EXPERIMENTAL COMPARISON OF MECHANICAL AND FATIGUE STRENGTH OF THREADS WHICH ARE MACHINED BY PUNCH TAP, THREAD MILLING AND COLD FORMING TAP PROCESSES.

PUNCH TAP, DİŞ FREZESİ VE OVALAMA KILAVUZ YÖNTEMLERI İLE AÇILMIŞ DİŞLERİN YORULMA DAYANIMI VE DİŞ MUKAVEMETLERİNİN DENEYSEL KARŞILAŞTIRILMASI.

ÇAĞRI KAÇMAZ

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Submitted to Graduate School of Science and Engineering of Hacettepe University as a Partial Fulfillment to requirements for the Award of the Degree of Master of Sciences in Mechanical Engineering

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This work named **"Experimental Comparison of Mechanical and Fatigue Strength of Threads Which are Machined by Punch Tap, Thread Milling and Cold Forming Tap Processes"** by **ÇAĞRI KAÇMAZ** has been approved as a thesis for the degree of **MASTER OF SCIENCE IN MECHANICAL ENGINEERING** by the below mentioned Examining Committee Members.

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Dedicated to my son and wife.

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ÇAĞRI KAÇMAZ

ÖZET

PUNCH TAP, DİŞ FREZESİ VE OVALAMA KILAVUZ YÖNTEMLERİ İLE AÇILMIŞ DİŞLERİN YORULMA DAYANIMI VE DİŞ MUKAVEMETLERİNİN DENEYSEL KARŞILAŞTIRILMASI

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Yüksek Lisans, Makina Mühendisliği Bölümü
Tez Danışmanı: Dr. Öğr. Üyesi Mehmet Okan GÖRTAN
Haziran 2018

Yeni geliştirilen "Punch Tap" prosesi ile deliklere iç dişler, konvansiyonel diş frezesi ve ovalama (ezme) kılavuzu proseslerinin çalışma prensiplerinin kombinasyonu şeklinde açılmaktadır. Bu durum iki konvansiyonel prosesin avantajlarını birleştirmekte ve imalat sürelerinin %75 oranında kısaltmaktadır. Ancak "Punch Tap" prosesi kullanılması halinde, vidalı bağlantılar için önemli olan iki özellik, mekanik ve yorulma dayanımının nasıl olduğu bilinmemektedir.

Ovalayarak diş açma ve diş frezeleme yöntemlerinin kombinasyonu olan "Punch Tap" prosesinde açılan dişlerde diş yüzeyinde yarım sonsuz sembolüne benzer bir şekil oluşmaktadır. Diş yüzeyinde oluşan bu durumun diş mukavemeti üzerine etkisi şu ana kadar bilinmemektedir.

Bu nedenlerle tezde alüminyum 6061-0 alaşımında, konvansiyonel yöntemler olan diş frezeleme ve ovalama (ezme) kılavuzu yardımı ile açılan dişlerin yorulma dayanımı ve diş mukavemetlerinin yeni teknoloji olan Punch Tap ile açılan dişler ile deneysel olarak karşılaştırılması yapılmıştır.

Yapılan çalışmalarda kullanılan alüminyum alaşımı 6061-0 olup, her üç yöntem ile açılan dişler çekme testine ve yorulma testlerine tabi tutulmuştur. Fakat çekme ve yorulma deneyleri için piyasada ki civatalar mukavemet olarak yeterli gelmeyeceğinden, soğuk iş takım çeliği olan 1.2379 malzemesinden cıvata üretimi gerçekleştirilmiştir.

Yapılan çalışmada imalat yöntemi kaynaklı farklılığın diş mukavemeti üzerine etkisi araştırılmış olup, konvansiyonel yöntemler ile arasındaki mukavemet ve yorulma farklılıkları araştırılmıştır.

Anahtar Kelimeler: diş frezesi, ovalama kılavuzu, punch tap, mekanik mukavemet, yorulma dayanımı, alüminyum alaşımları

ABSTRACT

EXPERIMENTAL COMPARISON OF MECHANICAL AND FATIGUE STRENGHT OF THREADS WHICH ARE MACHINED BY PUNCH TAP, THREAD MİLLİNG AND COLD FORMING TAP PROCESS

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June 2018

"Punch Tap" is a combination of conventional thread mill and cold forming tap processes for female threads. This method is shortening production times up to 75% in an efficient way while combining advantages of both conventional method of thread milling and cold form tapping. However, there are lack of knowledge about mechanical and fatigue strength of the threads which are produced by "Punch Tap".

On the threads produced by Punch Tap, there is a scratch on the thread surface, called as helical grove because of the machining process. There was no research about the scratch on the thread surfaces. Effect of that scratch is still unknown.

In this thesis; there will be comparison of mechanical and fatigue strengths of threads produced by thread milling, cold form tapping and the new technology of Punch Tapping on Aluminum Alloy 6061-0.

Aluminum alloy 6061-0 is subjected to tests of mechanical strength and fatigue strength test for all threads produced with thread milling, cold form tapping and punch tapping. Since most common screws are not so suitable for fatigue and mechanical strength test, screw from cold working steel of 1.2379 was produced by Hacettepe University Mechanical workshop.

In this master thesis effect of scratch has been investigated. Mechanical strength and fatigue strength of the threads which is produced by Punch Tap has been compared and investigated with the thread milling and cold form tapping threads.

Key words: thread mill, cold forming tap, punch tap, mechanical strength, fatigue strength, aluminum alloy

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I want to thank as a last to my family for their courage to write down this master thesis. They have always support me and I couldn’t even start without them.

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1 INTRODUCTION

1.1 Introduction

As a connection element in mechanical engineering; bolts and internal threads are common in the industry. These connections are generally loaded with dynamic loads. There are some standards about the behavior of bolts under dynamic loading. [1]–[3]. However, there are few researches about internal threads.

It is easy to measure or collect data on the external threads about dynamic loads and fatigue capability of the external threads [2]. Grierson, Anita E.; VanIngen-Dunn, Caroline investigated on the bolts loading for the defense industry and obtained the bolts failure at different loadings [4]. J.E. Field (1984) investigated the fatigue strengths of the internal threads regarding to different kind of materials with same internal thread size and they had found that production method effects fatigue strength of the threads [5].

However, internal threads are used more often than external threads in many designs. In many designs which has been done in the light of information of bolt's loading capacity, may lead to fatigue problems of deformations on the internally threaded connections. In many cases engineers can design a machine using this external thread load capacity. This is going to lead unexpected problems on the design. Fatigue based problems are common in especially internally threaded connections. In this master thesis fatigue characteristics of the internal thread will be investigated.

2 STATE OF THE ART

2.1 Cold Forming Tap

Cold form tapping technology is quite new when it is compared with the thread cutting technology. Due to literature first patent published in 1998 [6] . Cold forming process is basically shaping process with plastic deformation on metal.

Figure 1 Cold Forming Tap [10]

Because of cold forming process there are no chips produced on production. That leads several advantages. Forming process increases the quality of thread because there are forming instead of cutting. That means, material flows instead of cutting [7].

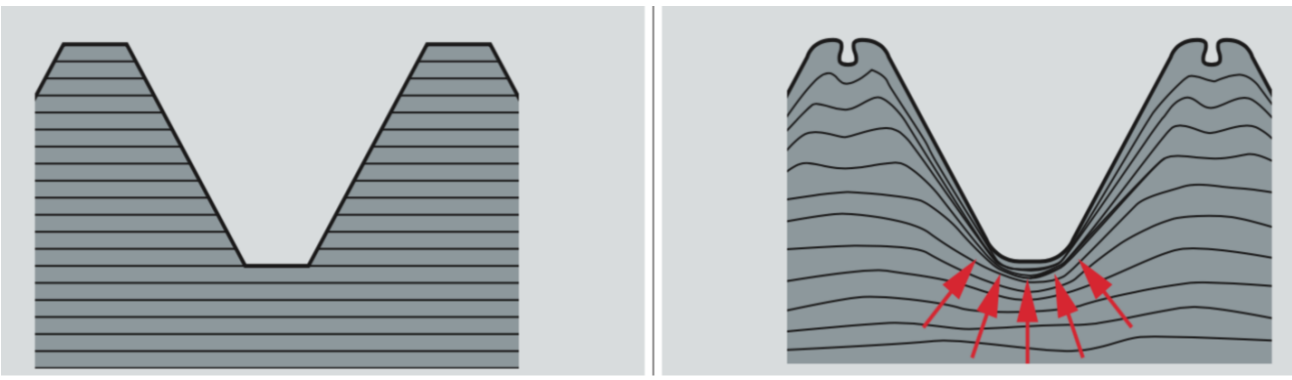


Figure 2 Difference Between Sharp Edge and Formed Edge of Thread [10]

Another effect is the lack of from sharp edges. At the sharp edges, notch effect is possible. However, at cold forming process material flow leads into more stable and strong teeth compared with cutting threads [8]. The cold forming of threads, according to DIN 8583-5, belongs to the pressure forming process [9]. The internal thread is produced by the impression of a helical sequence of thread teeth into the formerly prepared thread hole, the desired profile is formed by pressure.

The lead portion of a cold forming tap is made as a lead taper, in which the helical thread line is continuously increasing in diameter. In the cold forming process, the workpiece material flows from the thread crests along the thread flanks into the area of the minor thread diameter. This creates smooth flank surfaces and the minor diameter is, the typical space pocket [10].

The cylindrical guiding part of the cold forming tap makes the surface of the produced thread even smoother and serves to firmly guide the tool axially. Depending on the workpiece material, the essential advantages of cold forming include excellent surface quality but also increased static and dynamic strength of the thread.

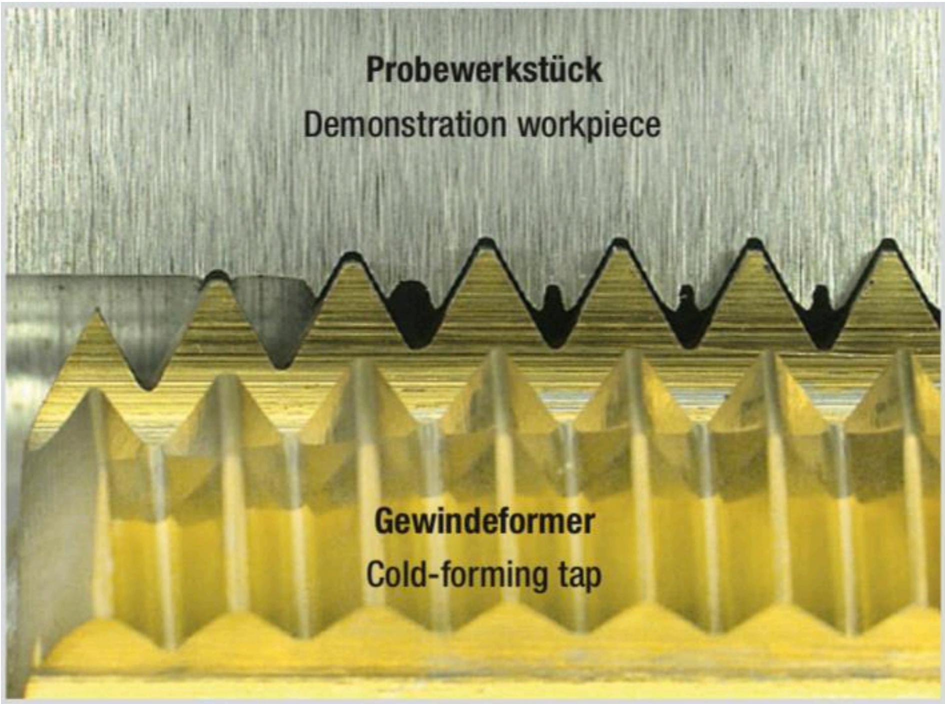


Figure 3 Thread Produced by Cold Forming Tap [10]

2.2 Thread Milling Cutter

Thread milling cutter is basically an end mill which is able to produce threads with the thread form of the product.

The tap operation requires same diameter with demanded size of the thread. The main difference from tapping and thread milling operation is that tapping operation is continuous cutting but thread milling operation is interrupted cutting.

For the thread milling operation basically 3 axis capable CNC machine is required because tool need motion in helical and circular direction [11].

Figure 4 Thread Milling Cutter [10]

For the mass production, thread milling cutter serves with several advantages.

- Short production times due to tapping process
- High degree of process safety
- Combination of different machining jobs with one tool
- Usable thread depth down to the very bottom of the hole
- No chip problem, because only short milling chips are produced during process
- Thread production independent of thread size and tolerance
- Suitable for thin-walled workpieces

2.3 Punch Tap

Punch tap is an invention from Emuge-Franken GMBH in Germany. The Emuge Punch Tap technology combines tapping, cold forming of threads and thread milling.

Figure 5 Punch Tap [12]

A comparison between the tool path of the Emuge Punch Tap with the tool path conventional taps or cold forming taps shows that the path of the Punch Tap approximately 15 times shorter for M6 thread with 13 mm thread depth. The result is a significant time saving up to 75% in a threading cycle.

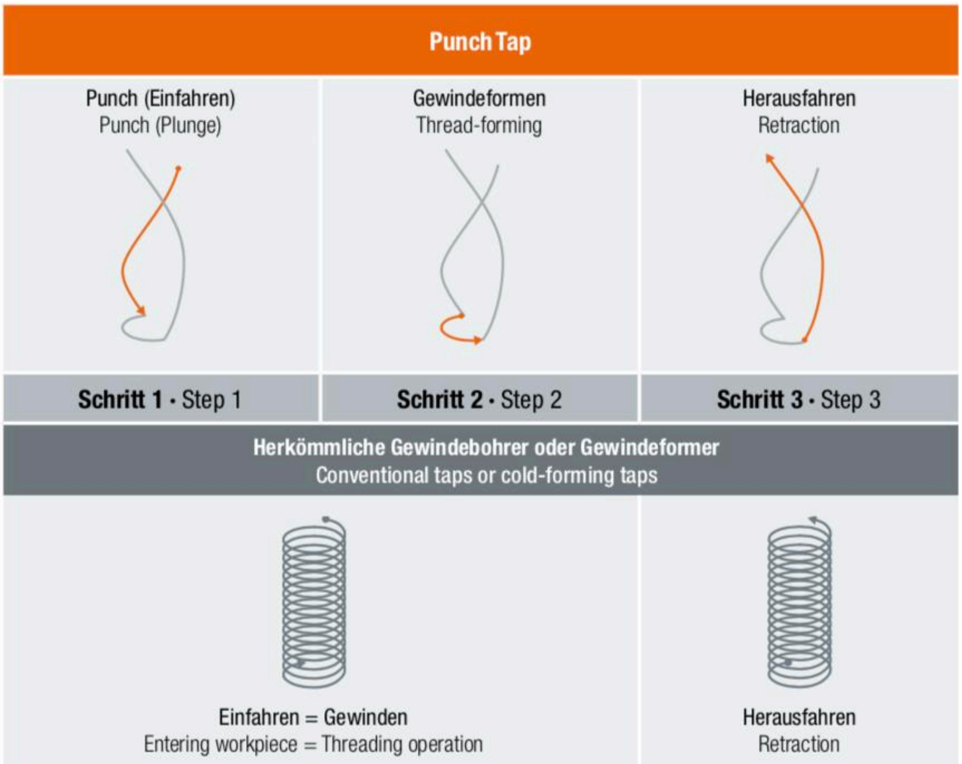


Figure 6 Illustration for Punch Tap and Conventional Threading [12]

Since, punch tap is combination of thread milling and cold form tapping operation there are some similarities and differences at the thread surface.

Thread strength is comparable with the cold forming tap since the material is formed [12]. Continuous fibre structure is seen at the thread surface compared to cutting threads. However, there are helical grove on the thread surface on the Punch Tap [13].

On the *Figure 6* process PT 1.0 has been shown. During punch tapping process there are pull out and compressive forces produced on the CNC machine spindle. To reduce this forces PT 1.5 and PT 2.0 had been improved by Emuge Franken GMBH.

Figure 7 Comparison of Cut, Cold formed & Punch Tap Threads [12]

2.4 Literature Review

There are several researches about tapping and thread milling. Irfan Ay and Kerem Demircioğlu (2005) investigated on cutting tap thread production and cold formed tapping production processes. They had researched on advantages of cold formed threads compared to cut threads. They had found that because of cold forming process is no chipping process; tool life is better than cut taps. Also they had found that cold formed threads are stronger than cut taps [10].

Kamil Feratoğlu (2015) investigated the tensile strengths of the threads which were produced thread cutting with tap. On that research, several pull out tests made on threads with different scenarios. The effect of thread length, thread size and thickness of nut had been investigated [14].

Also, Agus Santosa Sudjono, Lydia F. Tjong and Yohannes (2008) investigated the tension strength of thread connections due to depth of thread penetration. Due to their research thread depth has an influence on the thread's tension strength. They claim that thread depth must be at least 90% of the nominal thread diameter to get maximum tension strength from the thread itself. Also they found that, maximum load of the thread is not linear regarding to thread depth [15].

Alessandra Olinda de Carvalho, Lincoln Cardoso Brandão, Túlio Hallak Panzera and Carlos Henrique Lauro (2012) worked on cold form tapping. They investigated effects of pre hole diameter, cutting speed and tool coating on the microstructure of thread and also torque and force diagrams [16].

There are not so many studies on mechanical strength comparison of the thread forms like cut thread and cold formed thread. However, Peter Kopton, Dietmar Hechtle, Dirk Biermann, Yang Liu, Ivan Iovkov had worked on the punch tap working mechanism, torque & force diagrams. The strength comparison also had been done in this research and they showed that punch tap thread has similar mechanical strength value with cold forming tap [12].

3 AIM AND SCOPE OF THESIS

Punch Tap is a new technology. Because of the helical grove on the thread surface on the Punch Tap process; there is no consensus about thread strength.

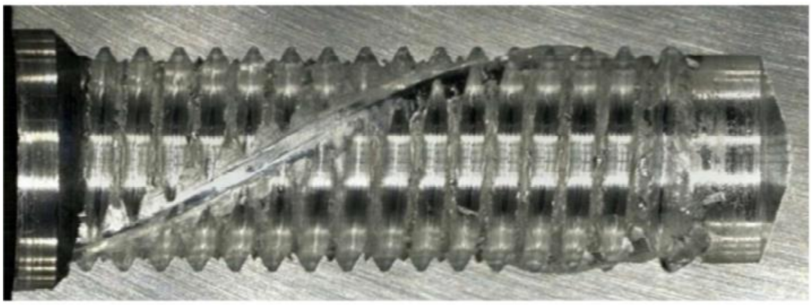


Figure 8 Punch Tap Thread with Helical
Grove

In this master thesis threads machined by Punch Tap will be compared with the threads machined by cold forming tap and thread milling cutter. There will be mechanical strength measurements and also fatigue strength measurements on the samples of Aluminum alloy 6061-0. In this thesis effect of helical grove on Punch tap on a thread surface will be investigated with mechanical strength and fatigue strength measurements.

4 SAMPLE PRODUCTION AND TEST MECHANISM

4.1 Production of Samples

Three types of samples were produced for this master thesis; namely thread milled, cold formed and punch tapped internal threads. All these thread samples were produced in Emuge Franken GmBH in Nuremberg Lauf an der Pegnitz, facilities. Detailed information about samples were already specified below.

4.1.1 Cold Formed Thread

Cold formed thread was produced in Brother TC-22A CNC tapping center. Tap and pre-hole diameter from Emuge Franken GMBH had been used to machine the Aluminum 6061-0 samples.

Figure 9Brother TC-22A Tapping Center
for Cold Forming Tap Sample

Because of the forming process pre-hole diameter of cold forming tap is calculated differently. Calculation formula is [2];

$$Cold\ Forming\ Drill\ Size = Tap\ Nominal\ Diameter(mm) - \left(\frac{65xP(mm)}{147{,}06}\right)$$

For M6 size Pre-Hole diameter calculated as;

$$M6\ Cold\ Forming\ Drill\ Size = 6 - \left(\frac{65x1}{147{,}06}\right) \approx 5{,}6mm$$

Produced samples had been machined by 6HX tolerance cold forming tap. Gauge control had been done on the sample threads. Also working conditions of the drill and tap had been specified below.

- Drill Working Conditions
  - Vc= 240 m/min
  - f=0,22 mm/rev
- Tap Working Conditions
  - Vc=20 m/min
  - f=1 mm/rev
- Hole Depth: 18 mm
- Thread Depth: 12 mm
- Production Time: 8 s

4.1.2 Thread Milling Samples

There are several methods to produce a thread. Tapping is one of oldest method in the machining. Basically, tapping operation requires certain nominal diameter for the required thread size. Because of the tapping operation is helical-circular motion there is continuous cutting on the tapping operation [11]. Cutting forces on the tapping operation can be calculated theoretically and these values would be reliable with practical values.

Although, thread milling cutters are used as thread tool in the market there are several differences compared to tap. As a first difference, thread milling operation requires interrupted cutting. Because of this interrupted cutting action; there are various cutting forces on the thread milling machining. That leads easy machining for large dimensions [17]. Thread milling cutter is working as helical interpolation and machines the pre-drilled hole to desired thread size. Since the thread milling needs interrupted cutting; required cutting force and machine power can be reduced with this method.

Thread milling samples machined in Deckel Maho DMC 835V Vertical CNC machine in Emuge Franken GMBH Lauf an Der Pegnitz facilities on Aluminum 6061-0. Also hole and thread specifications are listed below.

Figure 10 Deckel Maho DMC 835V CNC Machine for Thread Milling Cutters

Although tapping operation can be done by hand, thread milling operation needs thread milling NC cycle and at least 3 axis Synchronized CNC machine. NC cycle to produces test samples located below in Figure 11

CNC internal thread milling (climb milling, on the contour, incremental, acc. Heidenhain)

1	TOOL CALL		1 Z	S 6635				
2	L	X . . .		Y . . .	Z 2	R0	F MAX	M3
3	L	IZ- 14,000		R0	F MAX			
4	L	IY 0,5		F 265	(contour)	M 110		
5	L	IX 2,50		RL				
6	CC	IX- 2,50		IY 0				
7	CP	IPA 90		IZ 0,25	DR+	[F 26] 3) (1/2 centre point)		
8	CC	IX 0		IY- 3				
9	CP	IPA 360		IZ 1,00	DR+	[F 53] 3) (centre point)		
10	CC	IX 0		IY- 2,50				
11	CP	IPA 90		IZ 0,25	DR+			
12	L	X . . .		Y . . .	R0 M 111		F MAX	
13	L	Z 2		F MAX				

Machining time t_h : 6,0 sec.

Figure 11 Thread Milling NC Cycle due to Heidenhein Programming

4.1.3 Punch Tap Samples

Since punch tap is a combination of cold forming tapping and thread milling; process needs to have special requirements. Working mechanism of punch tap is shown in Figure 12.

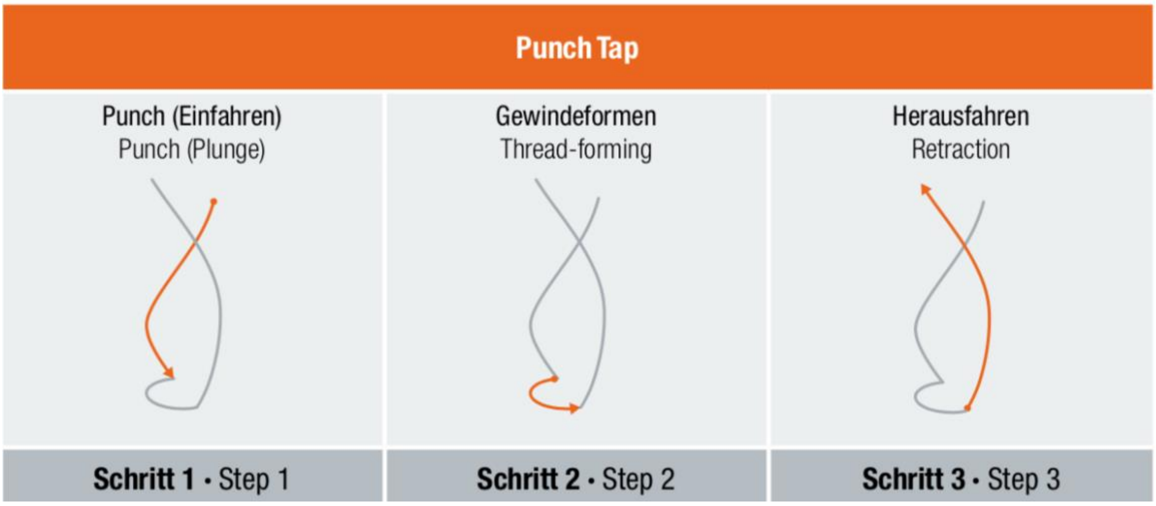


Figure 12 Working Mechanism of Punch Tap[13]

There is special NC cycle needed for the Punch Tapping operation. NC cycle already specified below in Figure 13.

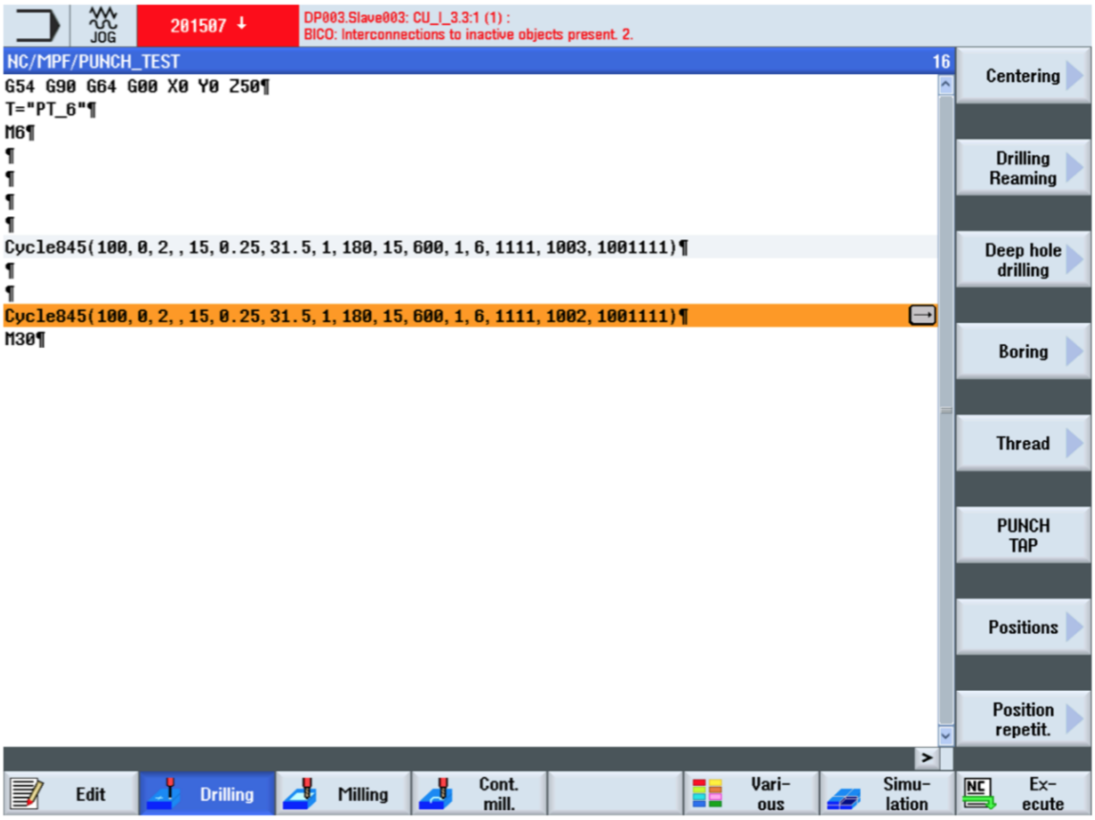


Figure 13 Punch Tap NC Cycle for Siemens Controller

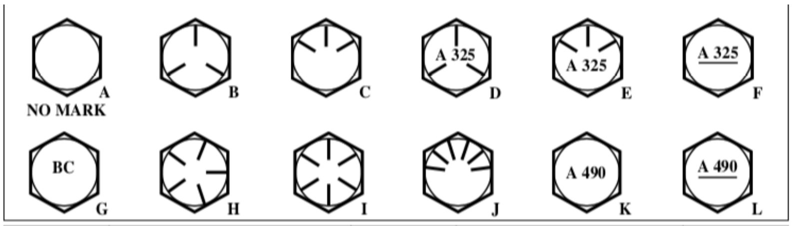
Punch Tap samples machined in Deckel Maho DMC 835V Vertical CNC machine in Emuge Franken GMBH Lauf an Der Pegnitz facilities on Aluminum 6061-0. Also hole and thread specifications listed below.

- Hole Depth:18 mm
- Thread Depth: 12 mm
- Production time: 0,7 s

4.2 Production of Screw for Pull Out & Fatigue Test

There are several types of bolts, screws and other fasteners in the industry. They are marked on the head with the class and their grades. These markings belong to the ASM and SAE standards [2].

Investigating the Figure 14; it is obvious that, screws in the industry is not available for the mechanical strength measurements of the threads produced. Because of that factor; screws had been produced from X155CrVMo12-1 cold working steel. This cold working steel is known as 1.2379 in the industry. Screws hardened to 55-58 HRC after production.



Identifier	Grade	Size (in.)	Min. Strength (10^3 psi)			Material & Treatment
			Proof	Tensile	Yield	
A	SAE Grade 1	¼ to 1½	33	60	36	1
	ASTM A307	¼ to 1½	33	60	36	3
	SAE Grade 2	¼ to ¾	55	74	57	1
		⅞ to 1½	33	60	36	
	SAE Grade 4	¼ to 1½	65	115	100	2, a
B	SAE Grade 5	¼ to 1	85	120	92	2,b
	ASTM A449	1⅛ to 1½	74	105	81	
	ASTM A449	1¾ to 3	55	90	58	
C	SAE Grade 5.2	¼ to 1	85	120	92	4, b
D	ASTM A325, Type 1	½ to 1	85	120	92	2,b
		1⅛ to 1½	74	105	81	
E	ASTM A325, Type 2	½ to 1	85	120	92	4, b
		1⅛ to 1½	74	105	81	
F	ASTM A325, Type 3	½ to 1	85	120	92	5, b
		1⅛ to 1½	74	105	81	
G	ASTM A354, Grade BC	¼ to 2½	105	125	109	5,b
		2¾ to 4	95	115	99	
H	SAE Grade 7	¼ to 1½	105	133	115	7, b
I	SAE Grade 8	¼ to 1½	120	150	130	7, b
	ASTM A354, Grade BD	¼ to 1½	120	150	130	6, b
J	SAE Grade 8.2	¼ to 1	120	150	130	4, b
K	ASTM A490, Type 1	½ to 1½	120	150	130	6, b
L	ASTM A490, Type 3					5, b

Figure 14 Grade Identification Marks and Mechanical Properties of Bolts and Screws [13]

Screws had been produced in the Hacettepe University Mechanical Engineering workshop. Produced screw is shown in Figure 15

Figure 15 Screw Made from
1.2379 Cold Working Steel

4.3 Tensile Test for Mechanical Strength Measurements

Mechanical Strength measurements had been done in the Hacettepe University Mechanical Engineering laboratories.

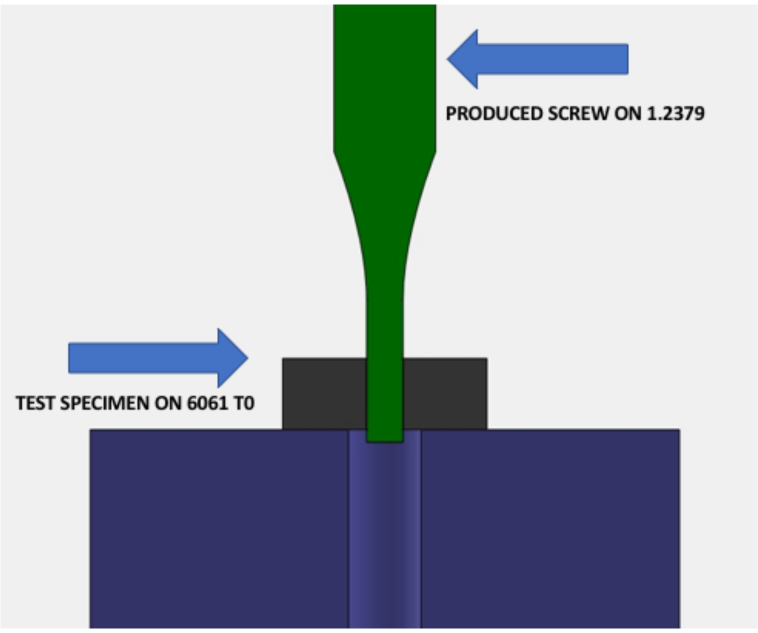


Figure 16 Test Setup Design for Tensile Test

Main criteria in these measurements is determination of the differences all of three different threads. Although thread sizes are the same, machining methodologies are different on the samples. All of the samples machined to M6-6H tolerance and also screw had been made with the size of M6-6g tolerance.

There are several researches on the threads which are machined by thread milling cutter or cold forming tap [11], [15]. However, there is no study on the threads which are machined by punch tap. In this master thesis, effects of helical grove on the punch tapping thread surface will be investigated and compared with the threads from thread milling cutter and cold forming tap. First step of this comparison is going to be mechanical strength measurements on the thread surfaces.

Test machine was supplied by BESMAK Laboratory machines. It has 300 mm piston stroke which is controlled by two stage dynamic servo valve with high flow rate and high step response. Test machine also work with 4 Hz frequency. However, during fatigue tests some concentricity problems were detected. To solve this problem special bearing for the piston strokes had been designed and produced in Hacettepe workshop.

Figure 17 Test Setup for Mechanical Strength Measurement

5 EXPERIMENTAL RESULTS

5.1 Tensile Test with Aluminum 6061-0

First test had been done on the 6061-0 grade aluminum alloy to determine yield and tensile strength of the test material. This test will guide us to determine real strength of the threads compared to material itself.

Due to test, tensile strength of Aluminum 6061-0 found as 149,4 MPa. Results are shown on the graph.

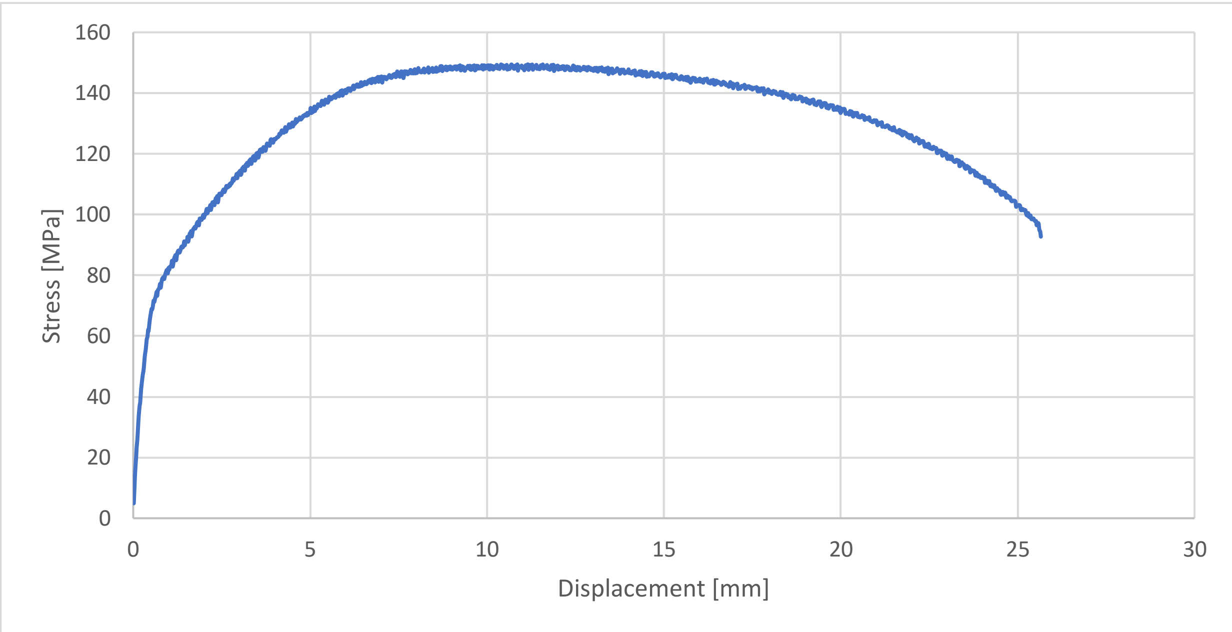


Figure 18 Tensile Test Result of Aluminum 6061-0 Grade

5.2 Tensile Test with Three Types of Threads

Tensile test had been done for three types of threads. Mechanical strength values from the pull-out forces found below;

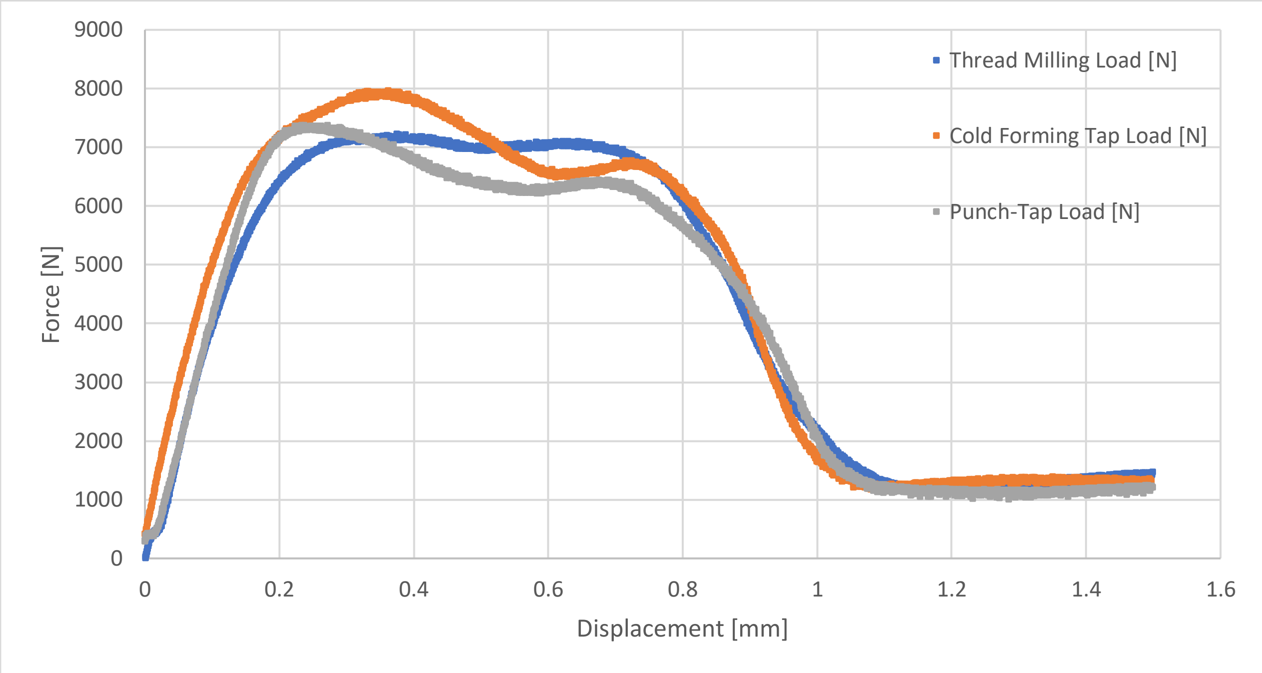


Figure 19 Pull-Out Test for Three Types of Threads

- Thread Milling Thread: 7219,52 N
- Cold Forming Thread: 7964,30 N
- Punch Tap Thread: 7367,54 N

Tensile test gave the results in the unit of Force [N]. to calculate tensile pressure as a MPa calculation specified below.

$$\sigma = \frac{F}{A}$$

$$A = \pi r^2$$

$$R = 6\ mm$$

$$r = 3\ mm$$

$$A = 3{,}141592 * 3^2$$

$$A = 28{,}275\ mm^2$$

From this calculation stress values calculated below;

- $\sigma_{Cold\ Forming}$=281,823 MPa
- $\sigma_{Punch\ Tap}$=260,706 MPa
- $\sigma_{Thread\ Milling}$=255,468 MPa

Also, tensile strength comparison of tread milling, cold forming and punch tapping threads are shown in Figure *20*.

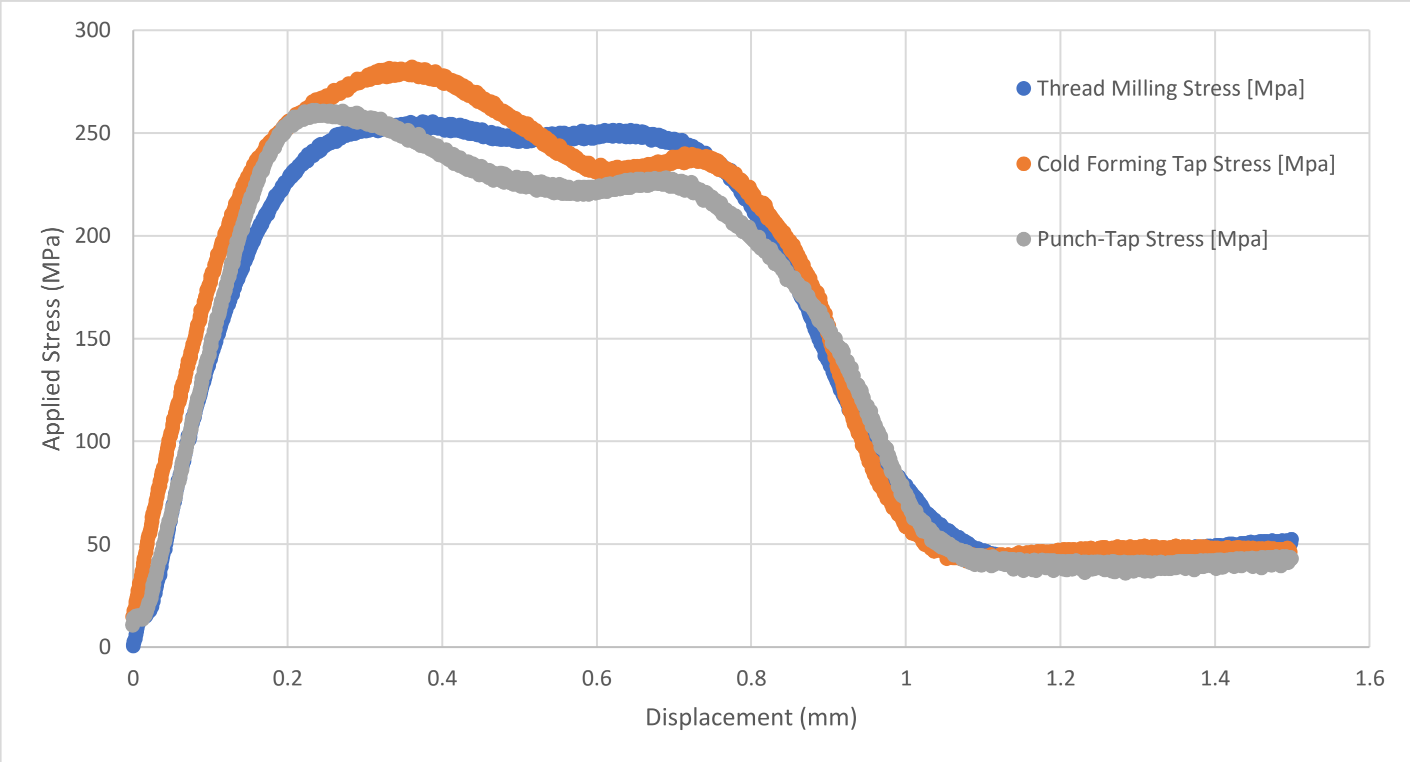


Figure 20 Tensile Strength Comparison of Three Types of Threads

5.3 Fatigue Test for Three Types of Threads

Fatigue test results are shown with S-N Curve in *Figure 21*. As expected cold forming tap has highest fatigue strength value because of the cold forming process. Continuous fibre structure on the cold forming process eliminate the notch effect which is coming from sharp edges on the thread cutting process. That explains clearly why cold formed thread has highest fatigue strength values.

Although punch tapping process is cold forming process, punch tapped thread is weaker than cold formed tap and thread milled thread in the fatigue strength comparison. It seems that, helical grove on the thread surface effects strength of the thread strength. Helical grove on the punch tapped thread surface may reduce the contact surface between screw and the thread and this could be the reason of the weakness of the thread instead of there is continuous fibre structure at the punch tapped thread.

On the other hand, punch tapping process could be the reason for the unexpected low life cycle of the punch tapped thread. On the PT 2.0 process over forming is possible. Over forming may be the main reason to reduce fatigue strength of the punch tapped thread.

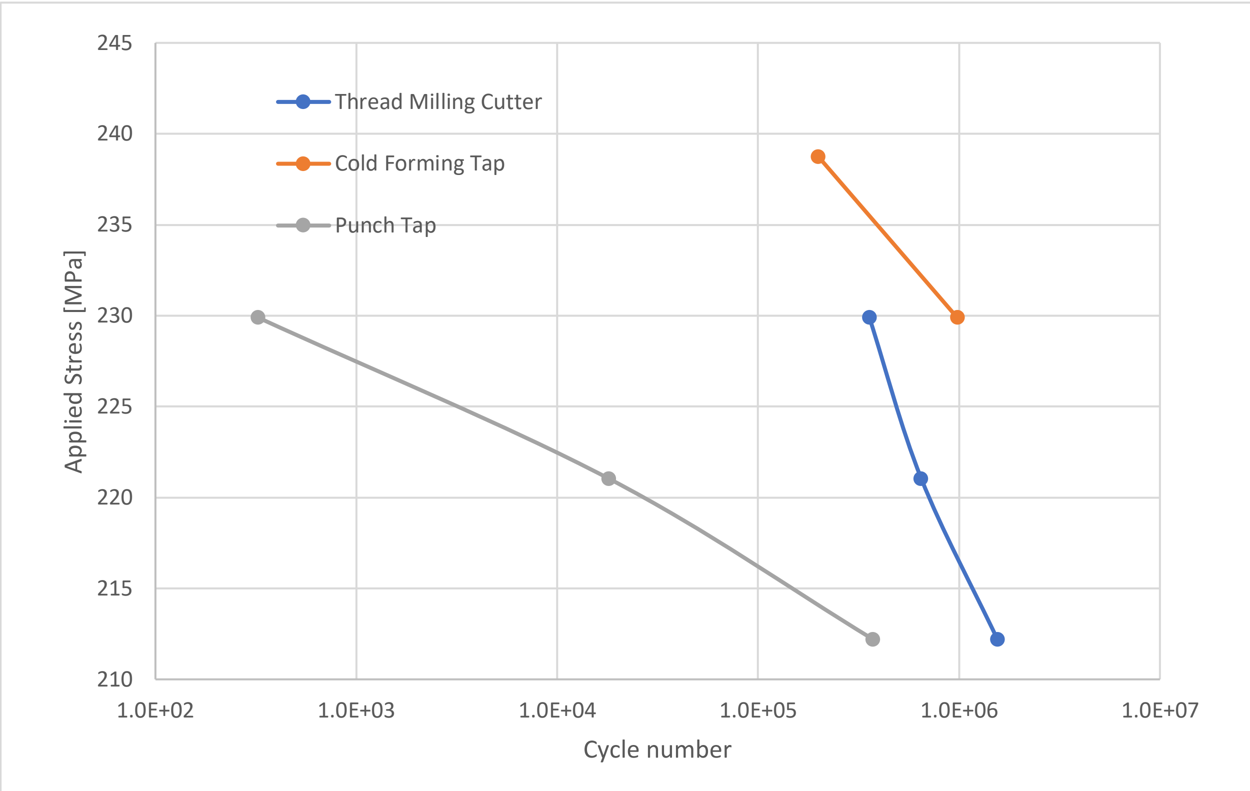


Figure 21 S-N Curve of Three Different Thread Type

6 CONCLUSION AND DISCUSSION

Due to plastic deformation during cold form threading process; mechanical strength values are higher than other two thread types. Continuous fibre structure on the cold form tapping and punch tapping leads more strength values for the internal threads compared to cutting threads.

On the other hand, thread milling cutters create sharp edges and these sharp edges may generate notch effect at the internal thread. Differences of thread milling cutter and cold forming tap is seen in microscope picture from the samples. Material structure and continuous fibre of the material is already shown in Figure *22*. As an additional information; punch tap thread and cold forming thread has same material structure.

Idea behind the cold forming tap and punch tap is basically producing of internal thread via forming of the material. Due to forming process, expected internal thread strength and fatigue strength of those internal threads are higher than cutting thread.

Processes cold forming tapping and punch tapping are providing high tensile strength on the internal threads as expected. However, on the fatigue strength thread milled internal thread unexpectedly has higher life cycle than punch tap. There could be some reasons for this unexpected result.

In Figure 23 three samples are investigated under optical microscope. Effects of cutting and rolling are shown clearly from material flow in Figure *22*. However, punch tapping thread sample is looking like over formed. Over forming is one of the main reasons of reduction life cycle.

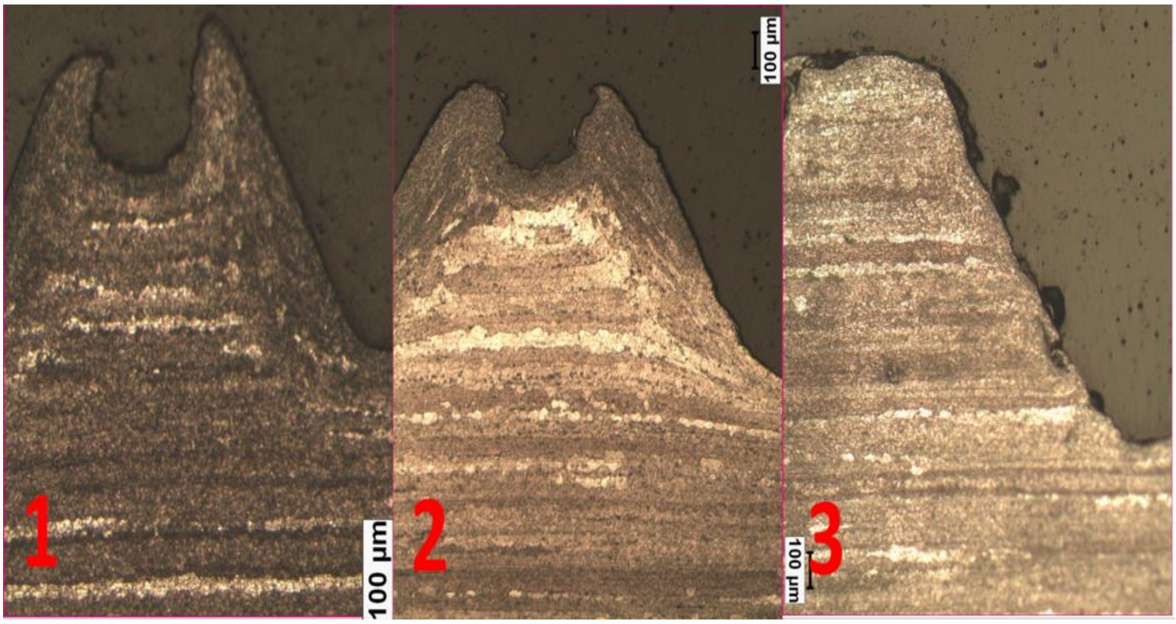


Figure 22 Microspoce Picture of the Threads 1- Cold Form, 2-Punch Tap 3-Thread Mill

On the thread forming process pre-drill diameter is simply larger than pre-hole diameter in thread cutting process. This is because of the forming philosophy. Under auspices of forming process, material is swelling to demanded tolerance minor diameter.

Although major and minor diameter of over formed threads are in between the tolerance values, over forming basically effects the strength of the threads because of the reduced contact surface with the screw. Also, perfect formed internal thread and over formed internal thread comparison is shown in *Figure 23*. This effect could be the explanation of lowest life cycle of punch tapped thread. Major diameters of the internal threads also shown in Figure *24*.

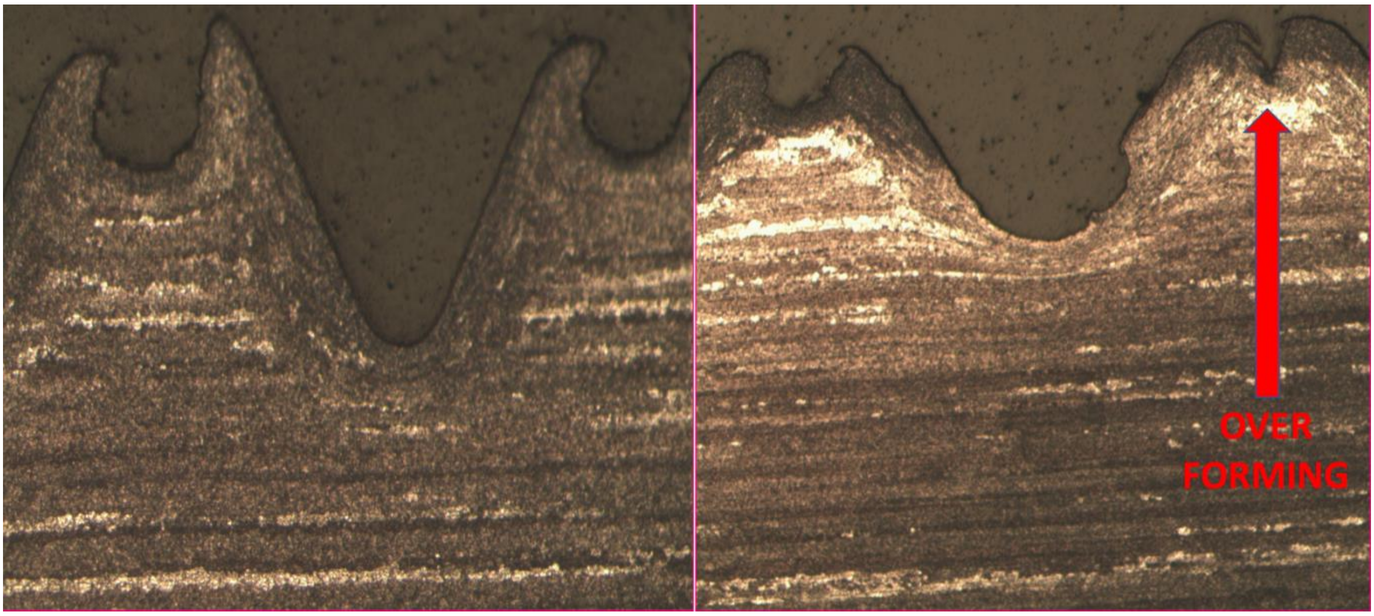


Figure 23 Forming Comparison of Cold Formed and Punch Tapped Internal Thread

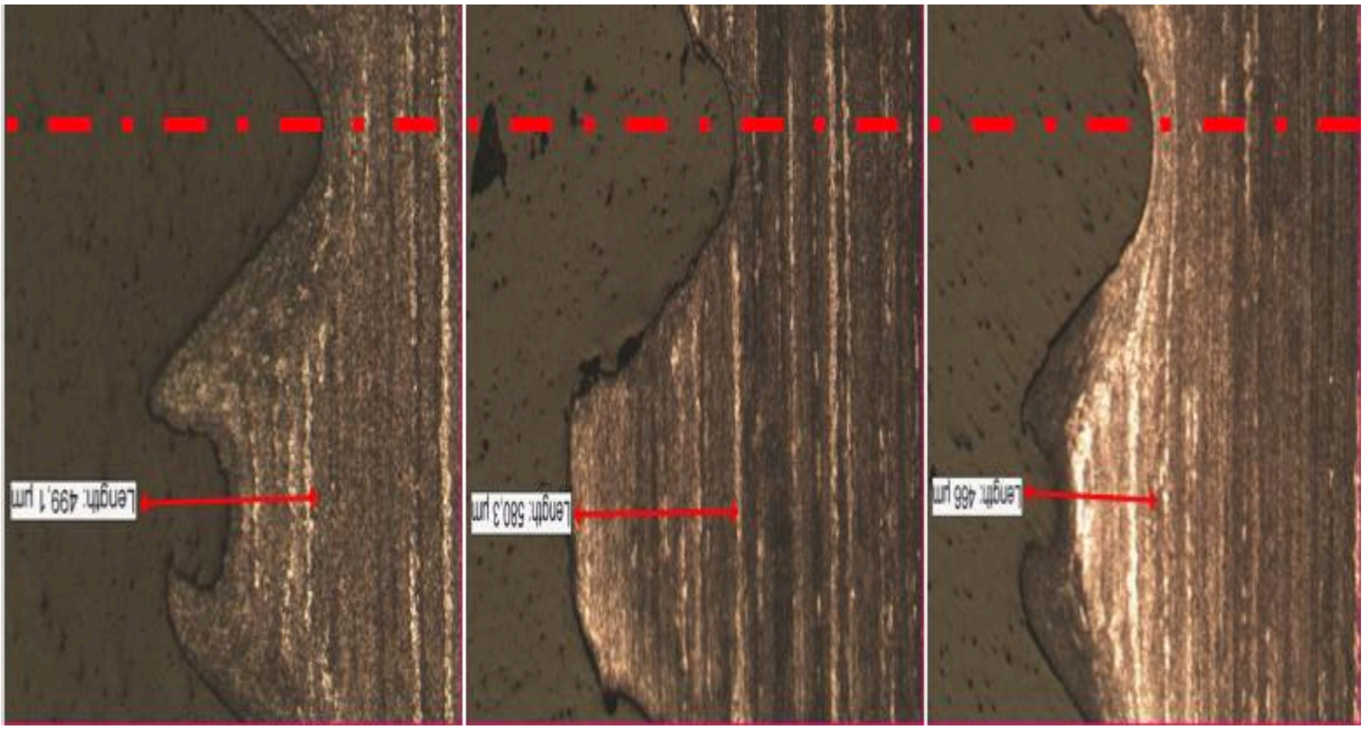


Figure 24 Major Diameters of Three Different M6-6H Internal Threads

As a conclusion, mechanical and fatigue strength of the internal thread had been investigated in this master thesis. As expected cold forming process leads more mechanical strength and load capability for internal threads. Due to forming process strain hardening had seen on the internal threads. First reason of the higher mechanical and fatigue strength of the threads is strain hardening effect according to machining process.

Second reason is that forming process eliminate the notch effect on the sharp edges from the cutting process on the internal thread machining. Because of its mechanical strength of cold formed and punch tapped internal thread is higher than thread milled internal thread.

On the other hand, although punch tap is mainly a forming process; dynamic load carrying capability is lower than cut tap in the fatigue strength measurements. It may have several reasons. First, owing to optical microscope investigations, over forming was shown on the punch tapped threads. Over forming is mainly a failure for internal thread machining process and reduces the load capacity of the internal thread. Secondly, there is a helical grove on the punch tap surface. This helical grove may reduce the contact point between bolt and internal thread and may cause the reduction of load capacity of the internal thread.

All in all, question marks about helical grove on the punch tap surface had been answered on a limited stage. However, since punch tap is a living project, there will be more test on the different internal threads with the improvement on punch tapping process.

REFERENCES

[1] German Institute for Standardisation (Deutsches Institut für Normung), "DIN 76-1 (2004-06) | Thread run-outs and thread underc... | SAI Global."

[2] E. Oberg and C. J. McCauley, *Machinery's handbook : a reference book for the mechanical engineer, designer, manufacturing engineer, draftsman, toolmaker, and machinist*. Industrial Press, 2012.

[3] DIN EN 22568, "Hand and machine-operated circular screwing dies and hand-operated die stocks."

[4] C. Grierson, Anita E.; VanIngen-Dunn, "Bolt Loading Standard," *Afmc*, p. 99, 1995.

[5] J. E. Field, "The fatigue strength of internal threads in three materials," *Mater. Des.*, vol. 5, no. 1, pp. 20–26, 1984.

[6] K. S. Teruo Sawabe, Isao Yokoyoma, "United States Patent (19)," no. 19, 1998.

[7] D. SÖZÜGÜZEL, "İnce Cidarlı CM22NBK Malzemesi için Sıvayarak Delik Delme (Flowdrill) Prosesi ile Diş Açma ve Alternatif Malzeme Analizi Dilek," 2007.

[8] E. F. GMBH, "Gewindeschneidtechnik · Spanntechnik Thread Cutting Technology · Clamping Technology," 2016.

[9] Deutsches Institut Fur Normung E.V., "DIN 8583-5," 2003.

[10] T. K. D. Asist. Prof. Dr. İrfan Ay, "Kesme ve ovalama yolu ile civate-vida dişi imalat yöntemlerinin kıyaslanması." 2005.

[11] M. Wan and Y. Altintas, "Mechanics and dynamics of thread milling process," *Int. J. Mach. Tools Manuf.*, vol. 87, pp. 16–26, 2014.

[12] I. I. Peter Kopton, Dietmar Hechtle, Dirk Biermann, Yang Liu, "Spanende Fertigung EMUGE 321ff.pdf." .

[13] E. F. GMBH, "Punch Tap," 2015.

[14] K. FERATOĞLU, "Vidalı Bağlantılarda Gövdeye Manuel Olarak Delik Açmada Yapılan Hatalatın Bağlantının Çekme Mukavemetine Etkisi," ISTANBUL TECHNICAL UNIVERSITY, 2015.

[15] A. S. Sudjono and L. F. Tjong, "The Tension Strength Experiment of Thread Connection Based on The Depth of Thread Penetration," vol. 10, no. 1, pp. 45–50, 2008.

[16] A. O. De Carvalho, L. C. Brandão, T. H. Panzera, and C. H. Lauro, "Journal of Materials Processing Technology Analysis of form threads using fluteless taps in cast magnesium alloy (AM60)," *J. Mater. Process. Tech.*, vol. 212, no. 8, pp. 1753–1760, 2012.

[17] S. W. Lee and A. Nestler, "Simulation-aided design of thread milling cutter," *Procedia CIRP*, vol. 1, no. 1, pp. 120–125, 2012.

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