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# Design and Analysis of High Carbon Steel Milling Cutter

**S.Arun[*1], M.Palpandi[2]**
[*1,2] Department of Mechanical Engineering, PSNA College of Engineering and Technology, Dindigul, India
arunsan656@gmail.com

## Abstract

Milling is a production process which is based on material removal using multipoint cutting tools, as a result higher material removal rates can be achieved along with high surface finish.

This paper presents the design of milling cutter and analyse the cutter made o HCS steel for the purpose of predicting the stress and deformation on it and compare the value with cutter made of HSS steel of same dimension at same speed and feed.

Basic design procedure is used to design the cutting for both cutting tools and FEA software is used to find the result..

**Keywords**: Carbon Steel Miling.

## Introduction

Machining is undoubtedly the most important of the basic manufacturing processes, since industries around the world spend billions of dollars per year to perform metal removal. That is so, because the vast majority of manufactured products require machining at some stage in their production, ranging from relatively rough operations to high-precise ones, involving tolerances of 0.001 mm, or less, associated with high quality surface finish .Milling is a process of producing flat and complex shapes with the use of multi-tooth cutting Tool, which is called a milling cutter and the cutting edges are called teeth.The axis of rotation of the cutting tool is perpendicular to the direction of feed, eitherparallel or perpendicular to the machined surface. The machine tool that traditionally performs this operation is a milling machine. Milling is an interrupted cutting

Operation: the teeth of the milling cutter enter and exit the work during each revolution. This interrupted cutting action subjects the teeth to a cycle of impact force and thermal shock on every rotation. The tool material and cutter geometry must be designed to withstand these conditions. As the cutter rotates, each tooth removes a small amount of material from the advancing work for each spindle revolution.

The relative motion between cutter and the work piece can be in any direction and hence surfaces having any orientation can be machined in milling. Milling plays a central role as a shape generating technique in the machining of hollow forms. Such hollow shapes are used in tools for presses, forges, and foundry work. This approach depends on a combination of factors including material, component design, and strength, rigidity of fixturing, and type and age of machine. This characteristic of a tool creates an uneven surface and reducing tool life. In order to reduce the chatter Vibration and increase the tool life, damper has been introduced. Therefore if a tool is to be designed with increased damping, it should have enhanced stability against chatter. The addition of a mechanical damper to the cutting tool can potentially help to stabilize the system against chatter vibration and allows higher productivity. Milling is an interrupted cutting operation: the teeth of the milling cutter enter and exit the work during each revolution. This interrupted cutting action subjects the teeth to a cycle of impact force and thermal shock on every rotation. The tool material and cutter geometry must be designed to withstand these conditions. Cutting fluids are essential for most milling operations.

## Cutting Conditions In Milling

In milling, each tooth on a tool removes part of the stock in the form of a chip. The basic interface between tool and work part is shown in fig.1. This shows only a few teeth of a peripheral milling cutter.

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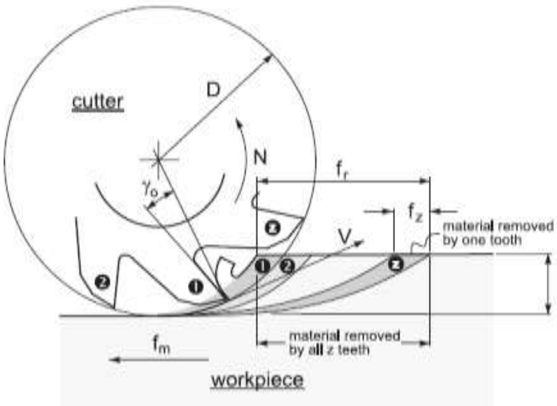


Basics of a peripheral (slab) milling operation.

***Figure1: Milling operation***

Cutting velocity V is the peripheral speed of the cutter is defined by V = πDN, where D is the cutter outer diameter and N is the rotational speed of the cutter.
Cutting speeds are usually in the range of 0.1~4 m/s, lower for difficult-to-cut materials and for rough cuts, and higher for non-ferrous easy-to-cut materials like aluminum and for finishing cuts.

Three types of feed in milling can be identified

- Feed per tooth(fz): The basic parameter in milling equivalent to the feed in turning. Feed per tooth is selected with regard to the surface finish and dimensional accuracy required. Feeds per tooth are in The ranges of 0.05~0.5 mm/tooth, lower feeds are for finishing cuts.
- Feed per revolution (fr): it determines the amount of material cut per one full
- Feed per minute(fm): Feed per minute is calculated taking into account the rotational speed N and number of the cutter's teeth z,

## Design Calculation

DESIGN FOR HCS MILLING CUTTER

Let assume following values

- Wide = 8mm
- Deep = 4mm
- Tensile strength of the work piece 650N/mm²

CUTTING FORCE

F = 60,000*H/π DN

F= 120N

1. ARBOUR DISTANCE
   L= (D/2.5)*10
   L= (110/2.5)*10
   L=440mm
2. TORQUE

   T= $\sqrt{0.07L^2 + 0.25D^2}$

   = $\sqrt{(0.07*440)^2 + (0.25*110)^2}$

   T= 6930 N-m
3. ARBOUR SIZE(A)
   A=$\sqrt[3]{(T)/(0.1*\sigma b)}$
   A= 20 mm
4. DIAMETER OF THE CUTTER
   D= 3*ARBOUR SIZE = 22*3
   D= 66 mm
5. NUMBER OF TEETH ON WHEEL
   N= 2*$\sqrt{D}$ =2*$\sqrt{66}$
   N= 17
6. TOOTH HIEGHT
   H= (D/N)*1.6 = (66/17)*1.6
   H= 6.2mm
7. RADIAL RAKE ANGLE$\alpha_r$ =15°
8. AXIAL RAKE ANGLE$\alpha_{a=}$ 35°
9. PRIMARY CLEARANCE=10°

   SIDE RELIEF ANGLE= 3°

## Material Properties of Tool

**FOR HSS**

Table 1

| | |
|---|---|
| Density (kg/m3) | 7850 |
| Young's modulus, E(GPa) | 205 |
| Poisson's ratio, n | 0.295 |
| Tensile strength(MPa) | 841 |

**FOR HCS**

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TABLE 2

| | |
|---|---|
| **Density (kg/m3)** | **7890** |
| **Young's modulus, E(GPa)** | **210** |
| **Poisson's ratio, n** | **0.30** |
| **Tensile strength(MPa)** | **970** |

**ANALYSIS OF HCS MILLING CUTTER**
CUTTING FORCE =120N
SPEED= 700 RPM
**STRESS**

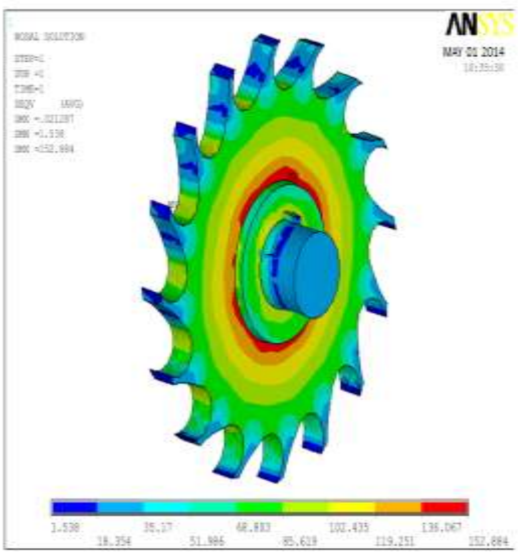

Figure 2

**DEFORMATION**

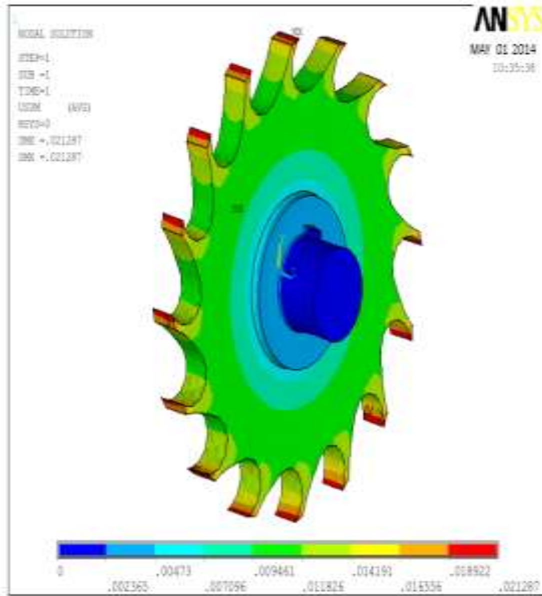

FIGURE 2

**ANALYSIS OF HSS MILLING CUTTER**
CUTTING SPEED =120N
SPEED=700RPM
**STRESS**

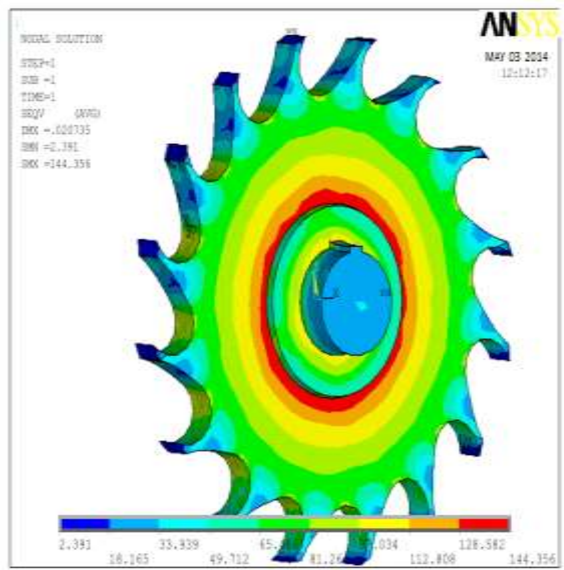

Figure 3

**DEFORMATION**

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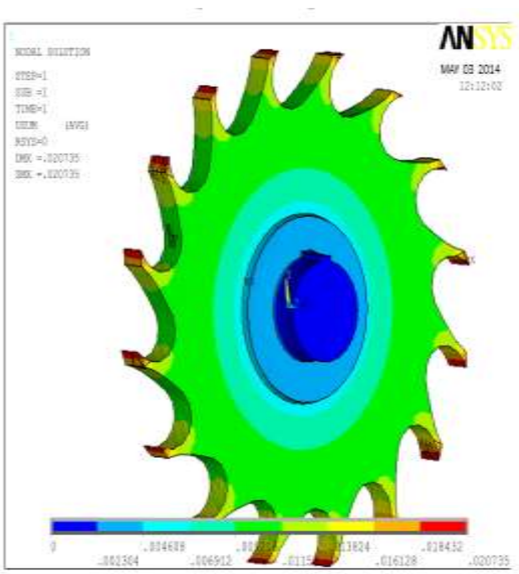


*Figure 4*

## Result And Comparison

Table 3

| Material | Stress (N/mm²) | Deformation (mm) |
|---|---|---|
| HCS | 152.88 | 0.02128 |
| HSS | 144.332 | 0.0207 |

From the table we can see that the more stress predicted in the HCS material. The physical properties are the HSS is more than HCS material. During the cutting action takes places the high impact takes places.

## Conclusion

Based on the stress and deformation analysis done on the milling cutter made of HSS and HCS material more stress and deformation exists on HCS milling cutter than HSS cutter.

So it concluded that HSS material is more suitable than HCS material for making milling cutting tools

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