The surface roughness analysis using sound signal in turning of mild steel

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Abstract. Among every other parameters of production process, surface roughness holds its ground as one of the most crucial factors for the quality analysis. Good surface finish is a major criterion in almost every machining process. If the surfaces aren't smooth, many kinds of mechanical, thermal, frictional, vibrational problems may occur. So minimizing the surface roughness should be the top priority. Surface roughness depends on many factors. But it has a direct relation with the tool conditions and overhang length of the tool. With the variations of tool conditions and overhang length the machining sound level also varies. In this present study, an analysis has been made based on captured sound signal to correlate the surface roughness parameters with sound level at different tool and overhang length conditions. As the cutting tool wears out due to continuous usage, surface roughness also develops on the tool surface. It has been observed that with the increase of overhang length the sound generated level within the cutting zone varied and surface roughness in the job also varied due to the effect of vibration and friction. A correlation factor has been investigated with the sound level variation to analyze the surface roughness condition with different tool wear and overhang length.

1. Introduction

Lathe machines are one of the most widely used metal shaping machines for cylindrical job pieces. For effective and multipurpose uses they are being used in almost every workshop. Many research works has already been conducted to improve the surface roughness of machined work-piece in turning operations using different types of process parameters, coolant, hot machining, cryogenic machining etc. G.M. Sayeed Ahmed et al [1] conducted an experiment using AISI 1050 material of different diameters of 20, 30, and 40 mm in which the surface roughness of the work piece was determined through experiments using constant cutting speed and feed rates with different depth of cuts (DOCs) and tool overhang lengths. Safeen Y. Kassab et al. [2] experimented to find relation between surface roughness and cutting tool vibration in lathe dry turning of medium carbon steel. They found that vibration of cutting tool depends strongly on cutting tool overhang length and with the increasing feed rate the surface roughness of work piece increase. H.H. Habeeb et al. [3] conducted machining of nickel based alloys 242 included using four different cutting tool materials under wet condition. Flank wear modes are noticed as acceptable results at lowest cutting depth with high cutting speed and moderate feed rate. Optimum surface roughness results were also recorded with decreasing of cutting depth. In a similar type of experiment by Anayet U. Patwari et al. [4] investigated the effects of overhang length on surface roughness, chip morphology to determine the suitability of over-hang...
length with coated carbide inserts so that with the proper selection of the overhang length the productivity will increase with the increased process parameters. Vladimir Aleksandrovich Rogov et. al. [5] used the Taguchi method to optimize the surface roughness with vibration in turning of Aluminum AA2040 under dry condition where Spindle speed, feed rate, depth of cut and tool overhang were chosen as cutting parameters. Kong Lingguo et al.[6] in their study found that within a certain range, the cutting speeds increased will first make the amount of vibration and surface roughness increase, then decreased, and more than this range, the surface roughness goes up along with the vibration increase. The cutting edge of the worn tool acting like un-uniformly larger nose radius which produced better surface was found in an experiment by S. Thamizhmanii et al. [7]. In this present study, several experiments have been conducted with different types of tool wear and overhang length and generated sound were captured at different cutting conditions in turning process. The captured sound level was analyzed to correlate the surface profile with the sound level in machining process and find out the relationship with sound level, surface roughness, tool wear and overhang length for conventional turning processes.

2. Experimental details

Many mild Steel bars of 200 mm length and 32 mm diameter were cut from the same bar using LET LH-280 power saw machine for conducting lathe operation using Pinacho Mod. L-1/180 Lathe machine. Three same types of coated carbide insert have been used with different tool wear. In the experiment, one new insert, one moderate wear insert and large wear insert has been used for machining purposes. During machining audio recorder was used to capture the sound for sound analysis and an open source software was used for sound analysis which was captured by audio recorder. After the machining process, Profilometer was used for measuring surface roughness. A detail of the experimental setup is shown in Figure 1.

![Image](image1.jpg)

**Figure 1.** Details of the Experimental setup used in this study.

For this experiment, same type of insert with different tool wear namely no wear-new insert, medium wear and high tool wear as shown in Figure 2 have been used for machining operation of different overhang length keeping all other process parameters constant. Conventional turning machining was done in the following manner:

- 1st work piece: High wear insert for 1st 10 mm, Moderate wear insert for 2nd 10 mm, no wear insert for 3rd 10 mm were used.
2nd work piece: No wear insert for 1st 10 mm, high wear insert for 2nd 10mm, moderate wear insert for 3rd 10 mm were used.
3rd work piece: Moderate wear insert for 1st 10 mm, no wear insert for 2nd 10mm, high wear insert for 3rd 10 mm were used.

2.1 Experimental conditions:
This experiment was conducted by using lathe machine where 3 types of (no wear, moderate wear, high wear) coated carbide insert were used for machining. In both machining process following parameters were applied Cutting speed, Depth of cut, Feed rate was kept constant throughout the whole experiment while overhang length became variable.
Constant parameter: Cutting Speed: 875 rpm; Depth of Cut: 1 mm; feed rate: 0.1 mm/rev; Variable parameter: Overhang length: 160 mm, 170 mm and 180 mm.

3. Results and discussions
While measuring the surface roughness, different surface roughness was found using different insert for each work piece. Comparing work pieces, insert 3 (no wear insert) had the best surface finish at various overhang length as shown below.

Surface Roughness

- For work piece 1: 160 mm Overhang, No wear insert
- For work piece 2: 180mm overhang, No wear insert
- For work piece 3: 170 mm overhang, No wear insert
In this experiment, using different insert for each job piece while varying the overhang length, it is found that 3rd insert (No wear) has the better surface finish for conventional machining. For job piece 1, in 160 mm overhang length for insert 3 (No wear) has the better surface finish of 0.360 μm. Similarly, for job piece 2 & 3 better surface finish is obtained using 3rd insert that has no wear for varying overhang length 180 mm & 170 mm as shown in Figure 3. It is clearly observed that with the increase of overhang length the surface roughness increased in case of no wear insert. In case of sound level analysis, it is also found that no wear insert generated less sound level compared to other two inserts. It is also observed that at overhang length 170 mm and 180 mm for moderate and high wear insert the surface roughness varied considering the frictional and vibration effect.

![Figure 3](image-url)  
**Figure 3.** Surface profile with average roughness and sound level variation at different overhang length.

While machining the job piece, different types of chips were formed as shown in figure 4 using different insert for varying overhang length. For 1st job piece, using high wear insert for 180 mm overhang length discontinuous chip was formed which was black in color (because of high friction between tool and job piece). For 1st job piece, during machining discontinuous chips were formed for other insert (Moderate & No wear) for varying overhang length (170 mm & 160 mm). But the chips which were formed during machining became bluish (because of friction between tool and job piece it slightly burnt) for insert 2 (Moderate wear) and silver for insert 3 (No wear).

For 2nd job piece continuous chip was formed using insert 3 (No wear) where overhang length was 180 mm and using insert 1 (High wear) with overhang length 170 mm formed continuous chips with build up edge due to excessive friction and vibrational effect between tool and job piece and it was coil type shape. For overhang length of 160 mm insert 2 (moderate wear) formed discontinuous chip...
which was brownish in colour. For job piece 3, continuous chips were formed using 2\textsuperscript{nd} (Moderate wear) & 3\textsuperscript{rd} insert (No wear) for varying overhang length at 170 mm.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{chip_types.png}
\caption{Different types of chip formed in machining processes.}
\end{figure}

But the chips which were formed during machining became bronze type color (because of friction between tool and job piece it slightly burnt) for insert 2 (Moderate wear) and silver for insert 3 (No wear). Beside this continuous chips with build up edge was formed using insert 1 (High wear) (overhang length 160mm) due to excessive friction between tool and job piece.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{sound_level.png}
\caption{Sound level variation at different overhang length for different insert.}
\end{figure}

Figure 5 shows the visual demonstration of sound analysis vs. overhang length, where machining is done for this experiment under same feed rate, depth of cut and cutting speed but overhang length is variable for each insert. From this histogram, it can be seen that sound level is decreasing with decrease of overhang length. When overhang length is decreasing less vibration occurs, that’s why sound level decreases and surface improvement is also achieved. Correlating figure 3 and figure 5, it is
found that for insert 1 (High wear) surface roughness first decreasing then increasing with the increase of overhang length and same tendency is reflected in sound level variation. For insert 2 (Moderate wear) surface roughness first increasing then decreasing with increase of overhang length. For insert 3 (No wear) surface roughness gradually decreases with decrease of overhang length. Generally surface roughness decreases with decrease of overhang length. Similar tendency has also been reflected in captured sound level variation. According to the sound analysis, it is showed that maximum sound is recorded [57db] for overhang length 180 mm in case of high wear insert and minimum [43db] is found in case of no wear insert.

4. Conclusions
In this study, surface roughness has been compared with the sound level variation at different overhang length for three different types of insert. Generally, it has been observed that with the increase of overhang length, the average surface roughness value is going to be increased. Overhang length variation results the cutting process stability and insert status reflects the frictional behaviour in between the tool and the work-piece. The performance of machining is related to the stated factors and sound captured during machining will be varied at various combinations of the process and system parameters. So, in this study, an attempt was made to investigate and correlate the output response in terms of average surface roughness and generated sound signal during cutting process. Surface profile response, tool life, vibration may be predicted from the sound level variation.

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