A Review: Potential Failures in Grinding Process of Bearing Rings and its Solution

Failures during grinding of Bearing ring

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Abstract— Grinding is a commonly used finishing process to produce components of desired shape, size and dimensional accuracy where the ultimate goal is to have the maximum workpiece quality, minimum machining time and high energetic efficiency by making a selective adaptation of the possible process strategy and chosen parameter selection. The focus of this study arose from a limitation that challenges the grinding process of bearing ring. The production rate of ring is generally constrained by surface topography, surface and near surface damages such as burns and micro and macro -cracking induced by phase transformations, residual stresses and many other criteria. These types of damage may reduce the life of critical components that are often subjected to severe working conditions with repeated loading and vibrations. So it is necessary to focus on the potential failure occur during grinding process. Paper shows the possible cause and its solution to respective problem. The main objective of this paper is to find out the possible cause of the failure of the bearing ring and solution to the respective problem.

Keywords— Bearing ring, grinding process, potential failures, review paper, residual stresses, clamping force.

I. INTRODUCTION

Cylindrical surface has long been widely utilized in various industries, and requirements for precision cylindrical surface have been increasing significantly in the continual pursuit of perfect quality and high-performance products. In bearing industry, great efforts have been focused for reducing the potential failure which causes bearing noise and vibration.[10]

Manufacture of bearings is a challenging production process. Even though its specific manufacturing operations are widely known and established, some operations in bearing manufacture must be performed within narrow tolerances ranging from only a few micrometers to comply with requirements of tolerance analysis done before the parts are manufactured to ensure that clients receive a quality product that influences safety of plant operation, therefore safety of people. The manufacturing comprises a number of operations needed to produce rings, rolling elements and cages. It includes hammering of forgings at the beginning, turning, heat treatment, cutting, forming, grinding, washing of parts, their description, assembling bearing components and packaging. A number of preventive, intra-operational and final inspections and dimensional, chemical, metallurgic, endurance and other tests are carried out during the manufacturing process.[1][2] Since race grinding was the bottleneck, the researchers focused on this operation.[3] So that whole concentration are done on the grinding process of bearing ring and failure of ring during the manufacturing.

II. GRINDING

Grinding is a process which utilizes various tiny and hard abrasive particles formed in a binder as a multitude of cutting edges to continuously remove unwanted material on a workpiece at very high speeds. The chips produced by grinding are therefore very small, by about two orders of magnitude smaller compared to other cutting operations. [13]. Figure 1 illustrates the basic grinding operation. Six basic elements are involved [14]:

- The workpiece: material, shape hardness, speed, stiffness, thermal and chemical properties
- The Abrasive tool: structure, hardness, speed, stiffness, thermal and chemical properties, grain size, and bonding
- Clamping material and clamping force.
- The process fluid: flow rate, velocity, pressure physical, chemical and thermal properties
- The atmospheric environment
- The machine accuracy, stiffness, temperature, stability, vibrations.

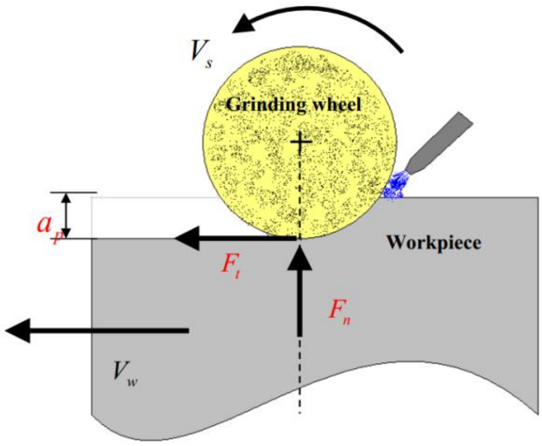

Fig. 1 Basic grinding Element [15]

Parameters in grinding process [11] and can be classified as

- Main parameters or machine parameters - that can be directly controlled by the operator.
- Secondary parameters or calculated – which are derived directly by calculating main parameters.
- Random parameters - which are difficult to control and may affect the surface integrity of workpiece.

III. RESEARCH METHODOLOGY

The aim of this study is to bring out the potential failure of ring during the manufacturing of bearing and to evaluate the cause of failure and its solution. It is an attempt to evaluate the possible failure experienced in the various bearing manufacturing industry. The initial part gives an overview of potential failure by various authors. In the next part literature review has been done to find out the possible causes and solution for respective failure. The considered cases are taken up from established journals and publications. However due to limited established research literature and the details of the problem are not generally disclosed easily by the author so only 7 most probably observed failures were considered.

The study of all the cases is then presented in the following sequence 1) Literature review for respective ailures. 2) Potential failures during grinding. 3) Problem with its cause and solution.

IV. LITERATURE REVIEW FOR RESPECTIVE PROBLEM

Syed Mushtaq al., 2011 [15]have observe that the residual stress occurs due to thermo metallo mechanical failure table below shows the cause, effect and its solution for the residual stress and its effect. He has use the Abaqus material library for defining materials constitutive behavior and user expansion coefficient respectively number of subroutine for numerical calculations and associated solution convergence.

Table 1 problem, cause and conclusion for problem

Problem	Cause of problem	Conclusion
Residual stresses & its effects.	Excessive heating (thermal failure)	To decrease the level of residual stresses due to thermal loading the grinding temperature may be lowered by enhancing the cooling power of the cooling fluid.
	Phase transformation (metallurgical failure)	For very slow cooling produce tensile stresses are likely to be present due to pearlite and/or bainite phases and for fast cooling rates compressive stresses due to martensite phase.
	Abrasion and Cutting (mechanical Failure)	The normal load and the friction coefficient have a critical role in changing the nature of residual stresses.

He concluded that with fully coupled thermal, mechanical and metallurgical analysis the mechanical grinding conditions may have stronger effects on the residual stresses.

Craig Seidelson al., 2014 [4] has done the experiment for retaining the cylindricity of outer diameter while grinding the inner diameter. He has done the experiment on the material ANSI 52100 steel bearing ring. He performs the 3 different test to evaluate a decrease in OD cylindricity attributed to the release of residual surface stresses during ID grinding. He uses different surface treatment for reducing the surface stresses in his experiment. His experimental results shows that the residual stress can be minimize using Heat tampering between OD and ID grinding. He has conclude that when residual surface stresses are high ID grinding imparts sufficient thermo-mechanical loading to release stresses resulting in reduced OD cylindricity.

E. Brinksmeier al., [5] have done the experiments for identification of dimensional and form deviation of bearing ring. He uses a steel ring made up of SAE 52100 for experiment purpose. he find the clamping force leads to an elastic deformation in the machining of rings, e. g., by using a 3-jaw-chuck a triangularity of the ring can be observed after releasing it. Form deviations mainly depend on the number of jaws and on the clamping forces and it is mainly observed in thin walled rings. He also evaluate that residual stresses also play important role in deviation increment. He conclude in two different ways

1. Reduction of dimensional and form deviation by selected machining parameters
2. Small depth of cut should be use because form change caused by a varying depth of cut
3. it is recommended to use a low feed to receive a minimal form deviation
4. Reduction of dimensional and form deviation by a selected clamping sequence

5. The chucks for inner and outer clamping must cause similar form deviations of the ring in the clamped state.
6. After the inner machining the ring must be clamped at the same angular position for outer machining.
7. The chuck for outer machining must clamp the ring around its whole inner radius to assure the transfer of the inner radius to the outer radius.

Below Figure 2 shows the deviation in each step of machining due to clamping force.

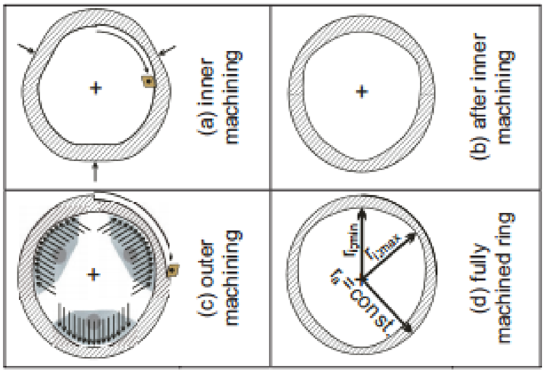

Fig. 2 Deviation of ring in each step of machining [5]

Anton Panda al., 2012 [12] have done the experiment for reducing the Ovality of bearing ring. He obtained his result by using ring of taper roller bearing made up of 100Cr6 (SAE 52100) material. He stated that Ovality results from non-symmetrical distribution of internal tensions before hardening and uneven heating and cooling. He observed that after grinding the similar deformation can occur. He stated that tampering has greater impact on ovality and tampering is done in order to obtain fine martensitic structure due to re distribution. He concludes that re tampering must be done between pre grinding and fine grinding of the bearing rings.

Jens Sölter al., 2008[6] has observed that the continuous wall thickness can be optimized using proper clamping sequence. he stated that an almost constant wall thickness can be produced for an angular shift of 60° and a strong decrease of the clamping force of inner clamping. He concluded that if rings are clamped on the outside with a 3-jaw-chuck and from the inside with segment-jaws the resulting elastic deformations and stresses are the same for different angular shifts and can be explained by the area contact of the ring with the segment jaws. As a consequence the out of round ness of the inner surface will be transferred to the outer surface which would lead to a constant wall thickness after machining.

Christian Grote al., 2009 [7] have made an investigation for the distortion of the rings during the clamping. He has done the experiments with two size of rings made up of SAE 52100. He observed the results of inner and outer grinding with different clamping techniques likewise hard jaw, mandrel, segment jaw, pendulum jaw and form locking camping system.. He concludes that the minimization of the outer form deviation of rings is possible. It can be achieved by using hard jaws for outer clamping and segment jaws for inner clamping. The segment jaws have to imply a triangular deformation of the ring which, in clamped state, eliminates the deformation caused by inner machining. The main drawback of this clamping strategy is the rising of the wall thickness towards the not-clamped side of a ring. The use of a mandrel enables the production of rings with a constant wall thickness. Since its acquisition is high in price and its use is time consuming it ought to be replaced by a standard clamping system.

[8] Holger Surm al., 2009 [8] have done the experiment to evaluate the change in roundness deviations of bearing rings due to quench hardening was exclusively determined by the used clamping technique during turning, which led to a characteristic manufacturing residual stress state. he also stated that Rearrangement of stresses in the complete ring can be correlated to temperature dependent change in roundness deviation. He simulates the result for the SAE 52100 ring with use of different chucks for clamping purpose. And observe the temperature range of 20 to 730 °C. He concludes that with increasing temperature, these plastic zones extended according to stress distribution in direction of lower stress levels. The progressive stress relief affects the development of roundness deviation: At 400 °C, an obvious increase of roundness deviation is calculated, which can be correlated with the additional expansion of the plastic zones. And also concludes that results of his roundness are more sensitive to clamping force. Figure shows mandrel, pendulum jaw and segmental chuck.

Fig. 3 Mandrel, Pendulum chuck and Segment jaws[9]

V. POTENTIAL FAILURES DURING GRINDING

During the grinding process many problem have been observed and needed to control. These different problems can be classified on the basis of their initial cause of occurrence. Some of the problem/failure occurs due to involvement of more than one phenomenon. This phenomenon can be classified in three different types.

- Thermal Failure – problem occurred due to excessive temperature, uneven temperature distribution and any thermally influenced phenomenon.
- Metallurgical Failure – Problem arises due to unwanted phase transformation, heat treatment corrosion erosion etc.

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- Mechanical Failure – Problem formulated due to uneven force, improper geometry, measurement issue, machining parameters etc.

On the basis of the literature review the problem can be classified on the basis of their primary cause of occurrence and it is tabulated below in table 2

Table 2 problem and type of failure

Problem	Reason of Failure		
	Thermal	Metallurgical	Mechanical
Residual Stresses	✓	✓	✓
Cylindricity	✓		✓
Dimensional and Form variation			✓
Ovality		✓	
irregular wall thickness			✓
Distortion	✓		✓
Out of Roundness	✓		✓

VI. PROBLEM WITH CAUSE, EFFECT AND SOLUTION

After the successful literature review of the different problems during ring grinding, all the necessary information regarding to the problem have been tabulated on the basis of type of failure, cause of failure, Effect of failure and Solution shown in table 3. The solution has been evaluated from the different paper during the literature review.

Table 3 Problem, its type, cause, Effect and possible solution

No	Problem	Type of Failure			Cause of Failure	Effect	Solution
		Thermal	Metallurgical	Mechanical			
1	Residual Stresses	✓	✓	✓	Excessive heating, Phase transformation, Abrasion and Cutting	Deformation of the rings, size change. And number of other failures	Proper use of Cooling fluid for the temperature reduction and heat treatment for stress relieving purpose.
2	Lack of Cylindricity	✓		✓	Heat and load are well enough to release residual stress.	Improper clamping during machining or grinding of ring.	Residual stress can be minimizing using Heat tampering between OD and ID grinding.
3	Dimensional and Form variation			✓	Clamping force leads to an elastic deformation in the machining of rings.	Shape and form of the ring deviates	Use of proper chuck for inner and outer clamping. Proper sequence along with feed rate and depth of cut.
4	Ovality		✓		Non-symmetrical distribution of internal tensions and uneven heating and cooling.	Produce non confirmative rate in machine.	Tampering between pre grinding and fine grinding.
5	irregular wall thickness			✓	Improper clamping force during grinding process.	Rejection and cause mis-alignment of both inner and out ring.	Proper sequence and 60° shift at outer and decrease in clamping force at inner clamping system.
6	Distortion	✓		✓	Due to clamping and Residual stress	Bending and deformation of ring.	Proper clamping sequence and Use of proper chuck. Proper cooling fluid and pre heat treatment.
7	Out of roundness	✓		✓	Excessive heating and improper clamping force.	Out of roundness.	Use of proper cooling fluid and proper clamping sequence.

VII. CONCLUSION

We have referred a number of papers to overcome the bearing failure and on the basis of that we can concludes the following.

- Proper amount of cooling fluid maintains the temperature and it helps to prevent the formation of residual stresses
- Internal grinding of ring must be done before external grinding in order to prevent the reduction of cylindricity.
- Heat tampering must be done between OD grinding and ID grinding for stress relieving purpose.
- Less feed rate and small depth of cut reduces the residual stress but increases the out of roundness.
- Inner clamping system should have distributed and small amount of clamping force. Segment chuck used for inner clamping purpose and 3 jaw chuck is used for external clamping.
- Ovality of the ring can be reducing using heat tampering between ID and OD grinding process.
- Wall thickness of the ring can be maintained by using angular shift of 60° and a strong decrease of the clamping force of inner clamping.
- After the inner machining the ring must be clamped at the same angular position for outer machining.
- The use of a mandrel enables the production of rings with a constant wall thickness. Since its acquisition is high in price and its use is time consuming it ought to be replaced by a standard clamping system.
- For high ring width the clamping system should be good enough to cover the full width
- Out of roundness is produce due to plastic deformation and clamping force.
- After plastic deformation the stress relieving is responsible for Out of roundness.

And it is not incompatible to conclude that the bearing ring failure during grinding resulted due to mainly Residual stresses and the Clamping force, so it is worth to pay considerable attention on both the phenomenon while grinding the ring.

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