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Investigation of vibration damping on polymer concrete with polyester resin

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Abstract

The feasibility of the polymer concrete in the manufacturing of machine tools beds was investigated with respect to its vibration damping. Samples that consist of the same polyester resin ratio and different ratios of filler (quartz) were used to investigate the changes in the damping characteristic. Damping tests were carried out using polymer concrete and cast iron samples. It was observed that the critical damping ratio of polymer concrete was approximately four to seven times higher than that of the cast iron. It has been shown that polymer concrete is an appropriate material with respect to damping.

Keywords: Polymer concrete; Polyester resin; Vibration damping

1. Introduction

Machine tools have an important role in the manufacturing industry. For this reason, it is desirable that the negative effects such as vibration and noise in the tools used today be brought to a minimum level. Metals used in manufacturing machine tools, especially when viewed in terms of their mechanical characteristics, have a great importance in comparison to other construction materials and this will continue in the future. But when viewed in terms of properties such as chemical resistance, ease of production, workability, and damping, plastic and composite materials are increasingly used in the manufacture of machine tools [1,2].

In these times, especially when there are intensive developments in the manufacture of machine tools, polymer concrete is a new production material in most developed countries and is still being investigated [3]. Polymer concrete that came into being years ago as a construction material and is still used in this way is considered by machine tool manufacturers as an alternative to cast iron and steel especially for the production of machine tools beds [2,4,5]. The advantages of using polymer concrete as a manufacturing material for machine tools beds can be stated as ease of manufacturing, resistance to corrosion, high strength-to-weight ratio, low thermal conductivity, ease of fabrication, and the most important, vibration damping [6,7].

In this study, damping tests were carried out using polymer concrete samples to determine if damping characteristic changes depending on the composition of the filler. Critical damping values were calculated and were found for cast iron under the same conditions.

2. Material

2.1. Choosing the resin

Polyester resin was chosen to produce the polymer. There are many kinds of polyesters available on the market. Among these, unsaturated isophatalic polyester resin was chosen. Polymer concrete made from isophatalic polyester is hard, rigid, and has high mechanical strength. Also, this resin was preferred because of its low cost, but there is the risk of cracking with thick block mouldings due to the internal stresses related to shrinkage of resin [8].

2.2. Choosing the filler

Quartz was preferred because it gives rigidity and great strength to the polymer concrete. It was used due to its high hardness. Although it can be found in many colors, crystals of white quartz that are generally rhombohedric in structure were used in this study. Its Mohs hardness is 7, and the specific gravity is 2.6 g/cm^3 [8].

Ground quartz was obtained in grain sizes of 0.5 to 1, 1

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Table 1
Ratios of the filler by Feret triangle

	Amounts of quartz sand (%)		
Sample no.	Fine (0.5–1 mm)	Middle (1–3 mm)	Coarse (3–5 mm)
N1	50	0	50
N2	25	25	50
N3	50	25	25
N4	25	50	25
N5	50	50	0

to 3, 3 to 5, and 5 to 8 mm. It is possible to use two methods for filler composition. The first is the method that is known as "Feret triangle," which categorizes the material into three groups. The filler was divided into three groups as 0.5- to 1-mm fine grain, 1- to 3-mm middle grain, and 3- to 5-mm coarse grain. A decision was made for the preparation of samples with five different compositions depending on the grain size of quartz. The amounts of these compositions are given in Table 1. The second is the so-called method of "sieve analysis." In this method, the analysis of the filler is made with sieves determined by codes.

Upon investigation of the studies conducted with polymer concrete, it was observed that grain sizes of different maximum aggregates were used for various applications. These are grain sizes of 16, 8, and 2 mm. In this study, 8 mm was chosen as maximum grain size. The sieve analysis of the filling material is given in Table 2. Using the mixture in groups III, IV, V, and VI, which were recommended by TS 706 [9], samples were prepared.

3. Methods

3.1. Sample sizes

For tests of polymer concrete, sample sizes were determined by code of DIN 51290-Section-3 [10]. In this code, lower limit values are given such that the smallest test samples are not allowed to be less than three times the biggest grain size in case granulated filling material is used, and not less than three times the length in case nongranulated filling material is used. In the current study, sample sizes were taken as 10 × 25 × 500 mm.

Table 2
Sieve analysis of the filler

	Group no.						
Sieve mesh (mm)	I	II	III	IV	V	VI	VII
8.0	100	100	100	100	100	100	100
4.0	54	60	68	75	78	85	91
2.0	27	35	45	53	65	70	80
1.0	14	22	33	43	48	56	65
0.5	5	13	17	27	33	40	47
0.25	2	5	9	12	15	22	30

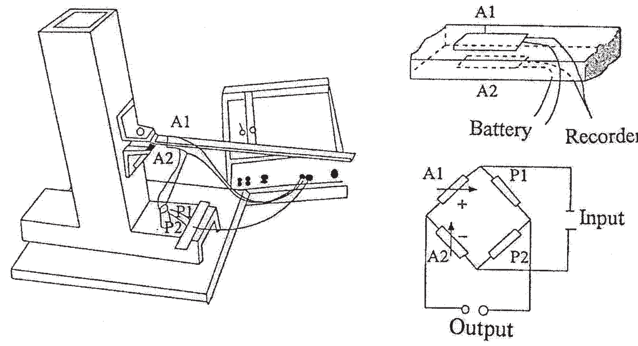

Fig. 1. Attachment scheme for the strain gauges and equipment used in the test set.

3.2. Composition of material

Saylan [8] conducted compression tests on samples with polymer ratios of 12.5, 17.5, 22.5, and 25.0% to determine the relationship between percentage of polymer and strength, and thus he investigated the change in compressive strength depending on the polymer ratio. He found that strength increased depending on the ratio of polymer but this increase was slow for a polymer ratio greater than 20%. For this reason, we used a polyester ratio of 20%. Filler was used in five different compositions with respect to the first method, and in four different mixture groups with respect to the second method.

3.3. Preparation of samples

Five different compositions were prepared of which the grain size distributions of the quartz sand were determined by the first method. The amount of polyester was taken as 20% of concrete weight. The mixture obtained by the required amount of polyester resin and with the addition of 1% (by weight of polyester) accelerator (cobalt oxalate) was added to the quartz mixture prepared. Before casting (1% ratio of polyester) hardener (50% methyl-ethyl-ketone peroxide) was added to the mixture. Polymer concrete mortar

Table 3
Test results

	Critical damping values (%)			(D/D_{dd}) ratio[a] (%)		
Sample no.	1	2	3	1	2	3
N1	1.78	2.35	2.25	4.26	5.62	5.38
N2	1.69	2.46	1.66	4.04	5.88	3.97
N3	1.84	2.25	1.77	4.40	5.38	4.23
N4	2.24	2.86	2.02	5.36	6.84	4.83
N5	2.28	2.46	2.05	5.45	5.88	4.90
G1	1.75	2.24	1.65	4.18	5.36	3.94
G2	2.21	1.83	2.54	5.28	4.38	6.07
G3	2.43	3.10	2.28	5.81	7.41	5.45
G4	1.68	2.15	2.58	4.02	5.14	6.17

[a] The critical damping of polymer concrete divided by that of the cast iron.

prepared this way was poured into moulds, and before hardening, the mortar was squeezed by a vibrator to remove the air voids to obtain a smooth surface, and the walls of the moulds were coated with a mould release agent. These samples were dubbed N1, N2, N3, N4, and N5. For TS 3068 [11] at least three such samples must be tested. Because of the possibility that the samples may get cracked while being taken out of moulds, five samples were prepared for each group but three samples were used during the test. The same procedure was followed when preparing samples for four mixture groups selected for the second method. These samples were labelled G1, G2, G3, and G4.

3.4. Set for damping test

To be able to investigate the damping phenomenon of the polymer concrete with polyester resin, a test set was prepared as seen in Fig. 1. To obtain measurements, strain gauges were

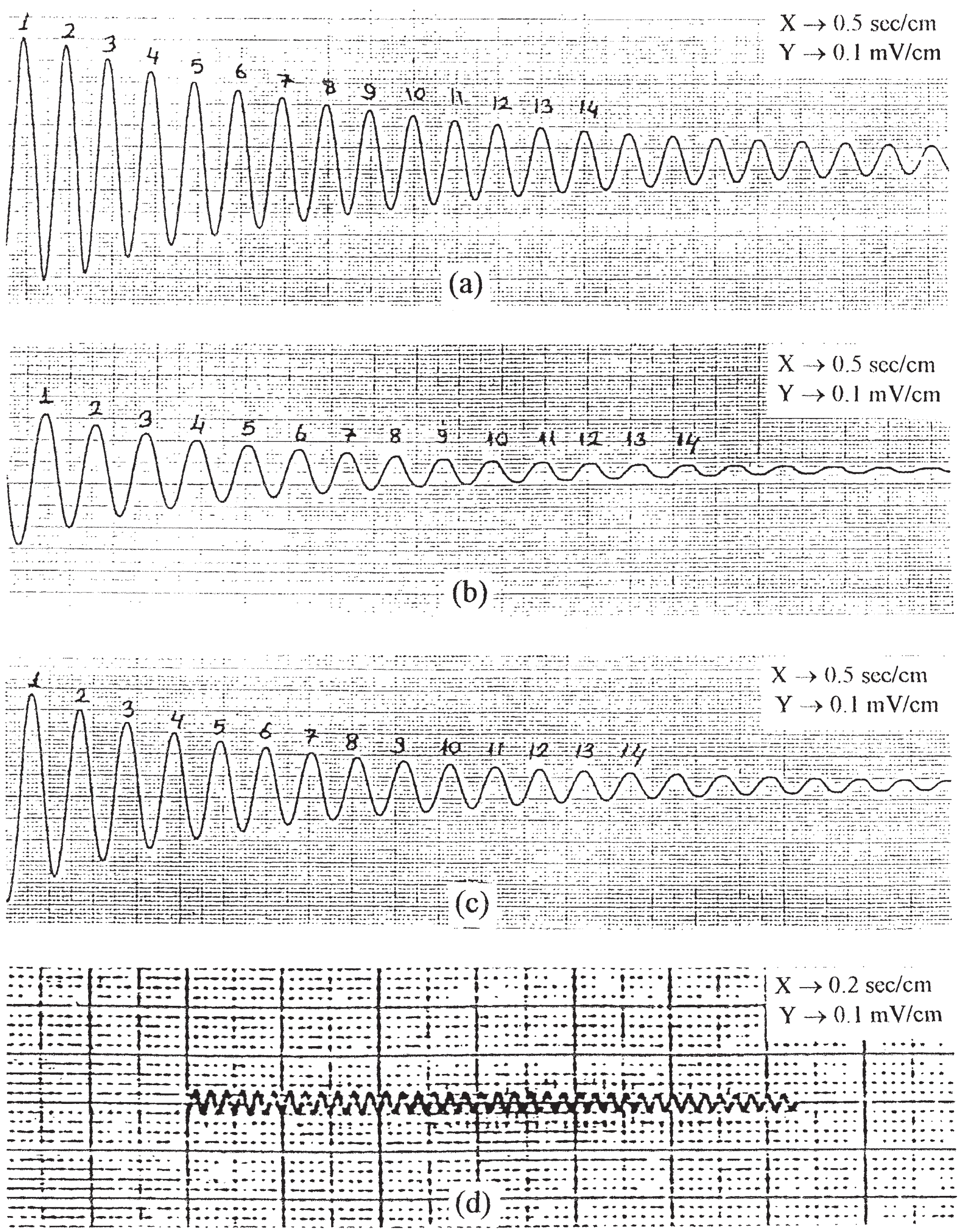

Fig. 2. Damping curves of the samples (a) N1.1, (b) N2.2, (c) N4.3, and (d) cast iron.

used. Vibrations were recorded with an "X-Y recorder" (ELE International, UK) with an embedded "strain indicator."

To perceive the strain that occurs in the sample that is under bending moment, strain gauges were attached on bottom and top surfaces of samples (A1, A2 active gauges and P1, P2 passive gauges). Care was taken not to leave any dust between the strain gauges and the surface of the samples. Of the Wheatstone bridge, a half-bridge was used.

3.5. Damping test

The prepared samples were tested by the test set up shown in Fig. 1. The sample attached to the test was set free after it deviated slightly from the balanced situation. The cantilever beam was in free vibration, which damped in the course of time. These vibrations were recorded by an X-Y recorder. In this study, the damping was based on the damping curves obtained from test samples, and values of amplitude in the successive 14 periods were gauged. Depending on these values, logarithmic decrement and critical damping were calculated [12] [see Eqs. (1) and (2)].

$$\Delta = [1/(n-1)]\ln(X_1/X_n) \quad (1)$$

$$D \cong \Delta/2\pi \quad (2)$$

where Δ is the logarithmic decrement, X_1 is amplitude in the first period, X_n is amplitude in the *n*th period, and D is critical damping value. Damping tests were conducted with samples of cast iron under the same conditions.

4. Results and discussion

Damping tests were conducted on three samples for each group. Critical damping values of these samples are given in Table 3, and damping curves of some samples are given in Fig. 2. Under the same conditions, damping values for samples of cast iron were found to be D_{dd} (%) = 0.418. The damping curve of the cast iron sample is given in Fig. 2. Damping values of polymer concrete samples (D) are given in Table 3 in comparison with those of cast iron (D_{dd}).

It was observed that damping characteristic might be four to seven times higher than cast iron, and with this property, it seems that polymer concrete would have an advantage in the manufacture of machines.

5. Conclusions and suggestions

The following conclusions can be drawn:

- It has been shown that polymer concrete with polyester resin and quartz is an appropriate material for manufacturing machine tool beds with respect to damping.
- It has not been possible to determine if the damping characteristic of polymer concrete changes depending on the composition of the filler. Critical damping characteristics of different samples were found to be similar.

In addition to the study we conducted on polymer concrete, studies to be carried out on the following subjects would add new information to the already accumulated data:

- the effect of heat application on polymer concrete on the performance of machine tools beds;
- the use of different resin and filler in the production of machine tools beds;
- studies on mixtures of different kinds of material; and
- polymer concrete combined with metal bearings to be used in machine tools.

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