Friction Polishing and Contact Tests of Diamond by Solid Metals

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Abstract

The presented work deals with the thermo-chemical reactions of diamond with solid metal by friction polishing and contact tests. Both experiments were carried out at elevated temperatures with pure iron to shape single crystal diamond substrates. To characterize the removal rate and topography of the diamond a white light interferometer and profilometer were used.

1 Introduction

The outstanding properties of single crystal diamond such as high hardness, high wear resistance, low friction and high chemical inertness are well known in the world of micro forming. Based on this properties diamond is a favourable material for applications like micro-forming tools. In contrast to the excellent material properties the shaping of diamond workpieces to precise parts is difficult and cost-intensive.

To overcome these restrictions, the removal of diamond material by thermo-chemical reaction with molten or solid metals instead of machining has been reported. E.g. Fe, Ce, La or Mn with a relatively high solubility of carbon has been applied [1, 2]. Paul et al. described that unpaired “d”-shell electrons in the metals increased the chemical activity of the diamond by contact with high temperatures. Firstly, the binding of the carbon within the diamond structure is broken. Then carbon atoms diffuse into the metal and react to carbide, graphitize or oxidize to CO or CO_2.

The final objective of this research is to develop a technology which enables the finishing of laser pre-shaped micro forming dies made from moncrystalline diamond.

2 Experimentel procedure

Friction polishing and contact tests were performed with synthetic monocrystalline diamond of type Ib and pure (99.5 %) iron rods. The dimension of the diamonds were

3.5 x 3.5 x 1.7 mm^3 with ((100) direction) a surface roughness of approximately 2 nm Sa as measured by a white light interferometer (WLI) over an area of 800 x 600 μm^2. The contact experiments were carried out with iron rods with a diameter of 2 mm and a length of 2 mm, for the polishing experiments iron rods with 1 mm diameter and several millimeters length were used.

Friction polishing experiments, fig. 1, were conducted on a drilling machine with a rotational speed of 1400 rpm. All experiments were carried out with the same load between the iron rod and diamond of approximately 20 N. The diamond as counterpart was fixed in a steel block. Heating elements placed in the steel block heated the diamond. Temperature measurements on the contact surface between diamond and iron rod were carried out by a Sensotherm MI 16 pyrometer. A second thermocouple was prepared on the block surface to control the heater elements. Experiments were conducted on the maximal power of the heating elements of 550 °C in the contacst area and with polishing times of 1 h, 2 h, 3 h and 5 h. For each test one seperate iron rod was used. To measure the maximum depth of the polished area a WLI was applied. For the contact experiments the metal rod was fixed in a holder on the cylindrical axis against the diamond which was clamped between molybdenum plates. A death weight on the holder was used to press the iron surface on the diamond top by approximately 9.6 N. To realize high temperatures the experiments were performed in a furnace with nitrogen atmosphere with continuous nitrogen flow. All experiments were carried out by a holding time of 2 h, 3 h, 4 h, 5 h, 6 h and 8 h plus heating and cooling time of the furnace to

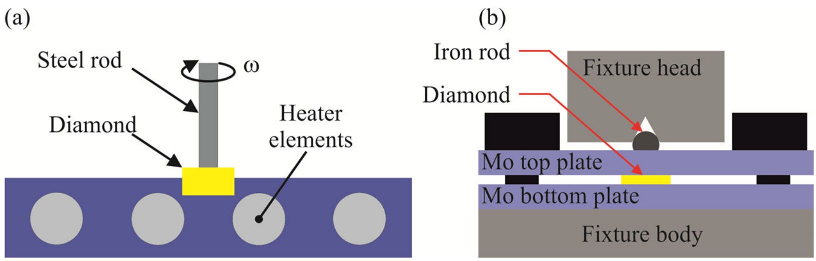

Figure 1: Schematic diagram (a) of friction polishing experiment and contact experiments (b)

achieve the maximum temperature of 850°C. A KLA-Tencor P-15 profilometer equipped with a 2 µm radius stylus probe and a cone angle of 45° was used to determine the maximum removal of diamond.

3 Results and Discussion

Figure 2 shows the maximal achieved removal depths for all tests. In case of contact tests (grey icons) a continuously rise of diamond removal was detected from 6.6 µm after 2 hours up to 14.2 µm after 8 hours. Furthermore, experiments showed that with increase of holding time the chemical reactivity decreases with decline of differences in concentration between diamond and iron rod. In the first 2 hours an average removal rate of 3.3 µm/h was observed against a removal rate of 1.3 µm/h between holding times of 6 to 8 hours.

Friction polishing tests showed in the first two hours constant removal rates of approximately 4.6 µm/h with a maximal removal depth of 9.8 µm. With increasing time of polishing a rise of removal depth could not be observed. The difference variation of maximal removal depth at polishing times of 2 h, 3 h and 5 hours was 1.8 µm. Both types of experiments show lower removal rates against those reported in literature, up to 1100 µm [4]. It should be noted that in literature experiments a relative velocity up to 30 m/s was realized compared to a maximum relative velocity of 0.07 m/s in friction polishing experiments shown here.

Figure 3 presents the diamond surfaces after contact test for 5 hours (a) and 3 hours polishing (b) measured by WLI. Both pictures show different removal depths on the overall area. In case of friction polishing different removal depths occur because of the insufficient true running accuracy of the machine tool applied.

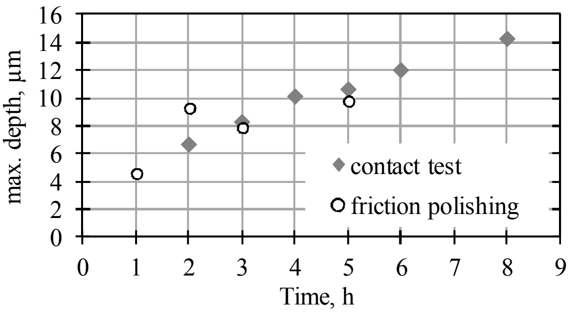

Figure 2: Diamond removal depth by contact test and friction polishing

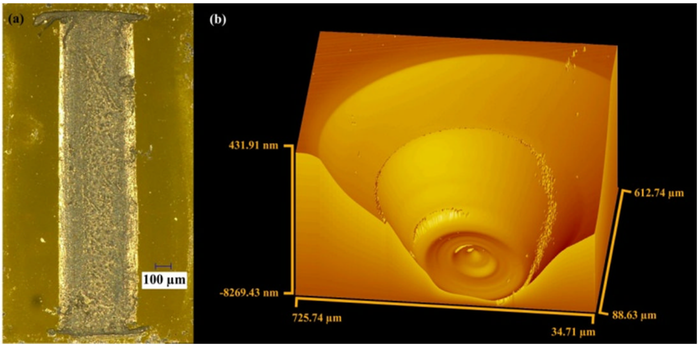

Figure 3: Diamond surface after 5h contact test (a) and 3h friction polishing (b)

4 Conclusion

Friction polishing and contact experiments between single crystal diamonds and iron rods were conducted. Both types of experiments show relatively low removal rates which decrease with increasing machining time. Some possibilities to raise diamond removal rates are the application of higher temperatures and the supply of fresh material in the contact area as well as in case of friction polishing the use of higher rotational speeds of the iron rod.

Acknowledge

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