Assessment and Influence of Double Impact Dampers in The Stability of Boring Tool

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Abstract- *Vibrations on machine tools occurring relatively between work pieces and cutting tool which leads to chatter vibration. Chatter vibrations leads to irregular scratches on the machined surface, increase the wear and tear on the cutting tool which results in poor surface finish and loss of accuracy. In this work in order to improve stiffness and damping capability of boring tool, an impact damper is provided. In this investigation, based on the availability, thermal conductivity, strength, density and Poison's ratio, four different types of damping materials are used to improve the damping property of boring tool and to suppress the chatter. In this study Topsis and Grey relational analyses method is used to analyses the boring tool with and without dampers. Phosphor bronze damped boring tool shows that there is a significant improvement in Temperature distribution and Tool wear when compared with other damping materials such as Brass, Structured steel (EN8) and Aluminum. The condition for the usage of Phosphor bronze as the damping material is favored by experimental analysis.*

Keywords- chatter; cutting force; cutting tool; impact damper; boring tool;

I. INTRODUCTION

Boring is a kind of machining process which is used to enlarge the already existing hole size. While doing boring operation chatter vibration induced. These chatter vibrations lead to increase the surface roughness of the machined surface. Vibrations on machine tools occurring relatively between work piece and tool can be reduced to different exciting mechanisms which however in a certain case can only be distinguished hardly. According to the fundamental research work into the vibration behavior of machine tools conducted especially by Tobias and Tlusty-Polacek, the observed vibration phenomena can be classified into two main types, they are Forced vibrations Self excited vibrations. Forced vibrations are often generated by external forces, which are transferred by the machine foundation, unbalanced errors and defects in gear drives and bearings have unfavorable effect chiefly in these cases, where their frequency correlates to a natural frequency of the machine. In this case resonances are excited with often very great vibration amplitudes at the outing point. In the shop the disturbance sources in general can be localized and removed easily.

Boring is often done with a cantilever cutting tool that is necessarily long and slender. So, it can fit into or through complex work piece. As one might expect, such tools lack dynamic stiffness, and consequently, this manufacturing operation is often plagued with self-excited vibrations known as chatter. Chatter vibrations spoil the machined surface with poor surface finish, increase the wear rate on the cutting tool and diminish the accuracy of machining parts. In this work, improve the damping property of boring tool and suppress the chatter.

Literature review showed quite a number of research work carried out with the aim of reducing chatter vibration and increasing the stability of boring tool.(Ramesh. K (et al,.2013) .'Investigation of chatter stability in boring tool and tool wear prediction using neural network', Int. J. Materials and Product Technology, Vol. 46, No. 1, and pp.47–70. Their study focused on effects of tool wear and tool temperature with and without using impact dampers in the boring tool.

Fang et al. (2008) investigated granular damping in transient vibrations using Hilbert transform-based technique. Their studies focused on granular damping and not in impact damping due to less energy distribution. Ramachandran and Lesieutre (2008) presented dynamics and performance of a harmonically excited vertical impact dampers and their work is limited in predicting dynamics and damping characteristics.
Jayabal et al (2010a)presented the application of soft computing techniques for the prediction of tool wear in drilling of polymeric composites and suggested systematic procedure for the statistical analyses in their work (Jayabal et al., 2011).

II. MATERIAL SELECTION

2.1Selection of damping materials

The best material is one which will serve the desired purpose at minimum cost. Factors are considered while selecting the material for machine tool and damping material listed below.

1. Availability
2. Cost
3. Mechanical properties
4. Manufacturing consideration

2.2Material properties

In this project, four different types of damping materials can be used to improve the damping capability of boring tool and suppress the chatter vibration based on their strength, density, Young’s modulus, thermal conductivity, poison’s ratio. High density materials only produce more inertial mass. So high density material is used to suppress the chatter in boring operations.

Table1. Material properties

Material property	Density kg/mm³	Young’s modulus (N/mm²)	Poison’s ratio	Thermal conductivity (W/mK)
Tool	7.84×10^{-6}	2.84×10^{5}	0.3	46.6
Phosphor bronze damper	8.85×10^{-6}	1.234×10^{5}	0.3	63
EN8 damper	7.84×10^{-6}	2.84×10^{5}	0.3	46.6
Brass damper	8.45×10^{-6}	2.4×10^{5}	0.3	115

2.3 Levels of parameters

The tool opted for experimental purpose is coated carbide tool insert. The following figure represents the carbide insert. The coatings offer high speed capability. It is an ideal grade for machining of work piece. Tool insert is coated on two sides shown in figure 1; hence machining can be done on both sides. It provides improved impact resistance, at the time of machining. So that the tool insert possesses extended working life.

Parameters used	Values
Speed in rpm	300, 400, 500
Depth of cut in mm	0.25, 0.5, 0.75
Dampers	Aluminium, brass, EN8 phosphor bronze
Position of dampers from cutting edge in mm	44, 54, 64

2.4 Tool geometry

The length of the tool holder is 234mm and width of the tool holder is 18mm.The boring tool material was chosen as structured steel, which has a high degree of hardness with compressive strength and abrasion resistance and is made of high carbon alloy steel. The composition of material EN31 is carbon.

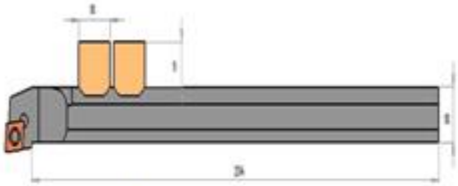


Fig 1. Tool geometry

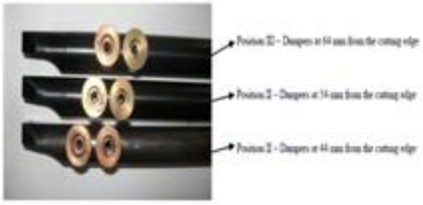


Fig 2. position of dampers

III. EXPERIMENTAL SETUP

The experiments were carried out with the help of an all geared lathe. Profilometer and chromel-alumel thermo couple was connected to all geared lathe. This set up was used to measure tool wear and temperature in boring operations. Boring tool holders were fabricated with four damping materials such as aluminium, EN18, phosphor bronze and brass. The recommended spindle speed, depth of cut, and feed rate were followed for boring operations in the mild steel cylindrical work piece based on literature. Tool wear was measured using profilometer by calculating tool profile dimensional difference before and after boring operations. Temperature was measured using chromel-alumel thermo couple set up as shown in Figure 3.

Fig 3. Experimental setup

IV. EXPERIMENTAL RESULTS

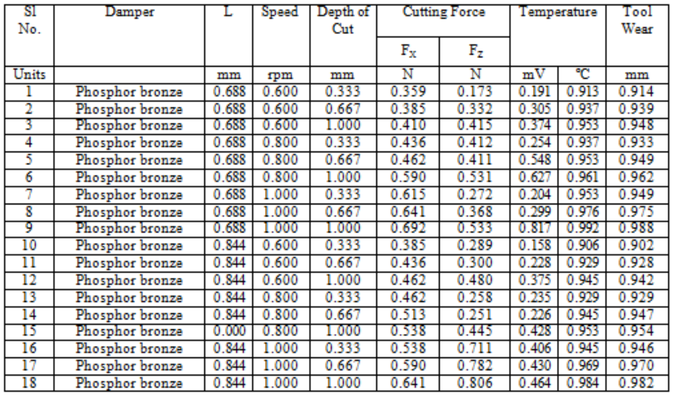
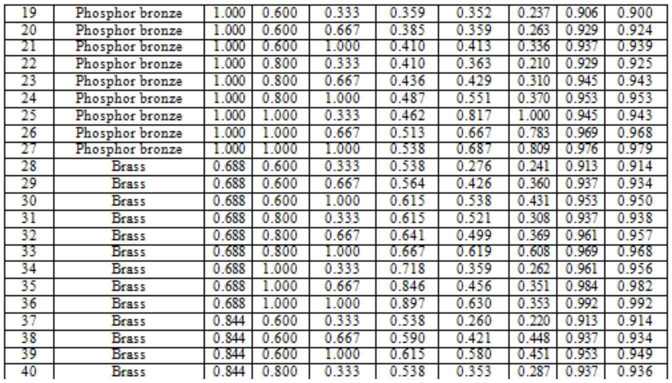
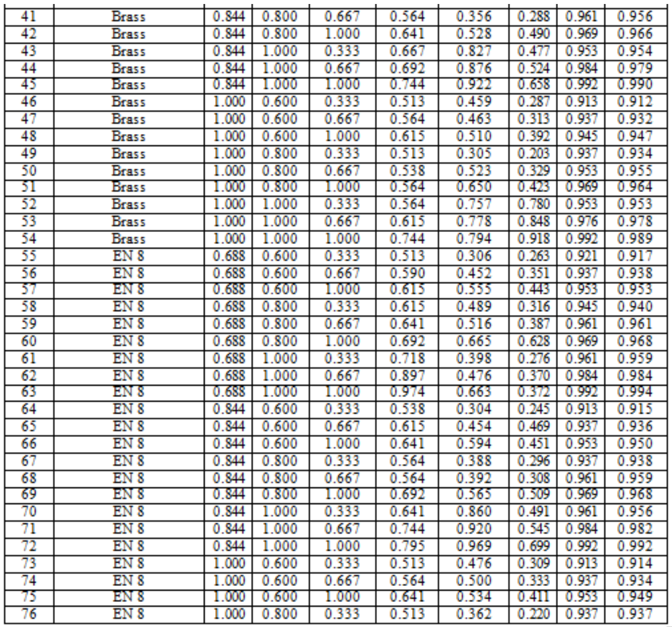
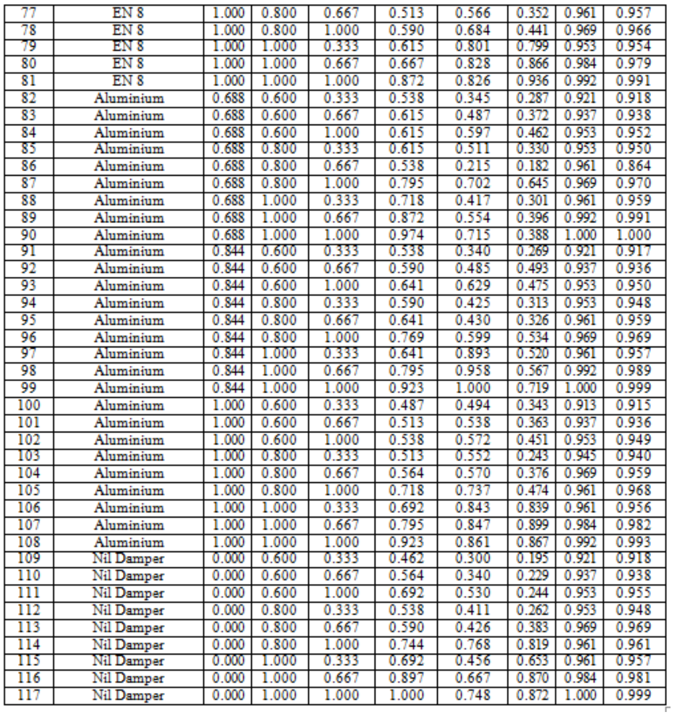
The total numbers of 117 trails were conducted. Finally, the output such as tool wear, tool temperature, cutting forces were obtained from the experimental results. The normalized experimental results were listed the table 3. From table 3, position of the damper from cutting edge can be noted as L.

V. OPTIMIZATION TECHNIQUES

Optimization is an important tool in making decisions and in analyzing physical systems. An optimization problem is a problem in which certain parameters (design variables) needed to be determined to achieve the best measurable performance (objective function) under given constraints in mathematical terms, an optimization problem is the problem of finding the best solution from among the set of all feasible solutions. Finding an alternative with the most cost effective or highest achievable performance under the given constraints, by maximizing desired factors and minimizing undesired ones. In comparison, maximization means trying to attain the highest or maximum result or outcome without regard to cost or expense. Two optimization techniques used to find the optimum cutting parameters among the 117 trails. Two optimization techniques are listed below.

- Grey Relational Analysis (GRA Technique)
- TOPSIS Algorithm (Technique for Order of Preference by Similarity to Ideal Solution)

Table 3. Normalized Experimental results

Sl No.	Damper	L	Speed	Depth of Cut	Cutting Force		Temperature		Tool Wear
					F_X	F_Z			
Units		mm	rpm	mm	N	N	mV	℃	mm
1	Phosphor bronze	0.688	0.600	0.333	0.359	0.173	0.191	0.913	0.914
2	Phosphor bronze	0.688	0.600	0.667	0.385	0.332	0.305	0.937	0.939
3	Phosphor bronze	0.688	0.600	1.000	0.410	0.415	0.374	0.953	0.948
4	Phosphor bronze	0.688	0.800	0.333	0.436	0.412	0.254	0.937	0.933
5	Phosphor bronze	0.688	0.800	0.667	0.462	0.411	0.548	0.953	0.949
6	Phosphor bronze	0.688	0.800	1.000	0.590	0.531	0.627	0.961	0.962
7	Phosphor bronze	0.688	1.000	0.333	0.615	0.272	0.204	0.953	0.949
8	Phosphor bronze	0.688	1.000	0.667	0.641	0.368	0.299	0.976	0.975
9	Phosphor bronze	0.688	1.000	1.000	0.692	0.533	0.817	0.992	0.988
10	Phosphor bronze	0.844	0.600	0.333	0.385	0.289	0.158	0.906	0.902
11	Phosphor bronze	0.844	0.600	0.667	0.436	0.300	0.228	0.929	0.928
12	Phosphor bronze	0.844	0.600	1.000	0.462	0.480	0.375	0.945	0.942
13	Phosphor bronze	0.844	0.800	0.333	0.462	0.258	0.235	0.929	0.929
14	Phosphor bronze	0.844	0.800	0.667	0.513	0.251	0.226	0.945	0.947
15	Phosphor bronze	0.000	0.800	1.000	0.538	0.445	0.428	0.953	0.954
16	Phosphor bronze	0.844	1.000	0.333	0.538	0.711	0.406	0.945	0.946
17	Phosphor bronze	0.844	1.000	0.667	0.590	0.782	0.430	0.969	0.970
18	Phosphor bronze	0.844	1.000	1.000	0.641	0.806	0.464	0.984	0.982
19	Phosphor bronze	1.000	0.600	0.333	0.359	0.352	0.237	0.906	0.900
20	Phosphor bronze	1.000	0.600	0.667	0.385	0.359	0.263	0.929	0.924
21	Phosphor bronze	1.000	0.600	1.000	0.410	0.413	0.336	0.937	0.939
22	Phosphor bronze	1.000	0.800	0.333	0.410	0.363	0.210	0.929	0.925
23	Phosphor bronze	1.000	0.800	0.667	0.436	0.429	0.310	0.945	0.943
24	Phosphor bronze	1.000	0.800	1.000	0.487	0.551	0.370	0.953	0.953
25	Phosphor bronze	1.000	1.000	0.333	0.462	0.817	1.000	0.945	0.943
26	Phosphor bronze	1.000	1.000	0.667	0.513	0.667	0.783	0.969	0.968
27	Phosphor bronze	1.000	1.000	1.000	0.538	0.687	0.809	0.976	0.979
28	Brass	0.688	0.600	0.333	0.538	0.276	0.241	0.913	0.914
29	Brass	0.688	0.600	0.667	0.564	0.426	0.360	0.937	0.934
30	Brass	0.688	0.600	1.000	0.615	0.538	0.431	0.953	0.950
31	Brass	0.688	0.800	0.333	0.615	0.521	0.308	0.937	0.938
32	Brass	0.688	0.800	0.667	0.641	0.499	0.369	0.961	0.957
33	Brass	0.688	0.800	1.000	0.667	0.619	0.608	0.969	0.968
34	Brass	0.688	1.000	0.333	0.718	0.359	0.262	0.961	0.956
35	Brass	0.688	1.000	0.667	0.846	0.456	0.351	0.984	0.982
36	Brass	0.688	1.000	1.000	0.897	0.630	0.353	0.992	0.992
37	Brass	0.844	0.600	0.333	0.538	0.260	0.220	0.913	0.914
38	Brass	0.844	0.600	0.667	0.590	0.421	0.448	0.937	0.934
39	Brass	0.844	0.600	1.000	0.615	0.580	0.451	0.953	0.949
40	Brass	0.844	0.800	0.333	0.538	0.353	0.287	0.937	0.936
41	Brass	0.844	0.800	0.667	0.564	0.356	0.288	0.961	0.956
42	Brass	0.844	0.800	1.000	0.641	0.528	0.490	0.969	0.966
43	Brass	0.844	1.000	0.333	0.667	0.827	0.477	0.953	0.954
44	Brass	0.844	1.000	0.667	0.692	0.876	0.524	0.984	0.979
45	Brass	0.844	1.000	1.000	0.744	0.922	0.658	0.992	0.990
46	Brass	1.000	0.600	0.333	0.513	0.459	0.287	0.913	0.912
47	Brass	1.000	0.600	0.667	0.564	0.463	0.313	0.937	0.932
48	Brass	1.000	0.600	1.000	0.615	0.510	0.392	0.945	0.947
49	Brass	1.000	0.800	0.333	0.513	0.305	0.203	0.937	0.934
50	Brass	1.000	0.800	0.667	0.538	0.523	0.329	0.953	0.955
51	Brass	1.000	0.800	1.000	0.564	0.650	0.423	0.969	0.964
52	Brass	1.000	1.000	0.333	0.564	0.757	0.780	0.953	0.953
53	Brass	1.000	1.000	0.667	0.615	0.778	0.848	0.976	0.978
54	Brass	1.000	1.000	1.000	0.744	0.794	0.918	0.992	0.989
55	EN 8	0.688	0.600	0.333	0.513	0.306	0.263	0.921	0.917
56	EN 8	0.688	0.600	0.667	0.590	0.452	0.351	0.937	0.938
57	EN 8	0.688	0.600	1.000	0.615	0.555	0.443	0.953	0.953
58	EN 8	0.688	0.800	0.333	0.615	0.489	0.316	0.945	0.940
59	EN 8	0.688	0.800	0.667	0.641	0.516	0.387	0.961	0.961
60	EN 8	0.688	0.800	1.000	0.692	0.665	0.628	0.969	0.968
61	EN 8	0.688	1.000	0.333	0.718	0.398	0.276	0.961	0.959
62	EN 8	0.688	1.000	0.667	0.897	0.476	0.370	0.984	0.984
63	EN 8	0.688	1.000	1.000	0.974	0.663	0.372	0.992	0.994
64	EN 8	0.844	0.600	0.333	0.538	0.304	0.245	0.913	0.915
65	EN 8	0.844	0.600	0.667	0.615	0.454	0.469	0.937	0.936
66	EN 8	0.844	0.600	1.000	0.641	0.594	0.451	0.953	0.950
67	EN 8	0.844	0.800	0.333	0.564	0.388	0.296	0.937	0.938
68	EN 8	0.844	0.800	0.667	0.564	0.392	0.308	0.961	0.959
69	EN 8	0.844	0.800	1.000	0.692	0.565	0.509	0.969	0.968
70	EN 8	0.844	1.000	0.333	0.641	0.860	0.491	0.961	0.956
71	EN 8	0.844	1.000	0.667	0.744	0.920	0.545	0.984	0.982
72	EN 8	0.844	1.000	1.000	0.795	0.969	0.699	0.992	0.992
73	EN 8	1.000	0.600	0.333	0.513	0.476	0.309	0.913	0.914
74	EN 8	1.000	0.600	0.667	0.564	0.500	0.333	0.937	0.934
75	EN 8	1.000	0.600	1.000	0.641	0.534	0.411	0.953	0.949
76	EN 8	1.000	0.800	0.333	0.513	0.362	0.220	0.937	0.937
77	EN 8	1.000	0.800	0.667	0.513	0.566	0.352	0.961	0.957
78	EN 8	1.000	0.800	1.000	0.590	0.684	0.441	0.969	0.966
79	EN 8	1.000	1.000	0.333	0.615	0.801	0.799	0.953	0.954
80	EN 8	1.000	1.000	0.667	0.667	0.828	0.866	0.984	0.979
81	EN 8	1.000	1.000	1.000	0.872	0.826	0.936	0.992	0.991
82	Aluminium	0.688	0.600	0.333	0.538	0.345	0.287	0.921	0.918
83	Aluminium	0.688	0.600	0.667	0.615	0.487	0.372	0.937	0.938
84	Aluminium	0.688	0.600	1.000	0.615	0.597	0.462	0.953	0.952
85	Aluminium	0.688	0.800	0.333	0.615	0.511	0.330	0.953	0.950
86	Aluminium	0.688	0.800	0.667	0.538	0.215	0.182	0.961	0.864
87	Aluminium	0.688	0.800	1.000	0.795	0.702	0.645	0.969	0.970
88	Aluminium	0.688	1.000	0.333	0.718	0.417	0.301	0.961	0.959
89	Aluminium	0.688	1.000	0.667	0.872	0.554	0.396	0.992	0.991
90	Aluminium	0.688	1.000	1.000	0.974	0.715	0.388	1.000	1.000
91	Aluminium	0.844	0.600	0.333	0.538	0.340	0.269	0.921	0.917
92	Aluminium	0.844	0.600	0.667	0.590	0.485	0.493	0.937	0.936
93	Aluminium	0.844	0.600	1.000	0.641	0.629	0.475	0.953	0.950
94	Aluminium	0.844	0.800	0.333	0.590	0.425	0.313	0.953	0.948
95	Aluminium	0.844	0.800	0.667	0.641	0.430	0.326	0.961	0.959
96	Aluminium	0.844	0.800	1.000	0.769	0.599	0.534	0.969	0.969
97	Aluminium	0.844	1.000	0.333	0.641	0.893	0.520	0.961	0.957
98	Aluminium	0.844	1.000	0.667	0.795	0.958	0.567	0.992	0.989
99	Aluminium	0.844	1.000	1.000	0.923	1.000	0.719	1.000	0.999
100	Aluminium	1.000	0.600	0.333	0.487	0.494	0.343	0.913	0.915
101	Aluminium	1.000	0.600	0.667	0.513	0.538	0.363	0.937	0.936
102	Aluminium	1.000	0.600	1.000	0.538	0.572	0.451	0.953	0.949
103	Aluminium	1.000	0.800	0.333	0.513	0.552	0.243	0.945	0.940
104	Aluminium	1.000	0.800	0.667	0.564	0.570	0.376	0.969	0.959
105	Aluminium	1.000	0.800	1.000	0.718	0.737	0.474	0.961	0.968
106	Aluminium	1.000	1.000	0.333	0.692	0.843	0.839	0.961	0.956
107	Aluminium	1.000	1.000	0.667	0.795	0.847	0.899	0.984	0.982
108	Aluminium	1.000	1.000	1.000	0.923	0.861	0.867	0.992	0.993
109	Nil Damper	0.000	0.600	0.333	0.462	0.300	0.195	0.921	0.918
110	Nil Damper	0.000	0.600	0.667	0.564	0.340	0.229	0.937	0.938
111	Nil Damper	0.000	0.600	1.000	0.692	0.530	0.244	0.953	0.955
112	Nil Damper	0.000	0.800	0.333	0.538	0.411	0.262	0.953	0.948
113	Nil Damper	0.000	0.800	0.667	0.590	0.426	0.383	0.969	0.969
114	Nil Damper	0.000	0.800	1.000	0.744	0.768	0.819	0.961	0.961
115	Nil Damper	0.000	1.000	0.333	0.692	0.456	0.653	0.961	0.957
116	Nil Damper	0.000	1.000	0.667	0.897	0.667	0.870	0.984	0.981
117	Nil Damper	0.000	1.000	1.000	1.000	0.748	0.872	1.000	0.999

5.1 Grey Relational Analysis (GRA Technique)

Grey Incidence Analysis model, was developed by a Chinese Professor Julong Deng of Huazhong University of Science and Technology. It is one of the most widely used models of Grey system theory. GRA uses a specific concept of information. It defines situations with no information as black, and those with perfect information as white. However, neither of these idealized situations ever occurs in real world problems. In fact, Grey relational analysis (GRA), also called Deng's situations between these extremes are described as being grey, hazy or fuzzy.

5.2 TOPSIS Algorithm (Technique for Order of Preference by Similarity to Ideal Solution)

The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is a multi-criteria decision analysis method, which was originally developed by Hwang and Yoon which further developments were made by Yoon in 1987 and Hwang, Lai and Liu in 1993. TOPSIS is based on the concept that the chosen alternative should have the shortest geometric distance from the positive ideal solution and the longest geometric distance from the negative ideal solution (NIS)

VI. RESULT AND DISCUSSION

The output response is entered in TOPSIS and GRA tools and the optimization is done by both tools. The output response was analyzed and model graphs were obtained. Then numerical optimization was done by TOPSIS and Grey Relational analysis after setting the goal to minimize the Tool wear and temperature. The numerical optimal solution is shown.

6.1 Effect of tool wear based on different positions

Figure 4 represents the tool wear characteristics of the boring bar fabricated with impact dampers at position I (44 mm from the cutting edge). These plots clearly depict that when impact dampers are employed the tool wear is reduced. Similarly, Figure 5 corresponds to boring bar fabricated with impact dampers at position II (54 mm from the cutting edge), and Figure 6 corresponds to boring bar fabricated with impact dampers at position III (64 mm from the cutting edge). From these plots it is clear that when the boring bars are fabricated at position III (i.e.) at a distance of 64 mm from the cutting edge, the tool wear is lower. This is because when the dampers are placed closer to the tool post in an all geared lathe the dynamic stability of a boring bar is found higher for a given overall length. This inherently reduces the tool chatter produced in the boring operation.

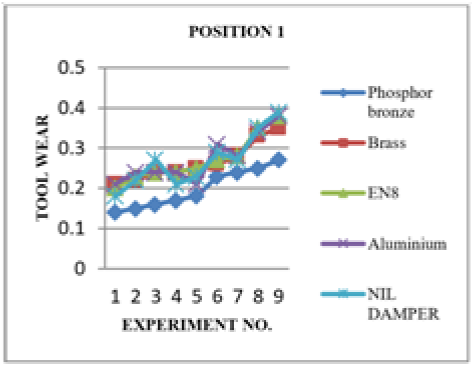


Fig4. Tool wear chart – Position 1

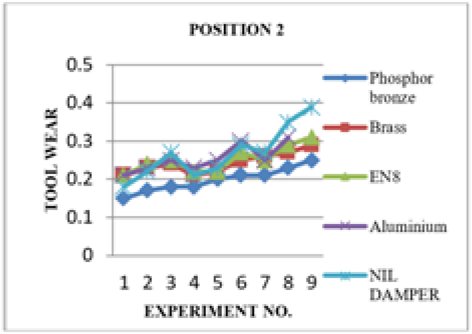


Fig 5. Tool wear chart – Position 2

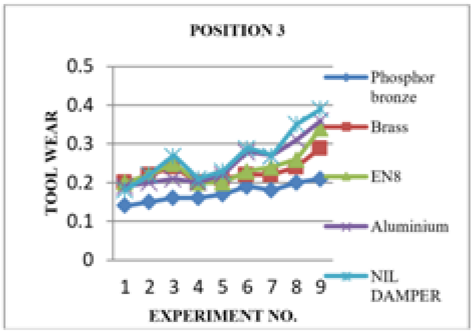


Fig 6. Tool wear chart – Position 3

6.2. Effect of temperature based on different positions

Figure 7 represents the temperature characteristics of the boring bar fabricated with impact dampers at position I (44 mm from the cutting edge). These plots clearly depict that when impact dampers are employed the temperature is reduced. Similarly, Figure 8 corresponds to boring bar fabricated with impact dampers at position II (54 mm from the cutting edge), and Figure 9 corresponds to boring bar fabricated with impact dampers at position III (64 mm from the cutting edge). From these plots it is clear that when the boring bars are fabricated at position III (i.e.) at 64 mm from the cutting edge, temperature values are lower. This is because when the dampers are placed closer to the tool post in an all geared lathe the dynamic stability of a boring bar is found higher for a given overall length. This inherently reduces the tool friction produced in the boring operation.

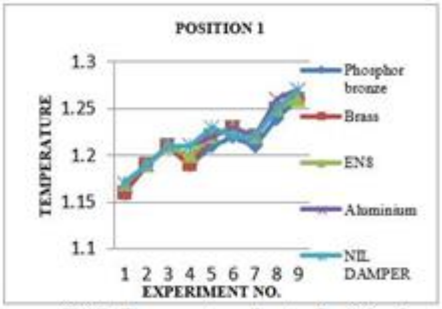


Fig 7. Temperature chart – Position 1

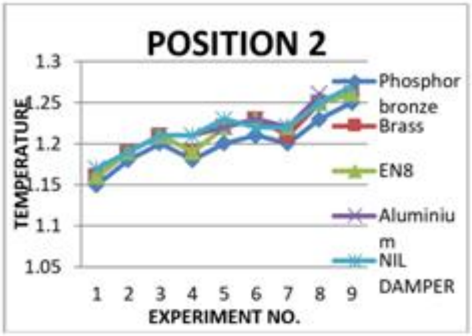


Fig 8. Temperature chart – Position 2

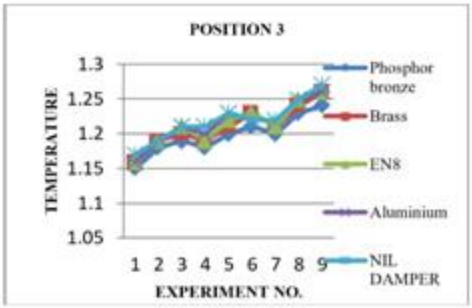


Fig 9. Temperature chart – Position 9

VII. CONCLUSION

The results were obtained from both experimental and modal analysis of boring tool with and without dampers using Topsis and Grey relational analysis methods. TOPSIS and Grey Relational Analysis methods greatly helpful to optimize the multi objective machining performance characteristic and the problem can be significantly simplified among 117 trials.

Position of dampers has shown the maximum contribution in machining performance followed by cutting speed and depth of cut. Phosphor bronze damped boring tool shows that there is a significant improvement in its Natural frequency, Temperature distribution, Tool wear. When compared with other damping materials such as Brass, Structured steel (EN8) and Aluminium.

The condition for the usage of Phosphor bronze as the damping material favoured by experimental analysis. The tool wear was accurately predicted for various set of input conditions using TOPSIS and Grey Relational Analysis method. The suitable parameters of the cutting tool at a distance of 64mm from the cutting edge running at a speed of 500 rpm and a depth of cut of 0.25 mm is suggested as favorable conditions.

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