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DYNAMIC PROPERTIES OF DEVICE BODIES MANUFACTURED OF POLYMER CONCRETE

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Abstract: *The paper shows the dynamic properties of device bodies manufactured of polymer concrete in order to show the advantages of this material in comparison with grey cast iron. Polymer concrete has many interesting material characteristics for workshop facilities, two of which are the good vibration absorption and the relatively low specific weight. On the basis of these properties, device base plates manufactured from grey cast iron may be replaced with base plates manufactured of polymer concrete. Overhanging device bodies may be constructed with an extended wall thickness at a weight comparable to grey cast iron device bodies. The second part of the paper is concerned with the application of the polymer concrete device bodies in milling machining. The behavior of the polymer concrete device bodies was tested with respect to surface quality, specifically the surface roughness of machined work pieces. Different settings were investigated to identify the influence of cutting speed and feed rate.*

Key words: *polymer concrete, vibration damping, workshop facilities, grey cast iron.*

1. INTRODUCTION

Polymer concrete has applications in several industries. Polymer concrete has had great importance in civil engineering and machine building for years.

Machine tools are counted among the most important production means in the metal-working industry. They are an essential factor of manufacturing systems engineering.

Machine bases manufactured of polymer concrete have also been in use with great success for thirty years. The main advantage of machine bases manufactured of polymer concrete is primarily the damping of vibrations, and secondarily its relative low price and malleability for manufacturing machine bases.

On the basis of the positive experiences with machine bases and the growing demands on workshop facilities, optimally designed device bodies consisting of polymer concrete can support the manufacturing of goods with respect to improved performance and work piece quality

This paper delineates the dynamic properties of device body elements manufactured of polymer concrete with respect to device body elements manufactured of grey cast iron. The modal properties and the influence on machining are shown with respect to dynamic compliance, surface roughness of machined work pieces and tool endurance. Several chipping parameters were investigated to identify the influence of cutting speed and feed rate.

2. DEVICE ELEMENTS PRODUCED FROM POLYMER CONCRETE

The manufacturing of polymer concrete device bodies makes the use of construction rules necessary. The rules are matched to the processing specifications, particularities of casting process as well as the material data like mechanic strength and specific weight. The most important construction rules for polymer concrete are listed below:

- Construction body should be designed as a full body.
- Minimal wall thickness of construction must be three times lower than the maximum grain diameter of filler material.
- Implantation elements (e. g. thread bolts) of metal must be used for transmission of force.
- Stress should be avoided as tensile force.
- Ratio between tensile strength and compression strength is 1:8 to 1:10.
- Undercuts and block-outs are to be avoided.

Polymer concrete with epoxy resin as a binder and quartz sand as a filler material shows the best result with respect to mechanical strength and shape accuracy after the hardening process of all types of polymer concrete. The most suitable filler material for thin plate structure elements used for device element bodies is a sand mixture composed according to Fuller's grading curve with a maximum grain size of 8mm in diameter. The polymer concrete normally consists of a ratio of 10 % weight epoxy resin and 90 % weight filler material.

Device element bodies normally consist of steel or grey cast iron. Grey cast iron is mostly used for base plates in modular systems and device elements like mounting cubes and mounting angles. For this reason, grey cast iron was selected for the comparison.

Table 1 shows the most important material data of polymer concrete in comparison to grey cast iron.

The data of the polymer concrete with epoxy resin were experimentally determined before completion of the modal analysis in order to obtain the most precise material data for this composition.

Table 1

Material data in comparison

Material data	Epoxy	Grey cast iron
Bulk density [kg/dm³]	2.27	7.19 – 7.28
Compressive strength [N/mm²]	153	840
Tensile strength [N/mm²]	20	250 – 350
Bending strength [N/mm²]	28	300 – 600
Modulus of elasticity [kN/mm²]	38	103 – 118
Poisson number	0.28	0.26
Damping	0.03	0.003 – 0.004

2.1. Design of device bodies

The following preconditions were assumed for the design of the device body elements manufactured of polymer concrete:

- base area of base plate comparable to grey cast iron base plate.
- outer dimensions of mounting angle must be comparable for both materials.
- maximum weight of the polymer concrete device body is limited to weight of grey cast iron device body.

Mathematical calculations have shown that the dynamic behavior of a base plate is at its optimum with a design (dimensions) comparable to a base plate of grey cast iron. In contrary, the mounting angle manufactured of polymer concrete must show an extended wall thickness (due to mechanical strength) of the plate structure or should consist of a full body. The behavior of the mounting angle of polymer concrete is at its optimum with a weight comparable to mounting angle of grey cast iron. The mounting angle of polymer concrete may be manufactured as two types, as a full body construction or as a jointed plate construction. The full body construction may be manufactured in one manufacturing step in comparison to a jointed construction, by which several plate elements must be manufactured and joined together. The joining process is an expensive manufacturing process because of several production steps and additional molds are also necessary for the manufacture of the single plates. The full body design is simple to manufacture and shows a maximum in dynamic and static stiffness. The disadvantage is that no slots for clamping the work piece are possible because parallel surfaces do not exist. The clamping area is limited to a grid with thread nuts.

2.2. Manufacturing of the base plate

The manufacturing of the base plate was done with a mold consisting of a machined steel plate (grinded because of surface quality) and a wood frame. This type of mold shows enough precision for the manufacturing of the test sample as well as for production of a small series. Figure 1 shows the mold prepared for casting process.

Fig. 1. Mold for base plate test sample.

The implantation elements used are made of steel. The implantation elements have two flat areas on the outside and an internal thread on the inner side. The flat areas are significant during the tightening of work pieces with respect to occurring turning moment. The internal thread has two functions: to keep the implantation element in the correct position during pouring and compaction of the polymer concrete and afterwards as function element for clamping the work pieces afterwards. The precision of the local position of the internal thread may be improved by drilling a smaller thread in the first step (fixation during pouring), and after hardening the internal thread may be expanded to a larger diameter by a milling machine.

The final manufacturing steps of the base plate made of polymer concrete are grinding of the rear side, deburring the corners and drilling out the internal threads. Grinding the rear side is necessary in order to achieve the necessary parallelism between the upper side and the rear side.

2.3. Manufacturing of mounting angle

The mounting angle was manufactured with a mold consisting of rectangular steel plates and side plates of wood. The implantation elements used show a tapped blind hole because of the full body design. It was not necessary to grind the fill in side because the fill in side fulfills no function. The shape accuracy of the right angle depends strong on the quality of the mold. Figure 2 shows the mounting angle after hardening and before removal from the mold. The final manufacturing steps are deburring corners and drilling out to M12 of the internal threads, for well-known reasons.

2.4. Comparison of device elements

The device elements used for the dynamic investigation are shown in Fig. 3. The base plate manufactured of polymer concrete shows a weight reduction of approximately 67 percent.

Fig. 2. Mounting angle after hardening.

Fig. 3. Comparison of test samples.

The mounting angle of grey cast iron shows a wall thickness of 35mm on the edges (reinforced margin). The reinforcement between the horizontal and vertical plate structure is 25 mm thick. Both grey cast test samples may be bought in specialty shops for machine tool accessories.

3. INVESTIGATION OF DYNAMIC BEHAVIOR

Vibrations stimulated through the chipping process and vibrations of the machine tool influence the surface quality of work pieces. A well-established method for the evaluation of dynamic stiffness is experimental modal analysis. The practical effect of good vibration damping may be detected on the surface of the work piece after machining.

The technological equipment used was the LMS Test.Lab System. Especially the dynamic compliance frequency response is of great importance for estimating dynamic stiffness. The test samples were decoupled during the measurement of the modal parameters. The vibration oscillation was done with an impulse hammer.

Figures 4 and 5 show the dynamic compliance frequency response of the base plate and mounting angle at the point of maximum compliance.

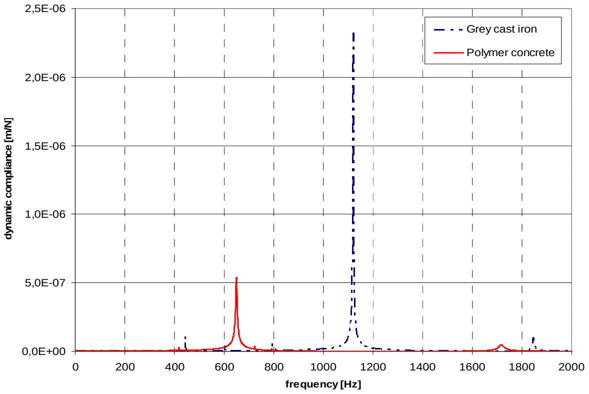

Fig. 4. Dynamic compliance of base plate.

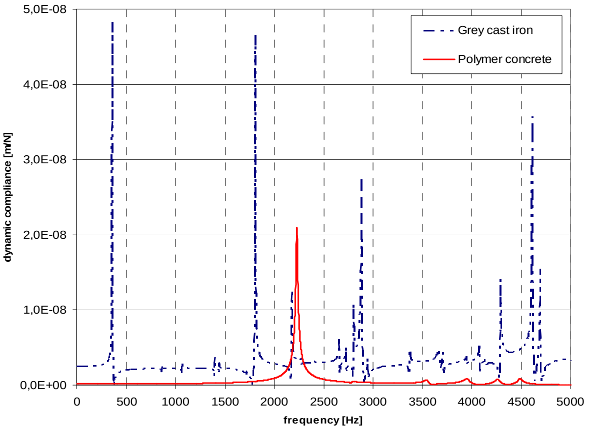

Fig. 5. Dynamic compliance of mounting angle.

The base plate manufactured of polymer concrete shows good dynamic stiffness with the exception of a natural mode at 730 Hz. The base plate manufactured of grey cast iron shows strong dynamic compliances at 450 Hz and at 1120 Hz (very strong) due to resonances.

The mounting angle of polymer concrete shows very good dynamic stiffness compared to the mounting angle of grey cast iron. The difference between both test samples results from the different constructions. The lower specific weight of the polymer concrete makes the full body design possible at a weight comparable to a grey cast iron mounting angle.

4. COMPARISON OF SURFACE QUALITY

The dynamic stiffness has a strong influence on the surface quality parameter of roughness. For this reason, the roughness of machined surfaces was selected.

The machining experiments were done with an overhanging end milling cutter (overhang 98 mm by 26mm diameter) with 3 cutting inserts. The overhanging construction of the milling cutter tends to stimulate vibrations resulting in a rough surface.

Table 2

Setting parameters of milling experiments

Setting	Cutting speed	feed rate
1	200 [m/min]	0.2 [mm/tooth]
2	200 [m/min]	0.1 [mm/tooth]
3	100 [m/min]	0.2 [mm/tooth]
4	100 [m/min]	0.1 [mm/tooth]

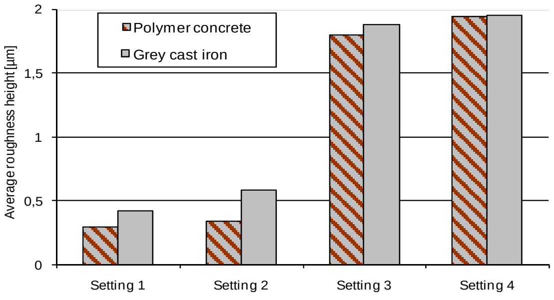

Fig. 6. Roughness of surface by base plate.

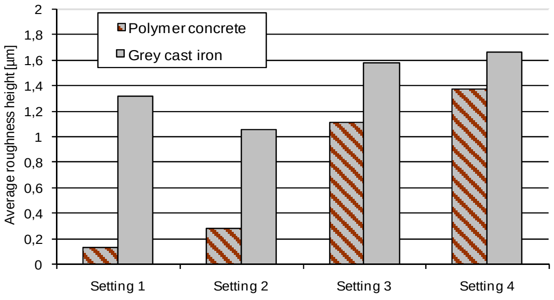

Fig. 7. Roughness of surface by mounting angle.

Machining experiments were done with the setting parameters shown in Table 2. The cutting depth and cutting width were kept constant during the machining experiments.

The cutting insert material was cemented carbide of the type P25.

The work piece material used was steel C45K. This type of steel was selected because the material is medium-heavy to machine.

Figures 6 and 7 show the surface roughness of the machined work piece with respect to device element bodies at different cutting parameters of Table 2.

The results of the machining experiment have shown that the base plate with polymer concrete shows a well improvement of the surface roughness on higher cutting speed. But, the surface roughness is nearly comparable between the two different base plates by lower cutting speed.

The surface quality of the machined surface shows a lowered average roughness height for all 4 setting parameters by the polymer concrete mounting angle. The improvement of the average roughness height is very well on higher cutting speeds for both device elements and therefore the application is very meaningful for smoothing.

5. WEAR OF CUTTING EDGE

The flank wear results from the friction between the cutting edge and the work piece surface during chipping and therefore vibrations inherently influence the extent of flank wear. If the vibrations are lower the tool flank wear is also lower and vice versa.

The measurement of the tool flank-wear land width was carried out with a measurement microscope of a total magnification of 50 fold.

Table 3

Increase of tool endurance

Device element	Tool endurance
Polymer concrete base plate	+ 19 %
Polymer concrete mounting angle	+ 69 %

A flank-wear land width with 0,3mm was selected for the evaluation of endurance of cutting inserts for the base plates. The flank-wear land width of the cutting inserts used for the mounting angles had to be limited to 0.15mm because of strong discrepancies between the flank-wear land widths.

The setting parameters used were the setting 1 of Table 2 because this parameters show the largest material removal rate. The results of the tool endurance with respect to grey cast device elements are shown in Table 3.

The endurance of the flank wear shows very positive results for all test bodies using polymer concrete. The dynamic properties as well as the economics of workshop facilities may be improved through the application of polymer concrete.

6. CONCLUDING REMARKS

The manufacture of polymer concrete device bodies requires a great deal of primary knowledge. The material offers interesting possibilities for its application in chipping. Especially the good vibration damping properties lead to an improvement of dynamic behavior and therefore to a better surface quality of machined surfaces during milling at higher cutting speeds. The weight of base plates may be reduced with this material. Overhanging device elements may be improved with respect to stiffness at a weight comparable to grey cast iron device bodies. The machining experiments have confirmed these properties, and further researches with respect to cutting tool lifetime at different setting parameters are of significance.

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