

Residual Stress Analysis in Milling

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ABSTRACT: The significance of machining parameter optimization is increasing day by day in the current manufacturing scenario. Many large industries have attempted to introduce the highly automated and computer-controlled machines as their strategy to adapt to the ever-changing competitive market requirement. Due to high capital and machining costs, there is an economic need to operate these machines as efficiently as possible in order to obtain the required pay back. This research looks to fill gaps in current residual stress modeling techniques. In particular, the research will focus on predicting residual stresses in milling. An investigation on influence of machining parameters such as number of teeth of the cutter (Z_c) and depth of cut (t) for milling, feed (S) and diameter of drill bit (d) for drilling. These parameters have large influence on the cutting force, and the response parameter is the residual stress. Experiments were conducted. Effects of input parameters on output responses were studied. The simulation is carried out with ANSYS workbench. And finally optimal parameter combination in milling.

I. INTRODUCTION

Residual stresses play an important role in the performance of machined components. Component characteristics that are influenced by residual stress include fatigue life, corrosion resistance, and part distortion. There are many sources of residual stress which include plastic deformation of a material or volume changes of a material due to thermal gradients. In the case of plastic deformation, the residual stress is due to the permanent displacement of the crystal structure. The residual stresses caused by thermal gradients are typically a result of a change in volume of the material.

This research looks to fill gaps in current residual stress modeling techniques. In particular, the research will focus on predicting residual stresses in milling. An investigation on influence of machining parameters such as number of teeth of the cutter (Z_c) and depth of cut (t) for milling. These parameters have large influence on the cutting force, and the response parameter the residual stress. The modeling techniques can be applied to a range of machining operations including orthogonal cutting, broaching, drilling, milling, and turning.

Different approaches to the determination of residual stresses can be summarized as experimental measurements, finite element calculations and analytical models. Although it serves as the ultimate validation tool for numerical or analytical simulations, experimental approach is too costly to be utilized in every scenario. On the other hand, finite element modelling serves as a good simulation tool; however, it is too time-consuming even with state of the art computational resources. And finally, analytical modelling provides a fast alternative.

II. EXPERIMENTAL PROCEDURE

The work piece of size 10cm × 5cm × 3cm is clamped in to the machine and a cut of depth 1mm at 100rpm with cutter having 10 teeth is done. The cutter is of 144mm diameter, the cutter material is HSS and cutter width is 5mm. During machining the work-piece undergoes plastic deformation and the stress induced in it after removing the load is the residual stress.

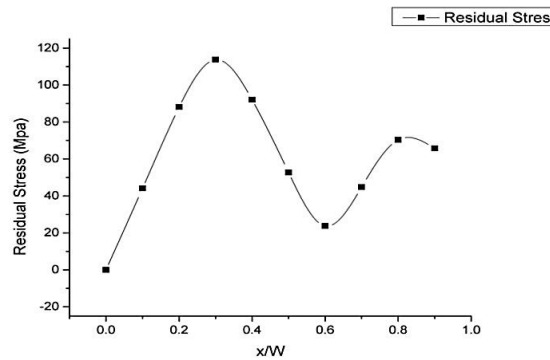


Fig. 1. Graph between residual stress and cutting length

After machining, the work piece is placed into a wire cut EDM machine. Cutting a slit at constant rate is done, at the same time strain is measured by a strain gauge which placed on the work-piece. Cutting length ‘a’ and the strain values are noted. After that the values are substituted in the equations and residual stress is obtained. The work piece is cut up to 4.9cm and the resultant strain values are measured. Now these values are substituted into the equations of crack compliance method. And finally residual stress is obtained. A graph is plot between residual stress and cut length which depends on the width of the workpiece. The highest value from the graph is taken.

We select the maximum value of residual stress from graph, and the residual stress obtained is 113.77 Mpa .From the analysis it is found that, for the cutter having 10 teeth and cutting depth of 1mm, the residual stress obtained is 116.8 MPa. The experimental result is approximately equal to the analytical result. So our model is validated.

Analysis And Optimization

For the analysis cutting force is taken as the input. For that, there are some equations to find the cutting forces. The resultant force acting on the work piece is

$$R = \sqrt{F_{mt}^2 + F_r^2} \tag{1}$$

Where F_{mt} is the mean tangential cutting force in N, F_r is the radial component of force in N.

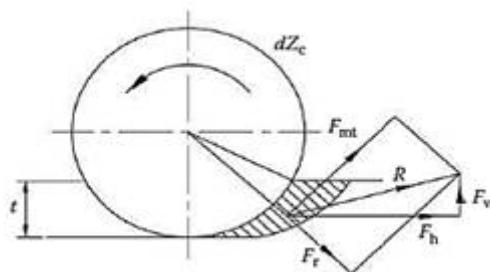


Fig. 2.Resolution of cutting forces in plain up milling

The total mean tangential cutting force, F_{mt}

$$F_{mt} = (K_s t f b_w) / \pi d N \tag{2}$$

Where k_s is the specific cutting energy (N/mm^2), t is the depth of cut (mm), f is the feed rate (mm/min), b_w is the milling cutter width (mm), d is the diameter of the cutter (mm), N is the rotational speed (rev/min).

The radial component of force, F_r

$$F_r = \text{yield strength} \times t \times b_w \tag{3}$$

Where t is the depth of cut (mm), b_w is the milling cutter width (mm).

We know the angle of cut, Θ

$$\Theta = \tan^{-1} \left(\frac{F_{mt}}{F_r} \right) \tag{4}$$

So by finding the cutting angle, we can find the cutting force on horizontal and vertical direction.

The cutting force acting on horizontal direction, F_h

$$F_h = R \cos \Theta \tag{5}$$

Where R is the resultant force (N), Θ is the cutting angle

The cutting force acting on the vertical direction, F_r

$$F_r = R \sin \theta \quad (6)$$

Where R is the resultant force (N), θ is the cutting angle

For each combination of parameter, we have to find the cutting forces.

III. RESULTS & DISCUSSIONS

The main result obtained from the ANSYS analysis for different parameters such as number of teeth and depth of cut is given in the table below and the optimum combination is the combination which having the minimum residual stress.

Table 1: Analysis result of milling.

Sl no	Depth Of Cut, t (mm)	No Of Teeth , Zc	Residual Stress (MPa)
1	1	10	116.8
2		12	119.28
3		14	239.75
4	2	10	120.96
5		12	158.9
6		14	243.08
7	3	10	108.56
8		12	160.61
9		14	246.43

The optimum parameter combination obtained from the analysis is for the cutter having 10 teeth and cutting depth of 3mm.

IV. CONCLUSION

Here residual stresses occurring due to thermo-mechanical effect of machining processes are investigated. The parameter for milling and drilling operation is optimized. Literature reviews on optimization were done. The machining parameters selected were number of teeth of the cutter (Z_c) and depth of cut (t). These parameters have large influence on the cutting force. These are the input parameters and the response parameter is the residual stress. Experiments were conducted to find the residual stress for milling and drilling. ANSYS software was used for analysis the result and these responses were validated experimentally. From the analysis result we have found the optimal combination of parameters for milling and drilling, which generates lowest residual stress. For milling, the residual stress obtained for the optimum parameter combination of the cutter having 10 teeth and cutting depth of 3mm is 108.56 MPa.

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