IMPROVISING SUPERIOR LEVITATION AND DYNAMIC CONTROL PERFORMANCE OF ACTIVE MAGNETIC BEARING

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ABSTRACT

In this paper, the application of optimal state estimation and optimal state feedback algorithms for constant dynamic magnetic bearing control is dealt with. A reduced switch converter for the dynamic magnetic bearing system is investigated and its exhibition is experimentally approved at 32,000 rpmon a 4-hub magnetic bearing test-rig. In view of the coupled coil created as of late as an option for the course of action and unidirectional current activity, the reduced switch converter is derived and its methods of activity are expounded. In contrast with traditional topologies, this converter diminishes the necessity on the quantity of switches, gate drives, and pulse width modulation signalsoriginating from the controller. The analysis and experimental outcomes effectively approve the activity of the reduced switch converter to meet the magnetic bearing activity prerequisites.

Keywords: Active Magnetic Bearing, adaptive control

INTRODUCTION

Active Magnetic Bearing (AMB) has been created in the ongoing barely any decades as an option incontrast to the regular mechanical bearings. AMB depends on the idea of utilizing electromagnetic power to suspend the rotor shaft in suspension without reaching the stator. Likewise, magnetic bearings can be coordinated with a machine to frame bearingless engines. Contrasted and ordinary speed engine applications, the magnetic bearing can perform with more advantages for rapid engineapplications.

The essential standard of magnetic bearing levitation in one hub has appeared in Figure.1. In every hub, electro-magnetics in different sides can create electromagnetic powers on the rotor to dislodge it. The electromagnetic actuator can be with or without perpetual magnets. With lasting magnets, thesize of the actuator can be reduced however the cost will increment. Lasting magnets are not utilizedin actuator and the magnetic field is energized by the windings in electromagnets. The structure of the spiral magnetic bearings is with eight shaft structure. It tends to be considered as a blend of two autonomous differential actuators an opposite way in one stator ring.

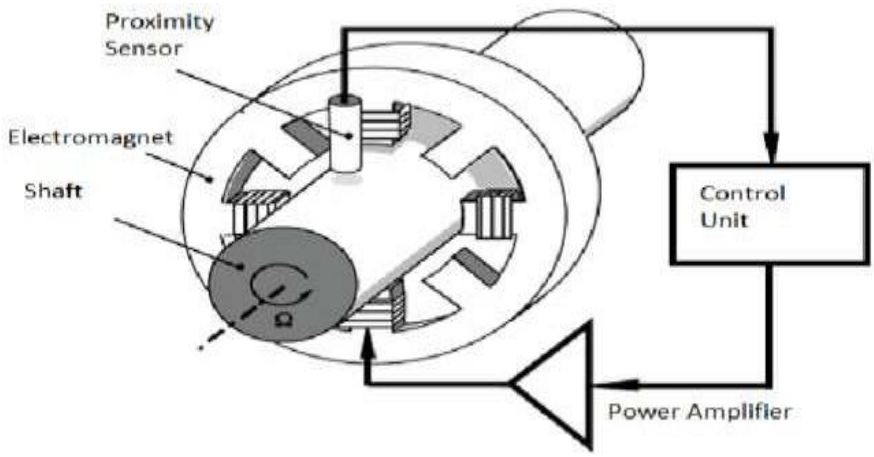


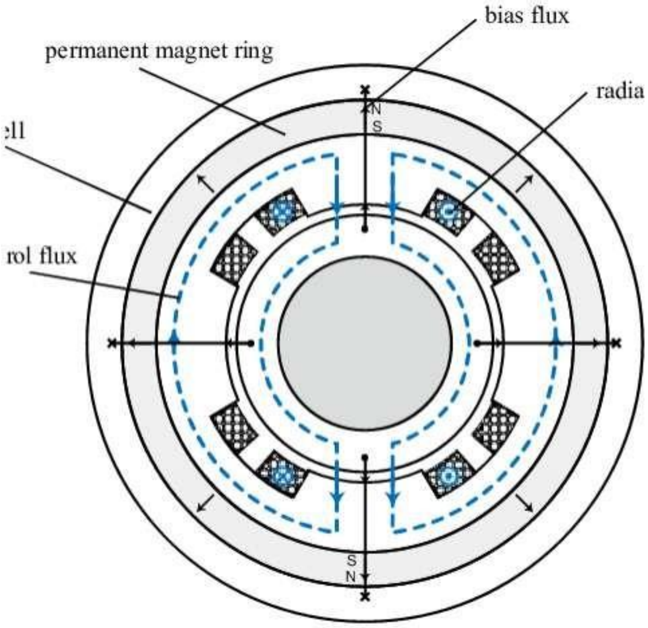
Figure.1 magnetic bearing levitation principle

Actuator itself can't accomplish stable levitation for the rotor, feedback control is vital with sensors,drive and controller. The rotor position is estimated by a position sensor and took care of back to the position controller. With the position controller, two windings' current are acclimated to create the electromagnetic power on the rotor, to accomplish position feedback control for magnetic bearing. Power amplifier, or magnetic bearing drive, is the center part in the magnetic bearing system. Its primary capacity is to create genuine winding current, which ought to be following the reference current in the controller absolutely and rapidly. Likewise, the expense and effectiveness of the magnetic bearing drive are the necessities.

Direct power amplifier is the original of the magnetic bearing drive. Because of its powerful misfortunes, it has been supplanted by switching power hardware converters. Full bridge converter has been applied for each twisting at first as the drive. Due to the unidirectional current qualities, a unipolar H-bridge converter can diminish the prerequisite of power gadgets for AMB drives.Likewise, a broadly utilized three-phase full-bridge converter can be utilized for AMB drive by sharing one phase-leg for two windings. AMB drives can be coordinated with engine drives for bearingless engine, as well. Topologies of power gadgets converters for the magnetic bearing drive have been in ceaseless advancement. References have done a systematic examination among the various topologies of the magnetic bearing drives. The twisting current in magnetic bearing is unidirectional and comparative with switched reluctance motors (SRM) and the current SRM drives can be alluded for AMB drives, as well. The current power gadgets converter topologies for the magnetic bearing drive are not completely using the gadget abilities. Numerous repetitive gadgets areexisted in the system, expanding the expense and unpredictability of the magnetic bearing drive system. The current in each winding creates an electromagnetic power on the pole. The distinction between the current in two inverse windings fills in as the control current, which creates the absolutemagnetic bearing power Fmag in the comparing pivot.

For entire rotor shaft levitation, four sets of windings are utilized in the spiral magnetic bearings, framing four-hub magnetic bearing. Figure.2 shows the left and right bearings for levitation and theirstructures. Four tomahawks: u1, v1, u2, and v2 are with four sets of windings and four-position sensors. The current is infused into each twisting by four magnetic bearing drives to create the electromagnetic power.

Figure 2. Levitation wing of AMB



So as to confirm the exhibition of the magnetic bearing and its drive, a test rig has been fabricated. Figure.3 shows the image of the magnetic bearing test rig. A 6 Hp acceptance machine fills in as thefooting machine and is associated with the 38 lb. shaft. Two arrangements of outspread control bearings are utilized to control the pole position with a 250µm air hole, with the structure appeared. The magnetic bearing is with 74 turns for each post, which produces 10mH inductance for each winding. So as to secure the magnetic bearing and the pole if there should be an occurrence of the control disappointment, two touch-down bearings with a 150µm air hole are additionally fixed to the test rig, which makes the position mistake resistance to be ±200µm.

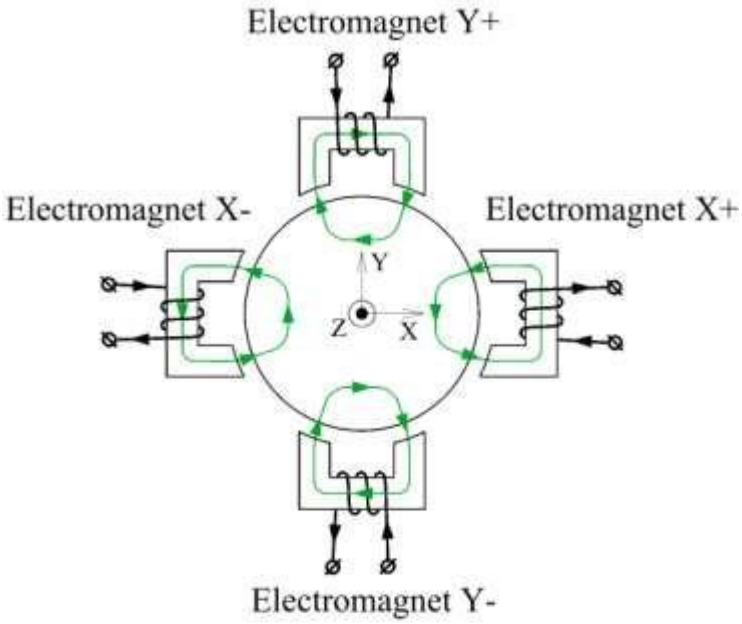


Figure 3. Magnetic bearing test rig

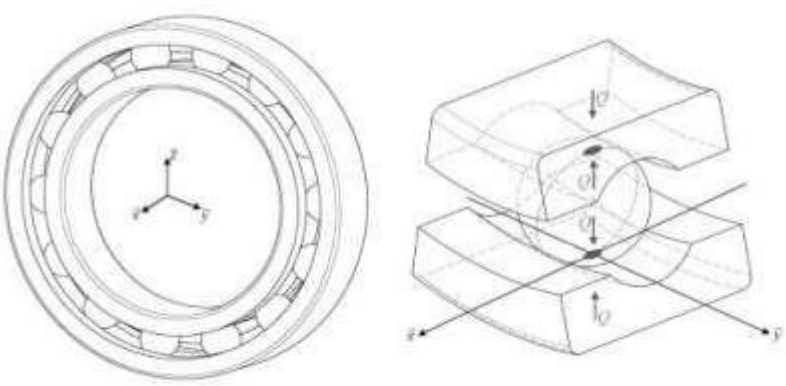


Figure.4 AMB together with touch down bearing

The touch-down bearing is a metal ball that will possibly work when a magnetic bearing fizzles. Thephysical model of the AMB along with a touch down bearing is appeared in Figure.4. Two spiral unsettling influence bearings are utilized to infuse annoyance powers to the pole to test the control execution. The controller could be confirmed in recurrence clear analysis, which can assist with foreseeing the position control execution in the rotational test.

PROPOSED METHODOLOGY

Without control, magnetic bearing is an unstable system. So as to steadily suspend the pole, the controllable current ought to be infused into the windings. At first, direct amplifiers were utilized as magnetic bearing drives. They are with large power misfortunes and have been supplanted by power gadgets converters. Various types of power hardware converter topologies can be utilized to control the current infusion. This area puts the proposed topology in correlation with existing topologies and portrays the standard and favorable circumstances of the proposed topology as a magnetic bearing drive.

Topology comparison

Figure.5 shows the various topologies for magnetic bearing drives. Figure. 5(a-c) are from [7-9], and Figure. 5(d-e) are proposed by this paper for magnetic bearing drive applications. Figure .5(a) is the situation of full H-bridge driving one winding. For the four-hub magnetic bearing system, eight windings are with eight of these converters. The magnetic bearing depends on the reluctance power of the actuator which is corresponding to the square of the current, so it isn't identified with the current course and could be unidirectional. Since the winding current could be with only one course, the decrease of two switches is conceivable. That is the unidirectional H-bridge, which appeared in Figure.5 (b).

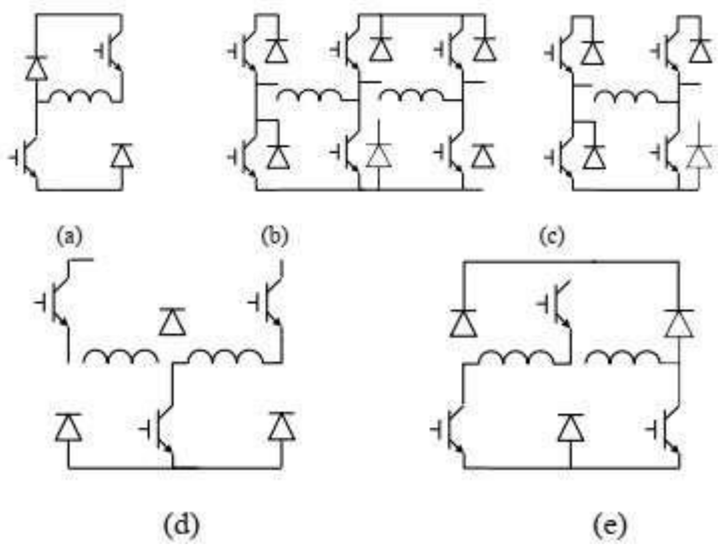


Figure. 5 MB various combinations (a): Half H-bridge topologies ; (b): Full three bridges topologies; (c) Full Hbridge topologies (d): Three-half-phase-legs (t-b-t) topologies (e): Three-half-phase-legs (b-t-b) topologies

Combining the concept of Figure.5 (b, c), unidirectional three phase-legs topology can be created. Figure.5 (d) is this sort of converter, with three half phase-legs to drive a couple of windings. In Figure.5 (d), two switches are on the top side and one switch is on the base side, which is called t-b-t engineering. Another three-half-phase-legs design is appeared in Figure.5 (e). It is with two switches on the bass side and one switch on the top side which can be called b-t-b engineering. For three-half- phase-legs structures, three switches and three diodes can be reduced from Figure.5(c).

Above gives the segment number examination of the five unique topologies for a four-pivot magneticbearing system with eight windings. With the novel three-half-phase-legs converters Figure.5 (d and e), power gadgets can be enormously reduced from different topologies. Additionally, the four-pivotmagnetic bearing with the topology of Figure.5e is with easier gate driver design. In the full four- pivot drive circuit, 8 of the 12 switches are with a similar ground (negative DC transport), just 4 switches are with the skimming ground and have more difficulties for gate drivers. The base switchesshare a similar gate power providers and every one of the top switches has one disengaged gate power provider, the number of power providers can likewise be reduced. The common gate driver power provider for all the base switches ought to be structured with capacity for all the gate drivers together. Since the b-t-b design moves four switches from the top to the base in correlation with the t-b-t engineering, the gate drive power providers for b-t-b engineering is additionally reduced.

Table.1 Comparison of components with different topologies for a four-axis magnetic bearing system

	Switches Diodes	Gate Drive	power suppliers
Full H-bridge	64	64	32+1
Unidirectional H-bridge	32	32	16+1
Full three phase-legs	48	48	24+1
Three-half-phase-legs (t-b-t)	24	24	16+1
Three-half-phase-legs (b-tb) selected topology	24	24	8+1

The significant penalty of utilizing the novel converter is that the focal leg switch will lead greater (roughly twice) current than the switch in the H-bridge topologies. Nonetheless, utilizing a higher current rating switch is less expensive than utilizing two lower rating switches with gate drivers in different topologies. The current in the focal leg is the whole of the different sides' phase current in the three-phase-leg based topologies. For exact misfortune computation, the non-linearity of the conduction obstruction Rdson, the gate charge power, and the opposite recuperation misfortunes ought to be thought about. The power misfortune could be greater than the aggregate of the power misfortunes in the two-phase legs for the two unidirectional H-bridges.

SIMULATION RESULTS

In this section, the assumptions made in the preceding sections shall be verified by means of measurements.

Optimal State Estimation The filter algorithm has been executed on a dSpaceDS1103 PowerPC controller load up (count time for one bearing pivot is around 20 µs). The test rig comprises of a completely magnetically suspended blower with a rotor mass of 250 kg just as an uneven magnetically suspended drive with a rotor mass of 25 kg. All significant test rig parameters can be found and the position sensor parameters are given. An image of the blower is portrayed in Fig. 5 shows the impact of the estimation algorithm on rotor situating exactness. As a position controller, atraditional linearized PIDT1-controller has been executed. On the off chance that rotor position control depends on the deliberate position signal x, the system shows exceptionally powerful control deviations (upper outline). Therotorposition" tops" are brought about by high-recurrence clamor contained in the estimations which is amplified by the subordinate piece of the controller. In the eventthat the evaluated rotor position x is utilized rather (lower outline), the greatest control deviation is reduced to about 80%. The second state variable in model is the spiral rotor speed v. The right estimation of this state will be verified by methods for a rotor position step reaction, estimated in the shut circle activity of the bearing. For each situation, the upper chart represents the position step reaction, where a high relationship between's the deliberate and the evaluated position sign can be watched. The lower graph contains is thought of, the overshoot is reduced (by about 5%) to 127%. At long last, if the estimation slack is considered by utilizing the "undelayed" rotor position estimation x, the subsequent overshoot has a measure of 110%. This conduct can be clarified as follows. On the off chance that no state estimation is utilized by any means, any difference in a system state is taken care of to the controller through the estimation system with its first-request slackattributes.

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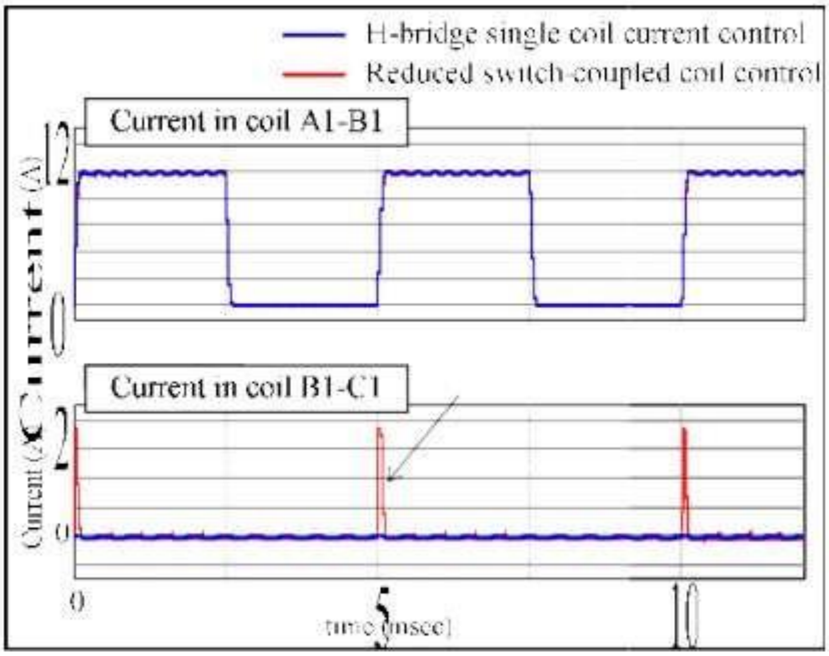

When utilizing a state estimator with a very simplified system model (no-estimation slack considered), the shut circle phase edge improves in any case somewhat because of the prescient structure of the estimator. By refining the system model, even parasitic time postponements can be thought of, and the shut circle phase slack can be reduced essentially, prompting higher system solidness and dependability.

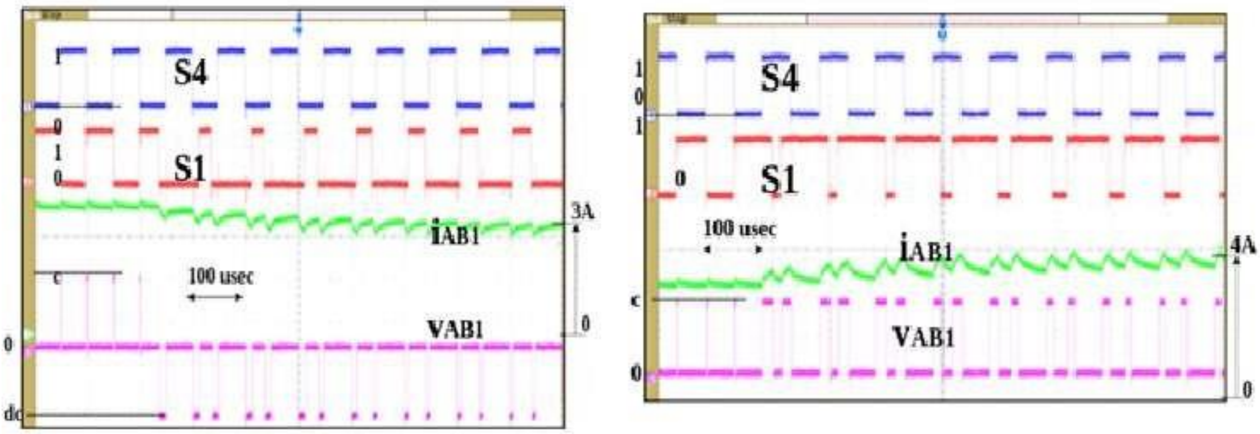

Figure 6 Experimental results of the converter stating performance improvement of AMB

To approve the working modes in the switch S4 of the focal leg has a fixed obligation pattern of 50 percent. To expand the current, the obligation pattern of switch S1 is expanded as appeared. The comparing voltage over the coil A1-B1 is increments and the current in the coil increments from 3A to 4A. To diminish the current in the coil, the obligation pattern of switch S1 is reduced beneath 50 percent during the transient condition. After the affectability tests, the rotor is increase to 32,000 rpm in 120s. The position blunders in the inclining up analyze are appeared. During the increase, the pinnacle position mistakes are under 30µm for all the four tomahawks, which is 15% of the leeway for the touch-down bearing. The outcomes approve the fruitful activity of the magnetic bearing system joining the reduced switch converter introduced and dissected in this exploration.

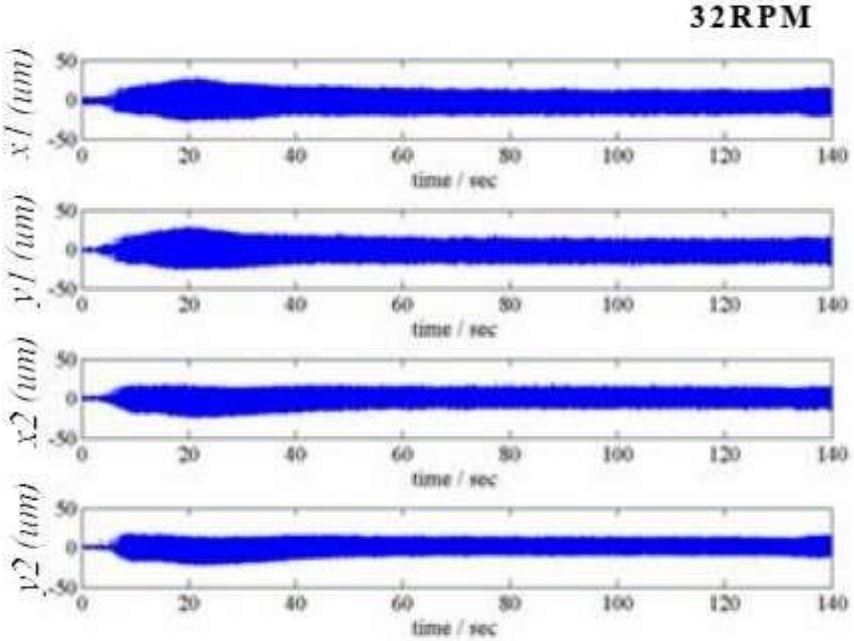

Figure 7 Sensitivity test output

CONCLUSIONS

In this paper, a converter with novel topology is created for the magnetic bearing drive. Beginning with the guideline of magnetic bearing, the magnetic bearing test rig is introduced. At that point the novel converter topology of three-half-phase-legs is presented and contrasted and the other existing topologies for magnetic bearing drives. A conspicuous decrease of power hardware gadget amount can be accomplished with the proposed topology. The current control capacity of the novel converter is concentrated to accomplish high transmission capacity and less current wave, as well. Reenactment and experimental outcomes are given to check the current control execution of the proposed converter for magnetic bearing. At that point the novel converter is gone after job control of four-hub magnetic bearing with its current control capacity. Experimental outcomes for magnetic bearing position control in the rotational tests are given to assess the presentation of magnetic bearing with the proposed drive design. A few ends can be drawn from the paper:

(1) Compared with the current topologies for magnetic bearing drives, the proposed converter can diminish the power gadgets and gate drivers by using the unidirectional conduction and phase-leg sharing standards. (2) In the novel converter, the freewheeling status (01 and 10) can accomplish a

little current wave and ought to be completely used in switching cycles. With an inversed pulse between the two base switches and the focal top switch, the current wave can be a lot littler than the adjusted pulses. (3) With the half obligation cycle in the focal leg switches, the novel converter can accomplish expanding and diminishing current ability by expanding and diminishing pulse width in the base switches. (4) By adjusting the pulse width of the focal switch, the current control transfer speed can additionally increment, yet in addition brings the coupling issues. (5) With the novel converter and the tuned controller, magnetic bearing functions admirably in the test rig for the pivoting test up to 32,000 rpm. The position mistakes in the entire procedure are inside 15% of the air hole of the touch-down bearing.

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