications, the temperature of the surroundings.

A process can be or implemented based on the output parameters. In this case, some of the few output characteristics are surface finish, material removal rate and accuracy. In the literature section, we will be discussing these following characteristics in detail.

II. LITERATURE REVIEW

There are many parameters which affect the chemical machining process like, Etchant concentration, Nature of etchant which is the most important factor for Material removal rate. The material removal rate affects the surface finish on the workpiece which in turn is the factor affecting accuracy. In this article, we will be looking at process characteristics like material removal rate, accuracy and surface finish.

1) Material removal rate:

Material removal rate is mainly dependent on the selected etchant. However, etchants that remove metal faster tend to have many side effects including reduction in surface finish, increased undercutting, higher heating, greater chance of etch rate with temperature and attack on the bond between the maskant and the work piece. The higher heating might lead to higher stress, which can have an impact on the strength of the material. Uncontrolled rate of material removal rate can lead to problems which can affect accuracy and surface finish. The material removal rate should not be very less as it takes more time for machining. More time in machining affects the production rate and the cost per piece may increase. The etch rate is generally limited to 0.02-0.04 mm/min when surface finish and accuracy are not important, the etch rate as high as 0.1-0.2 mm/min have been achieved. Although these penetration rates seem to be low, overall metal removal rates are quite high. In an aircraft industry, the metal removal rate on an aluminium is reported to be about 140cm /min^3. [2]

Table 3: Material Removal Rate [5]

Material	Etch Rate mm/min	Tolerance mm
Aluminium	0.025	+/- 0.025
Magnesium alloys	0.033	+/- 0.025
Stainless steel	0.13	+/-0.025
Titanium alloys	0.13	+/-0.09

The Table 3 shows removal material rate for few elements.[2]

2) Accuracy

Machining is done to a workpiece for better accuracy of the element. It is very important to know about the range of accuracy of a process before implementing it. Here we will be looking at few materials and their accuracy range if this procedure is utilized. The main factor affecting accuracy is undercut. So while designing this factor has to be kept in mind giving it its allowance for respective alloys. Maximum taper, when produced by slow immersion or withdrawal rates, is usually 0.08mm for 100mm depth in steel and 0.08mm in aluminum alloys. Sharp radii cannot be produced in the cutting direction.

The table 4 gives the allowance factor of aluminum, iron, titanium alloys and other general metals. [5]

Table 4: Tolerance on Depth of Cut in Chemical Machining [5]

Material	Depth of Cut (0-1.3)	Depth of Cut (1.3-2.5)	Depth of Cut (2.5-6.4)	Depth of Cut (6.4-13)
Al alloys	+/-0.025	+/-0.040	+/-0.050	+/-0.075
Fe alloys	+/-0.050	+/-0.075	+/-0.100	+/-0.150
Ti alloys	+/-0.075	+/-0.100	+/-0.150	+/-0.250
General	+/-0.050	+/-0.075	+/-0.100	+/-0.150

The other factor affecting the accuracy is material removal rate. If the rate is optimal, higher accuracy can be obtained. There are other ways to improve accuracy. With the help of electrochemical machining, the rate of accuracy is increased. And further developments have lead to Laser assisted chemical machining and by using precision process we can achieve new levels of accuracy and repeatability, with etched channel / feature sizes in the region of 25-30 microns with tolerances generally around +/-10% of the material thickness. With the help of photochemical machining, a part of size 0.5mm can be achieved.

3) Surface finish

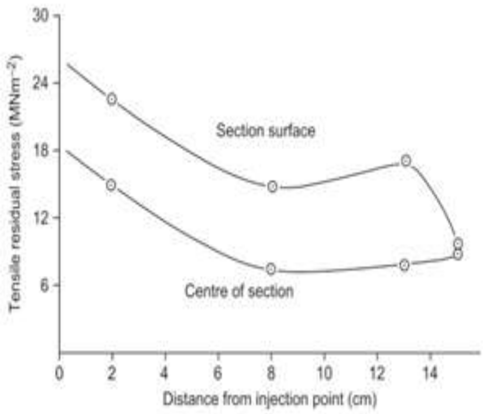
Initial surface waviness and defects are not greatly altered in contouring most metals, but may be smoothened out to a certain extend. The quality of finish is lower for extrusions, forgings and castings. The surface finish obtained may be around 5 µm. Aluminium alloys show better surface of the order of 1.6 µm. Hydrogen embrittlement may occur owing to the absorption of hydrogen in chemical machining in some metals. Aluminium alloys are not subjected to hydrogen embrittlement. Considerable care should be taken to avoid hydrogen embrittlement in steel, stainless steel, copper alloys and nickel alloys. If hydrogen embrittlement occurs, it can be overcome by heating the work piece 120^0 C for 1 to 4 hours. The surface produced by CHM process are otherwise stress free and show no thermal effects. [2]

Surface finish depends on surface quality of original workpiece. On most materials, scratches and local damage will be reproduced and magnified. Chemical milling removes small defects or scratches in magnesium, and to some extent in steel and titanium sheets. At deeper etching, the influence of original work surface diminishes, the surface finish produced being nearer to typical finish for a particular work material, which has undergone a particular history of heat treatment, and for a particular etchant formulation and etching parameters. Here is a list of elements and their surface finish after 0.25-0.40mm removed from the surface.

SURFACE FINISH ACHIEVED BY CHEMICAL MILLING

MATERIAL	FORM	SURFACE FINISH AFTER 0.25 – 0.40 mm REMOVED (μm CLA)
Aluminium alloys	sheet	2.0 – 3.8
	casting	3.8 – 7.6
	forging	2.5 – 6.4
Magnesium alloys	casting	0.75 – 1.4
Steel alloys	forging	
	sheet	0.75 – 1.5
	forging	
Nickel alloys	sheet	0.75 – 1.0
Titanium alloys	sheet	0.2 – 0.8
	casting	0.75 – 1.5
	forging	0.38 – 1.0
Tungsten	bar	0.5 – 1.0
Beryllium	bar	3.8 – 6.4
Tantalum	sheet	0.25 – 0.5
Columbium	bar	1.0 – 1.5
Niobium	sheet	1.0 – 1.5
Molybdenum	sheet	1.5 – 3.3

Fatigue crack growth examples from discontinuities produced by surface chemical treatments and shot peening. There is a wide variety of chemical treatmentswhich include pickling, anodizing and chemical milling, that are used to shape and finish metallic aircraft components. All these treatments can have detrimental influences on fatigue nucleation, but within limits this must be accepted. However, shot peening can be used both for surface cleaning, forming, and to improve the fatigue life, and it is not usually understood that the poor application of this process Pickling, anodizing and chemical milling are common treatments for aluminum alloys, and they can all cause etch pits. The composition of the alloy, its manufactured condition (e.g. plate, forgings and extrusions) and heat treatment can all influence the size and nature of the pits, which are usually at grain boundaries and surfaces breaking constituent particles. These may be removed during the treatments, resulting in angular pits. The shapes of the pits, particularly their depth profiles, determine the ease with which fatigue cracks nucleate and start to grow.



Besides pitting, grain boundary attack or even cracking can result from chemical treatments, notably in high strength steels. These grain boundary 'penetrations' have sharp tips that allow crack growth to commence as soon as the components are subjected to service loads. Here is a graph, of the tensile residual stress versus distance from injection point.

III. CONCLUSION

Chemical machining is a process used for machining of complex shape workpieces. There are a number of advantages in this process. It has less stress induction compared to other processes. Since there is no metal to workpiece contact, there is no formation of burrs. While having its many advantages, it also has a disadvantage. They include environmental impacts due to the usage of etchants. The etchants are also costly and the chance of harming the operator is also high. Hence, taking all into consideration, the process has to be considered.

The material removal rate is an important factor in selecting this process. Depending on the amount of metal to be removed, a suitable etchant should be considered. This selection of etchant is very important as it affects the accuracy and surface finish. A variety of technology is combined to achieve better rate of material removal rate. A slight change in etchant can improve the metallic properties of the metal.

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