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Mechanized adhesive applying for porous aerostatic bearings

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Abstract

Aerostatic bearings based on porous restrictors commonly consist of two components: the bearing body and the restrictor. The bearing body is usually steel or aluminium, and the restrictor is often graphite or some other porous material. The porous restrictor and the body are bonded together with adhesive. Aerostatic bearings are commonly utilized in precision engineering applications which require narrow manufacturing tolerances and a highly repeatable manufacturing process. The adhesive application in the assembly process of aerostatic bearings is vulnerable to variations, as the adhesive bonding process is sometimes carried out by hand. Thus, variances in the operation have effect on the final product's quality. This study presents a system for mechanized adhesive application for manufacturing of aerostatic bearings. The presented system was developed for mechanized adhesive application using a standard 50 ml handheld, two-component epoxy cartridge. A six-axis robotic arm was utilized to dispense and direct the bead of epoxy in a specified pattern, and a statistical inspection of this method's repeatability is performed. The study investigates the repeatability of this type of automated adhesive application, aiming to minimize the risk of poorly bonded restrictors in future studies.

Aerostatic bearing, adhesion, robot

1. Introduction

Aerostatic bearings are categorized according to the air feeding structure. Nozzle type bearings are common and widely adopted in the industry. Meanwhile, porous material bearings are also favoured in several industrial applications. The structure of porous material bearings commonly consists of a metal body and a porous material restrictor jointed to the body. Illustration of a porous aerostatic bearing structure is presented in Figure 1. The porous material restrictor not only limits the air consumption but also increases the stiffness of the air film compared to other type of aerostatic bearings [1]. Synthetic graphite is a common material utilized as the porous restrictor; however, it can have significant variation in its material properties [2].

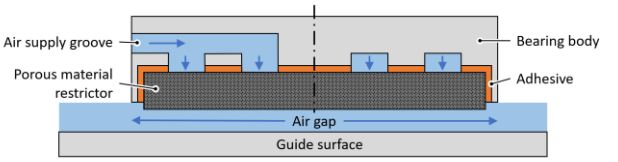

Figure 1. Simplified cross-section of circular porous aerostatic thrust bearing. Restrictor is adhesively mounted to the body.

In addition to the varying material properties of graphite, the adhesive bonding process between the graphite restrictor and the bearing body may introduce inconsistencies [3]. An excessive amount of adhesive may cover the open pores of the graphite or fill the air supply grooves. This can reduce the area of the air passages in the bearing body and limit airflow to the graphite restrictor. Additionally, an insufficient amount of adhesive may cause air leaks or a failure of the adhesive bond. Limited, uneven, or obstructed airflow to the restrictor causes losses in performance due to the uneven pressure distribution in the air gap.

Repeatable adhesive application process can be achieved with volumetric dispenser [4]. Dispensing unit can be mounted to an automated multi-axis machine, for example 6-axis robots are used in automotive industry [5]. This allows the adhesive to be applied in specified patterns and amounts. In cases where small series of bearings are manufactured, manual adhesive application may be required. Manual adhesive application leads to inconsistent dispensed pattern shape and the amount of applied adhesive. In attempts to eliminate any human error in the adhesive application process, this study introduces a simple, automated, and low-cost method of applying the adhesive by means of a robotic arm, two component epoxy cartridge, and a custom dispensing system.

The goal of this study is to validate only the repeatability of the mass of the adhesive bead applied to the bearing body. The data collected in this study demonstrates satisfactory levels of repeatability and this system may be suitable for use in future aerostatic bearing research endeavours. In future studies the adhesive target mass will be defined.

2. Methods

2.1. Machinery

The machinery consisted of UniversalRobots UR10 robot and a custom epoxy dispensing system. The epoxy dispensing system utilized a standard 50 ml handheld, two-component epoxy cartridge. The dispensing system is presented in Figure 2. A NEMA 17 stepper motor was connected through a 10:1 ratio planetary gearbox to a lead screw which actuated the piston pressing the adhesive cartridge pistons. The stepper motor was controlled to operate with constant rotational speed and thus maintained constant volumetric flow of the adhesive.

The mixing of the two epoxy components was performed with a 151 mm long, 21-element static mixing nozzle with an inner diameter of 6.3 mm. The cross section of the nozzle is circular, and the mixing elements are attached to each other only from the middle in a helical pattern thus reducing the possibility of air remaining in the nozzle. Air trapped in the nozzle will be compressed during the process, and after dispensing, the expanding air will cause undesirable flow from the nozzle. A 0.84 mm diameter 13 mm long stainless-steel dispensing needle was mounted to the tip of the static mixing nozzle. The dispensing needle enabled more accurate application of the adhesive bead, although the thin needle increases the pressure in the mixing nozzle and increases the force required to apply the adhesive from the cartridge.

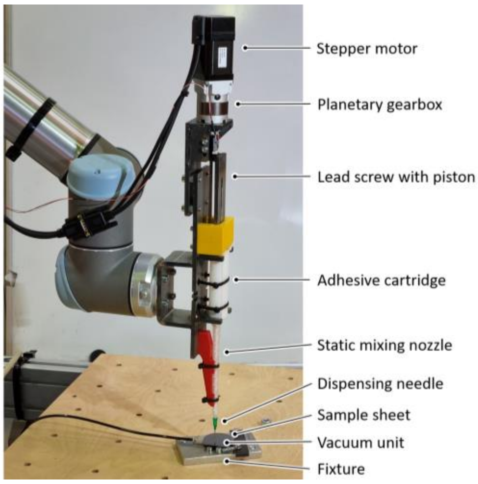

Figure 2. Adhesive dispensing system mounted to a robotic arm.

2.2. Test procedure

The test procedure consisted of the application of adhesive to plastic sheets with a controlled pattern identical to the one used in bearing manufacturing. During the measurements, the bearing body was replaced with a vacuum unit to hold the plastic sheets in place during the dispensing of the adhesive. The mass of each plastic sheet was measured before adhesive application. After dispensing, the adhesive was allowed to cure completely and the sheets with the adhesive were weighted.

2.3. Dispensing procedure

The system was initialized by extruding the adhesive to the mixing nozzle while the nozzle pointed upwards. Extrusion speed during the initialization was extremely slow due to the high viscosity of the adhesive. Filling the nozzle upwards with slow speed minimizes the amount of trapped air in the mixing nozzle. After the nozzle was filled, the first test extrusions were performed. According to the test extrusion results, the robot and extrusion speeds were adjusted. The final tool speed was 10 mm/s. All samples were extruded in one batch with a 35 s cycle time including the sheet changing time. A sample is presented in Figure 3.

Figure 3. Adhesive applied to plastic sheet with the same pattern utilized in the aerostatic bearing manufacturing process.

3. Results

The measurement results are presented in Figure 4. During the adhesive application, it was visually observed that approximately 10 consecutive samples were required before the extrusion results became uniform between samples. The same conclusion can be made from the data in Figure 4. Therefore, the last 30 consecutive samples were selected for analysis. The average mass of the adhesive of the selected samples was 406.15 mg, and the standard deviation was 4.84 mg (1.19 % of the average).

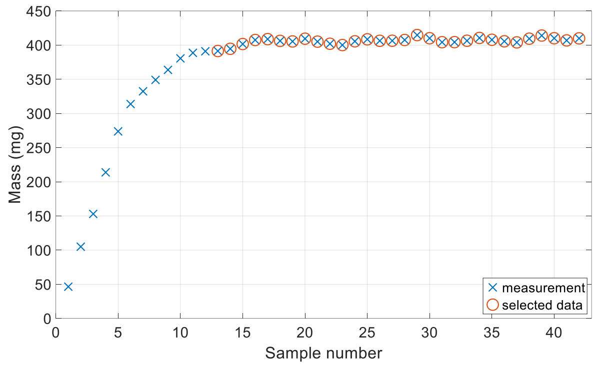

Figure 4. Dispensed adhesive mass. Initial gradient was excluded from statistical analysis.

4. Discussion

The system presented in this study reached an adequate level of accuracy and repeatability. The level of repeatability compared to commercially available solutions is in the same range. The system provided by Techcon reaches ±1 % level of accuracy according to the manufacturer [6]. Most of the commercial solutions are based on volumetrically adjusted dispensing which is a more accurate system by principle.

The main effect on the accuracy of the system originates from excess adhesive dripping from the needle between dispensing events as the pressure is released from the nozzle. To increase accuracy of the system, the authors suggest utilization of a shorter mixing nozzle and a pneumatically operated dispensing valve placed before the dispensing needle. The dispensing valve allows for a higher constant pressure applied in the cartridge without pressure loss between dispensing events. This stabilizes the flow properties and increases repeatability.

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