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Application of Mineral Casting for Machine Tools Beds

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The article provides state of the art and the latest development trends in the manufacturing of machine tool beds. The emphasis is placed on modern materials whose mechanical and dynamical properties may prove to be a breakthrough in the field of machine tool design.

Keywords: Mineral casting, mineral beds, machine tool bed, mechanical and dynamical properties of mineral cast

1. Introduction

The global industry is constantly looking for new design solutions and new materials which properties may improve the quality of manufacturing products, reduce the costs associated with the manufacturing process, increase the flexibility of this process, etc [1]. Unfortunately, most of the manufacturing companies still rely on technology and machines from the eighties of the last century, or even older. In general opinion these machines were very durable, and the accuracy with which they can machine the product was sufficient for that time. Since then the structure of machine tools has changed from single to modular, however some elements of the machine tools, such as beds, are still made using traditional methods, such as casting technology. Contemporary technological halls are equipped with new machines. Cast iron, used for all kinds of bodies, as well as machine tool beds, has a very good damping capacity, which during the manufacturing process results in high accuracy of the object.

Recent research and development trends show that there is a clear tendency to move away from the traditional iron casting in the direction of mineral casting, due to better dynamic properties. Mineral cast (PC – polymer concrete) is a complex material composed of particles of inorganic aggregates, such as basalt, spodumene, fly ash, river gravel, sand, chalk etc. connected by resin (usually epoxy resin) [2]. The volume ratio of the filler (aggregates) to the binder (resin) is about 9÷1 [1]. Fig. 1 shows an example of the structure of mineral cast with aggregates of different grain size.

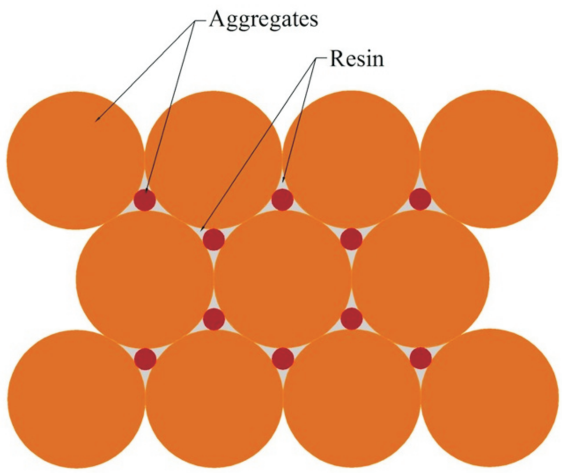

Figure 1 An example of the structure of mineral cast with aggregates of different grain size

Depending on kind of aggregates used in the mineral cast the grains may have a size from tenths of a micron to about ten millimetres [2]. Depending on the type and size of used aggregates and quantity of the resin, curing time may take from several minutes to several hours. Depending on the requirements for the achieved precision, tolerances, surface roughness, mineral cast can be made in wood, plastic, metal, cast iron mould or a combination of the above [3].

2. Current state of the art of the mineral casting used in construction of machine tools

The current development trends include application of mineral casting instead of cast iron in the construction of machine tools. In some cases, such as the precision industry, mineral casting is used only to selected components of machine tools, such as guides. This is due to insufficient strength properties of mineral casting [3]. In other cases, where the precision of the object does not need to be so high, and strength considerations permit, even the entire bed can be made of cast mineral [4]. In order to visualize the size of the item Fig. 2 shows the centre lathe with marked bed of machine tool.

Figure 2 Centre lathe with marked bed of machine tool

Table 1 shows the basic mechanical properties of cast iron and mineral cast.

Table 1 Mechanical properties of cast iron and mineral cast

	UNIT	**CAST IRON**	**MINERAL CAST**
COMPRESSIVE STRENGTH	MPa	600-1000	≤ 100
TENSILE STRENGTH	MPa	410-560	≤ 10
FLEXURAL STRENGTH	MPa	150-400	25-40
DENSITY	kg/m^3	7150-7250	2100-2400
YOUNG'S MODULUS	GPa	80-140	15-40
THERMAL CAPACITY	$J/(kg \cdot K)$	0,5	0,9-1,1
THERMAL CONDUCTIVITY	$W/(m{\cdot}K)$	45-50	1,3-2
THERMAL EXPANSION	$10^{-6}/K$	9-12	12-20

As shown in Table 1 mineral and iron cast have different values of tensile strength and compressive strength. Regardless the type of binder, ratio of compressive strength to tensile strength is about 9:1. A very important feature of mineral cast is also low density, which is 3 times lower in comparison to cast iron, what makes mineral cast a lightweight construction material. The mechanical properties of mineral cast depend of the temperature. With an increase in temperature from 20 $^\circ$C to 80 $^\circ$C a reduction of the compressive strength can reach up to 50%. The value of mineral casting fatigue strength, at which there is no damage of the item after reaching a limited number of stress cycles, is about 50% of the static loads. The phenomenon of creep may occur in the tenths of microns if a compressive loads are greater than 20% of the nominal compressive strength. The thermal conductivity of mineral casting is an order of magnitude less than that of cast iron, thermal capacity is twice as large and the thermal expansion of both casts is at a similar level [3].

The damping is one of the most important factors determining the dynamic properties of the machine and has a significant impact on the machining capabilities of machine tool. Typically, machine parts are made of cast iron, which has high damping factor. However, casting processes require an open structure and small thickness, due to the possibility of voids it can result in low resonance frequency. Mineral casting allows using closed structures with thicker walls, which leads to higher resonance frequencies [6].

Research [1,4] has been carried out in order to determine the tool flank wear and surface roughness of the workpiece, depending on the cooling (wet, MQL, dry) and type of material of the bed of machine tool (mineral cast, iron cast) during turning. The results show dependency of tool flank wear as a function of turning time [1] or the volume of material which was removed [4], using a bed of iron and mineral cast. In both cases it was evident that the tool flank wear was higher in case of the cast iron bed regardless the method of cooling. The other dependency of surface roughness as a function of turning time [1] or the volume of material which was removed [4], using a bed of iron and mineral cast, has been also determined and examined. Also in these two cases, it is apparent that by using the bed made of mineral casting, the surface roughness of the workpiece is lower than by using the bed made of cast iron. These differences result from the fact that the mineral cast has from 4 to 7 times higher vibration damping properties than cast iron [4]. In order to perform detailed analysis of these properties, the research was further carried out. Both beds were equipped with accelerometers placed at various points in order to record information about the vibrations. The recorded output signals (single force [1], constant periodic excitation [4]) were presented in the form of dependence of acceleration versus time and acceleration versus frequency. The first resultant dependencies present acceleration versus time and acceleration versus frequency at a single force. They show that the mineral bed is characterized by lower amplitude of resonance vibrations than iron bed [1]. The following two dependencies present acceleration versus time and acceleration versus frequency at constant periodic excitation. Also, in this case it could be seen that the mineral bed has much smaller amplitude of resonance than that of the iron bed [4]. The research has also been carried out to investigate the frequency of occurrence the further modes of free vibrations in search of two identical shapes of machine tool spindle models made of cast iron and mineral cast. Dynamic analysis of the subsequence modes has shown that the frequency of vibrations of model made of mineral cast is twice as high as the frequency of a model made of iron cast [5].

3. Conclusions

The article presents the current state of the art of the mineral casting used in construction of machine tools. Application of mineral casting requires thorough research both theoretical and experimental in the field of material and strength. The research should be also focused on evaluation of mineral casting application capabilities for technological machines elements e.g. beds of machine tools etc. Mineral cast due to its excellent dynamic properties and low density is willingly introduce to the machine tool industry. Research has shown that commonly used cast iron may be partially or even completely replaced by modern construction materials such as mineral casting in the nearest future.

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