**Vibration Analysis of Cutting Tool insert in Turning of 42CrMo4 alloy steel**

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**Abstract.** This investigation, vibration analysis of cutting tool in turning of 42CrMo4 alloy steel using CNMG120408SMRH13A insert. Tool vibration is the important phenomenon which affects the life of the cutting tool, machining quality and behaviour of the metal cutting process. In metal cutting, tool vibration is the significant factor affecting the surface quality of machined surfaces. In this experimental work, control this vibration should be arrested by external force. In the proposed system damper method has used to control the tool vibration. It will be predicted by comparing the parameters of cutting speed, feed, depth of cut, material removal rate and surface roughness of turning operation. The generated vibration is measured. The machining performance has derived by the analytical method and experimentally.

**1. Introduction**

Machine tool chatter has been examined as a fascinating phenomenon. Many researchers have been done on tool vibration and it is as yet a noteworthy obstacle in accomplishing machining for the vast majority of the metal cutting forms including turning and other metal cutting processes. Gallent, S.I., et al., [1] introduced a novel chattering control within sight of coordinated aggravation and bungled unsettling influence based on an extended state observer. The hypothetical examination demonstrates that the system states can be settled to an area of the balance point under the proposed controller. Chen H.M et al., [2] recommended, a functioning of utilizing two Actuators and a versatile regulator is researched for smothering the two-DOF reactive chatter in micro milling. By utilizing the created to control approach, tool chatter in two ways vertical to every one other are effectively smothered. Ramesh Kannan. C., et al., [3,5] proposed a functioning dynamic surface control tool wear and surface
integrity. Yang, S., et al., [4] defined multi-segment cutting power detecting frameworks in assemblings forms connected to cutting tools are step by step turning into the most critical observing pointer. Their signs have been widely connected to assess the machinability of workpiece materials, prophesy shaper breakage, evaluate cutting tool wear, control machine tool chatter, decide stable machining parameters and enhance surface wrap up. BaniHani K., et al., [6] defined about the new technique for simultaneous optimization of cutting force resistance with time of machining. Darwish, S.M., et al., [8] discussed machining forms a few phenomena happen between material cuttings. These marvels can influence the creation through the lessening of value or exactness or by expanding costs. Ramesh Kannan et al., [7,9] built up a sliding mode control is a straightforward and magnificent strategy for the hearty control of indeterminate systems. Wan F., et al., [10] proposed an improved form to improve sliding capacity and state spectator for the movement following power of a nano positioning framework driven by piezoelectric system. Ramesh Kannan.C., et al., [11,15] exhibited a streamlining based algorithm for balancing out impeded systems utilizing a state-subsidiary feedback controller. It is demonstrated that utilization of such a controller brings about the unbiased flow of the shut circle system if little feedback delays happen Ni Y.Q., et al., [12]. Lam, H.F., et al., [13] clarified a time optimal-based time mode control and chatter investigation. Perreault, D.J. and Liao.C., et al.,[14,16] explored another control procedure is planned, which coordinates both the order input influential and the sliding methods. Tang L., et al., [18] talked about around a few control ways to deal with the active concealment of machining chatter, a self-energized vibration that points of confinement metal evacuation rate, are inspected utilizing an uncommonly developed turning test. The test uses a magnetic bearing for the invitation and imitates the progression of an adaptable rotor. J.Rajaparthiban,et al.,[20] managed the utilization of relapse examination methods together with fuzzy rationale keeping in mind the end goal to beat the difficulties in tool wear checking. The proposed approach is tried with information from drilling tests. Ramesh Kannan.C., et al., [21, 22, 23] deals with the improvement of a variable vibrating and working condition is evaluated from estimated information. The intention of the process examine is to analysis the importance of parameter namely speed, feed and depth of cut during turning of 42CrMo4 alloy steel using undammed and dambed cutting tool through mathematical models, B.Stalin, et al, [24,25]. Ramesh Kannan .C., et al., [17,19] defined the experimental design used face Center Cubic Structure (CCD) for four controllable factors namely speed, feed rate depth of cut and nose radius each are four levels.

2. Experimental Details
The experimental work was carried out for various machining conditions given. The regression analysis using TRFC and VRNN-ALM model was performed. For each cutting condition a regression model was built. It is desirable to have one regression model for all possible cutting conditions; however, in practice, this leads to an unacceptable error in the predicted value. In order to have high model accuracy separate model was built for each cutting conditions.

2.1. Selection of Work Material and Insert
42CrMo4 steel is common chromium–molybdenum steel that usually used as a work material.DIN42CrMo4 alloy material has high hardness, fatigue strength and low temperature impact toughness.

| Grade     | C     | Si   | Mn   | Cr  | Mo  | P    | S     |
|-----------|-------|------|------|-----|-----|------|-------|
| 42CrMo4 (%) | 0.45  | 0.4  | 0.9  | 1.2 | 0.3 | 0.025 | Remaining |

The applications of 42CrMo4 alloy steel are large engine traction gears, deep oil drill pipe joints and fishing tools, etc. The Chemical compositions of work material are Table 1. The work materials are purchase from sun steel Coimbatore. CNMG Tungsten Carbide Insert is the tool material used which
has elevated strength impact power. Identify the Nose radius of the tool insert based on the turning parameters and the benefits are vibration resistance, Weak cutting edge, better chip breaking, High feed rate, large depth of cut and increasing radial force. Tool inserts are procured from sandvick Coimbatore. The mechanical properties of 42CrMo4 alloy steel is presented in Table 2.

| Tensile strength (σb/MPa) | Yield strength (σy/MPa) | Elongation (Δ5%) | Reduction of area (ψ(%)) | Poisson’s ratio | Impact absorbing energy (AKV/J) |
|---------------------------|-------------------------|------------------|--------------------------|----------------|-------------------------------|
| 1300                      | 900                     | 10               | 40                       | 0.30           | 35                            |

2.2. Details of damper
After building the regression models and regression controller, the active damping is to be employed. For this purpose, a MR damper is to be fabricated. The MR damper is created by utilizing a straightforward twofold acting pneumatic barrel with necessary changes. The major modification is that the components made of magnetic materials in the pneumatic cylinder are replaced by non-magnetic materials. Here copper is used to replace the magnetic materials as shown in Figure 1. Because the non-magnetic material will allow the magnetic field to flow through it, whereas the magnetic materials will observe the magnetic field. Hence the magnetization effect on the MR fluid will not be uniform. The arrangement is made in the piston pole of the pneumatic chamber to hold the exhausting tool. The MR is filled in the one side of the piston, and the exhausting machine is settled toward the finish of the piston bar (Katsuaki Sunakoda 2000). The two openings of the pneumatic chamber are legitimately fixed utilizing the fakers, to ensure that, there is no spillage of MR liquid from the opportunities.

![Figure 1. Image of Damping Setup](image)

The other essential component of the damper is magnetizing loops; two magnetizing curls are utilized as a part of both side of the chamber. From Figure 2 (a) the coils are made by winding the copper wire on the fashioned iron material. The loops are settled in a container molded structure made of aluminum Figure 2 (b). Here again aluminum, a non-magnetic material is utilized for a similar reason. The entire setup consisting of MR damper and coils are fixed in the aluminum box as shown in Figure 2 (d) to make it convenient for fixing on the machine. Some supporting structure is fabricated using the wood to fix the aluminum box in the machine.
The adjustment of the focal point of the exhausting bar with machine focus, by altering the stature of the wood. An elastic material is connected to the base surface of the wood to ensure that the machine vibrations are not transmitted to the damper. The whole setup is mounted in the machine has appeared in the Figure 2 (d).

![Figure 2.](image)

Figure 2. (a) Double acting pneumatic cylinder (b) Magnetizing coils (c) MR damper fitted with aluminum box and (d) MR damper mounted in the machine.

The experimental procedure described with MR damping for various machining conditions and corresponding vibration signals were recorded. The damping coefficient of damper was varied dynamically by regression controllers by varying input current. The regression controllers used are based on the following models.

2.3. Selection of Factors
The responses investigated were the Material removal rate and surface roughness. The Table 3 represents the parameter levels.

| Parameters       | Levels |
|------------------|--------|
| Speed: N (m/min) | 110 165 210 275 |
| Feed: F (mm/rev) | 0.1 0.15 0.20 0.25 |
| Depth of Cut: D (mm) | 0.4 0.8 1.2 1.6 |
| Nose Radius: NR (mm) | 0.4 0.8 1.2 1.6 |

2.4. Turning Rule Feedback Control Model
The use of a turning rule feedback controller is established in an underlying illustrative model. A sound model must be connected where the impacts of the negotiation are very much recognized and where the production procedure of the impacts is appropriately understood.

2.5. Construction of the MRF-based Optimal Turning Model

To recognize parameter for every work piece, angle position and estimations of continually pivoting magnetic field values are recorded.
2.6. Testing Under Constant Magnetic Field
The progressions to straight-line driving at whatever point the straight-line driving will decrease the blunder quicker than an edge based on the present division from the target.

\[
\text{Thersold} = -\frac{1}{2} \sum_{i=1}^{n} v_i \sqrt{x_{rc,t}(t)^2 + y_{rc,t}(t)^2}
\]

2.7. Turning Rate Parameter Analysis
A uniform magnetic field to switch low location of a substantial gathering of focuses. In our future applications, huge quantities of concentrations to control objects have been used.

\[
S_x = \frac{1}{n} \sum_{i=1}^{n} (x_i - \bar{x})^2, S_y = \frac{1}{n} \sum_{i=1}^{n} (y_i - \bar{y})^2, \sigma = \sqrt{S_x + S_y} < \text{tolerance}_H
\]

where \((\bar{x}, \bar{y})\) is the point of convergence of the mass of the social event. The proposed approach uses an appealing turning field to collect concentrations together and uses a steady alluring field to swimming centers to the goal. For this circumstance, concentrations locations are unreasonably spare (tolerance \(H\)) then fold the levels using prediction method, portraying the mark as \((S_x, S_y)\). When the concentrations accumulate inside (tolerance \(H\)), then change to a relentless appealing field levels dip as one toward the mark.

3. Result and Discussion

3.1. Microstructure Analysis
SEM image represent the microstructure view of the damped and undamped cutting tool insert after completion of the machining operation.

![SEM image of (a) Undamped Insert (b) damped Insert](image)

**Figure 3.** SEM image of (a) Undamped Insert (b) damped Insert
The SEM images confirm the cutting tool insert before and after damber used. In this insert, used the minimum usage of tool material used to reduce the tool vibration.
3.2. Analysis of Material Removal Rate

MRR is determined by the rate of change in volume. Ramesh Kannan et al., (2016) observed that MRR increases with increasing the speed similar pattern has been observed in case of depth of cut. Improvement of depth of cut, the MRR also increased because the high thickness of chip may be
removed [26-36]. The detailed analyses of material removal rate are described as shown in Figure 6 (a-d).

Figure 6. Analysis of MRR and Surface roughness with selective parameters

3.3. Comparative Analysis
Comparative analysis of the four testing conditions is discussed in this section.
Figure 7. Comparison images for (a) MRR (b) Surface roughness

Table 4. Performance under Varying Runs of Turning

| Protocol          | Performance Metrics |
|-------------------|---------------------|
|                   | MRR     | SR       | S/N    | RMS     |
| Run 1             |          |          |        |         |
| ANN Regression    | Low      | Low      | High   | Medium  |
| Linear Regression | Medium   | Low      | Medium | Low     |
| Run 2             |          |          |        |         |
| ANN Regression    | Low      | Low      | High   | High    |
| Linear Regression | Low      | Medium   | Medium | High    |

From Table 4, determine the simulation results of ANN Regression, Linear Regression, TRFC, VRNN-ALM are detailed in previous sections. Based on the derived results validation of the analytical result with experiment has been carried out which shown in the table. Also, the Table 4 shows that the machining parameter of Material Removal Rate (MRR) and surface roughness (SR) for simulation results and experiment result.

4. Conclusions
The modelling of surface roughness in turning operation process by using an MRF-based novel controller.
To accomplish this objective, the use of extensive and predictable information by directing turning investigates a CNC machine under four turning parameters:
The created model was assessed by execution criteria of Mean Squared Error (MSE). Along these lines, it can realize the attention of supporting element and insightful chatter control in turning operation. Finally, the trial framework, utilized as a part of chatter concealment, of smart vibro controller bar is setup on the machine of CA6140. The outcomes demonstrate that this technique can hinder chatter rapidly and proficiently in turning, and enhance the surface quality significantly. Second work proposed about Vibrant Regressive Neural Network (VRNN), control of the component stability of turning device dampers, has developed as a new progressive innovation as of late to design "smart structures". A limited scale MR damper model with the valve mode component has been investigated in this research employing dynamic alternate neural system displaying a way to deal with duplicate its hysteretic nonlinear control. The Adaptive Levenberg-Marquardt (ALM) improved the energetic behind neural system is proposed for far reaching preparing information for the nonlinear chatter concealment in the machine. Another Vibrant Regressive Neural Network based control calculation has been produced and tried in the software simulation of dynamic control of a cutting edge structure. The versatile Levenberg-Marquardt technique acts more than usual strategy when the parameters are a long way from their ideal esteem and results the parameters are near their ideal esteem. At last a progression of approval tests were led on the proposed show which demonstrated the proper execution of the model regarding precision and ability for acknowledgment. Henceforth an arrangement of Magneto Rheological liquid parameters that can offer better damping qualities to limit instrument wear and advancing better cutting execution amid turning off with the negligible liquid application utilizing hard metal embed with molded rake confront. From the outcomes, it was observed that the nearness of VRNN with ALM advanced control of Magneto Rheological liquid setup amid turning with negligible chatter lessen instrument wear and delivered better cutting execution. Commercialization of this thought is certain to profit the metal cutting industry.

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