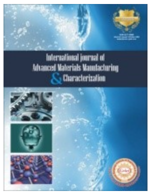

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Residual stress evaluation of mild steel subjected to varied processing Conditions in milling operation

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Abstract

Residual stresses are generated upon equilibrium of material, after plastic deformation that is caused by applied mechanical loads, thermal loads or phase changes. Mechanical and thermal processes applied to a component during service may also alter its residual stress state.

The current work focusses on evaluation of residual stresses when mild steel components are subjected to varied cutting conditions on a milling machine. Varied cutting conditions like depth of cut, coolant conditions, speed and feed are potential machining parameters which have been performed to study the effect of these on residual stresses. Hardness studies before and after machining have also been tabulated.

It is seen that the hardness of the materials have not profound change with varying cutting conditions. It is also seen that the residual stresses have shown significant changes with varied cutting conditions of machining on a milling machine.
Keywords: machining parameters, milling, residual stress, x ray diffraction, hardness

1.Introduction

Residual stresses play vital role in the performance of machined components. Fatigue life, corrosion resistance, and part distortion are depending on the residual stress. The functional behavior of machined components can be enhanced or impaired by residual stresses. Machining-induced residual stress prediction has been a topic of research since the 1950's. Research efforts have been composed of experimental findings, analytical modeling, finite element modeling, and various combinations of those efforts.[1] Henriksen [2] experimented on low-carbon steel orthogonally machined. Their work concluded that mechanical and thermal effects played a role in the residual stress development, but mechanical influence dominated. Sadat and Bailey [3] performed orthogonal cutting experiments on AISI 4340 to determine the effects of cutting speed, feed rate, and depth of cut on residual stress profiles. They used a deflection etching technique to measure the residual stresses. They found that the absolute value of the residual stresses increased with an increase in depth beneath the machined surface. Additionally, peak residual stresses at low speeds were tensile but became increasingly compressive at high feed rates. Sadat [4] also experimented with machining on Inconel-718. That research was an effort to determine the effect of cutting speed and tool-chip contact length on the surface integrity produced by machining. They concluded that both thermal and mechanical effects produced the residual stress distribution and the plastically deformed layer. They showed that the depth to which residual stresses extend beneath the machined surface increases with a decrease in cutting speed. This was due to lower temperatures for lower cutting speeds. Additional residual stress experimental work has been conducted by Schlauer [5]. The work showed that tensile surface residual stresses were due to nano-sized grains while shear bands in the subsurface corresponded to compressive stresses. Jang[6] used turning experiments on AISI 304 stainless steel to determine the effect of machining parameters. Residual stresses were measured using X-ray diffraction. The work showed that the tool sharpness has a strong influence on the surface residual stress. Matsumoto [7] performed experiments on

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residual stress generated in hard turning. Fatigue life tests were conducted which showed that the hard turned components were comparable to fatigue life of ground components due to the high levels of compressive subsurface residual stress. Tsuchida et al [8] experimented on the effect of cutting conditions on the residual stress distribution. They performed tests in which speeds, feeds, and depths of cut were varied. They concluded that a decrease in the cutting speed decreases the tensile residual stress near the surface, and increases the depth of the residually stressed layer. Also, an increase of feed shifted the surface residual stress towards tension while increasing the residually stressed layer. Konig et al.[9] found that a more aggressive feed increases the depth of the affected zone and the level of compressive residual stresses in hard turning of bearing steel. Dahlman et al. [10] reported that an increased feed rate results in significantly higher compressive residual stresses and that a greater negative rake angle gives higher compressive stresses with a deeper affected zone below the machined surface, while depth of cut does not affect residual stress generation. Brinksmeier and Scholtes [11,12] showed that the tensile residual stresses and the depth of the stressed region tend to increase with feed rate.Schreiber and Schlicht [10] and Brinksmeier [11] found that residual stresses increase with cutting speed. The use of a coolant [13] at low cutting speeds reduces the maximum residual stress and the depth of the stressed region, when compared with the results obtained with dry cutting.

2. Experimental Procedure

2.1 Hardness Evaluation

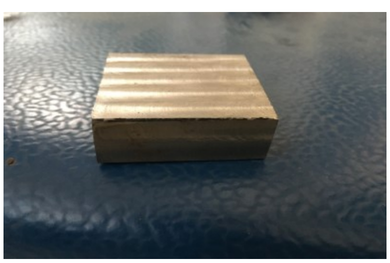

Figure 1: Before milling

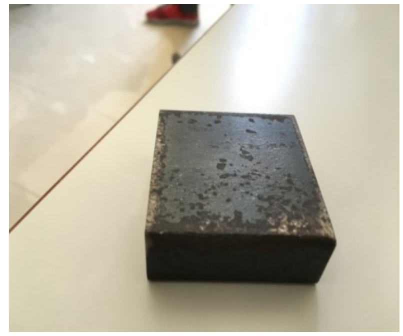

Figure 2: After milling

Rectangular pieces were ground on a belt and emery to obtain a flat surface. A load of 150 kg was applied. The load was applied for 20 seconds and then released. The readings obtained give the hardness of the sample on the Rockwell 'C' scale. The number for all the samples is recorded by converting the hardness values of the Rockwell C scale.

2.2 X-Ray Residual Stress Measurement*:*

The X-ray residual stress measurement test rig works on the basic principle of X-ray diffraction technique as per ASTM standards.

2.3 Cutting Conditions:

Varied cutting conditions like depth of cut, feed, coolant conditions have been performed on mild steel pieces. The different processing conditions are as shown in table 1. Fig 1 and 2 shows the sample subjected to cutting conditions in milling operations.

3. Results and Discussion:

Material Designation	Speed (RPM)	Feed (mm/min)	Depth Of Cut (mm)	Coolant (On/Off)	Machining Time (s)	Hardness “B Scale”	Residual Stress
1	1130	82	0.5	Off	207.35	B65.66	182
2	1130	82	1	Off	214.95	B67	191
3	1130	82	1.5	Off	214.15	B64.66	203
4	1130	30	1	Off	580	B65	212
5	1130	50	1	Off	380	B66.33	250
6	1130	82	1	Off	210.85	B65.66	262
7	1130	82	1	Off	210.85	B66	262
8	260	82	1	Off	217.85	B68	115

Material Designation	Speed (RPM)	Feed (mm/min)	Depth Of Cut (mm)	Coolant (On/Off)	Machining Time (s)	Hardness “B Scale”	Residual Stress
9	690	82	1	Off	212.6	B66	165
10	1130	82	0.5	On	210.8	B68	151
11	1130	82	1	On	214.95	B68.33	155
12	1130	82	1.5	On	212.2	B67.66	162
13	1130	30	1	On	585	B69	171
14	1130	50	1	On	375	B66.66	177
15	1130	82	1	On	141.45	B66	183
16	1130	82	1	On	139.25	B67.33	183
17	690	82	1	On	122.35	B68.33	151
18	260	82	1	On	135.4	B69	101

Table 1: Variation of hardness and residual stress

It is observed from the table that with speed and feed constant and with varying depth of cut the residual stress have increased on the tensile axis showing that the temperature has played a significant role in the residual stress. The thermal effects due to the cutting process can have a significant effect on the residual stresses produced. Researchers have shown that increased cutting temperatures [15-16] result in greater tensile residual stress on the surface of a machined component. The same effect has also been observed with other cutting parameters as shown in table.

4. Conclusions:

- Mild steel specimens have been subjected to varying cutting conditions on a milling machine.
- Cutting conditions like feed, depth of cut, speed and coolant conditions have been successfully carried out mils steel specimens on a milling machine.
- Residual stresses have moved towards a tensile axis for cutting conditions.
- Temperature has played a significant role in inducing residual stress.
- However, with coolant conditions the residual stresses have shown a significant decrease (towards compressive).

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