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Machining of Aircraft Bearing Rings using High Quality Bearing Steel

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Abstract
Bearing rings for Aircraft application are machined using high quality M50 High Speed Steel conforming to AMS 6491B. The raw material for the rings of Ball bearing is prepared from a single bar stock using trepanning. Special collet type soft jaw and Mandrels were devised and used on CNC Lathes to reduce manufacturing problems like ovality. Raceway forms are turned using single point copy turning insert. The problems faced during rings manufacture were discussed in this study.
Key words: HSS M50, Trepanning, Ring Inner and Outer, Collet, Soft jaw, raceways, Ovality

I. INTRODUCTION

Traditionally bearings have been manufactured either from high carbon through hardening steel or low carbon case hardening steel. Both high-carbon and low-carbon materials have survived because each offers a unique combination of properties that best suits the intended service conditions. But these materials are mostly used to manufacture bearings, which are intended for normal service applications [1]. Whereas, in the case of special applications like Aircraft and stationary turbine engines where the bearings have to undergo high speed and higher temperature environment, high quality alloy steels are preferred most. Of the alloy steels, high quality High speed Steel as per AMS 6491B (M50) is one of the most widely used materials for aircraft applications. The attempt to machine such high quality steel for the specified application was taken up for the first time and the experiences, findings / problems encountered during machining are reported in this paper.

II. BEARING RINGS

Ball Bearing mainly consists of two parts viz. Outer race called Ring Outer and Inner race called Ring Inner. These bearing rings are required to be manufactured out of high quality high-temperature bearing steel M50 HSS. It is high carbon medium alloy steel consisting of important carbide forming elements like Chromium, Molybdenum and Vanadium. The composition of the material is given in Table-1. The extent of temperature ranges that are encountered during service is from -54°C to 150°C.

The geometries of the outer and inner rings are shown in Fig.1&2. As the raceway surfaces are needed to be created before finishing operations, stringent geometrical accuracies have to be maintained during semi-finishing stage itself. Some of the important geometrical requirements that are to be maintained are circularity on OD and ID, squareness of the face, offset of the raceways and profile of the surface of the raceways. All these parameters should be maintained within 20micron.

Table-1: Chemical Composition of HSS M50

Element	Percentage	
	min	max
Carbon	0.80	0.85
Chromium	4.00	4.25
Cobalt	-	0.25
Copper	-	0.1
Manganese	0.15	0.35
Molybdenum	4.00	4.50
Nickel	-	0.15
Phosphorus	-	0.015
Silicon	-	0.25
Sulphur	-	0.008
Tungsten	-	0.25
Vanadium	0.90	1.10

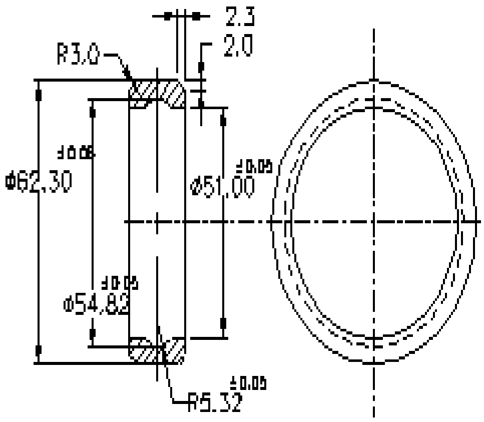

Fig.1: Outer ring

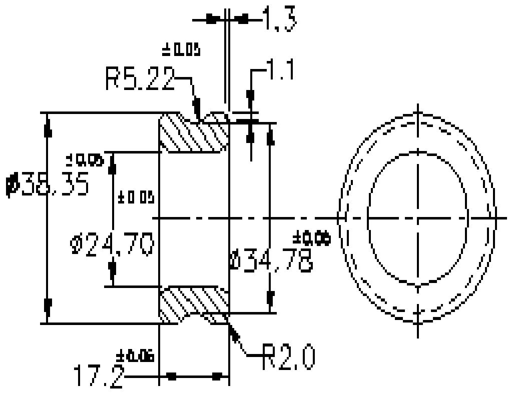

Fig.2: Inner ring

III. MACHINING OF INNER AND OUTER RINGS

Machining of rings is carried out in the annealed state before heat treatment. In the first stage they are rough and semi-finished in annealed state and in the second stage they are subjected to special heat treatment cycles followed by grinding and super finishing before final assembly. The process sequence for machining the bearing rings in the first stage is given below:

3.1 Process Plan

1. Raw material Preparation for Rings from single bar stock
2. Rough Machining of rings.
3. Semi finishing of rings
4. Raceway Machining
5. Inspection

IV. PROBLEMS FACED AND METHODOLOGY FOLLOWED

Generally, Inner and Outer rings of the ball bearings are processed individually from separate bar stocks. But in this venture, an economical way of manufacture was followed considering the cost and availability of raw material. The raw material for the two rings was prepared by trepanning on the face of the material followed by parting to separate them into two pieces thereby saving considerable raw material. Trepanning on the face was attempted

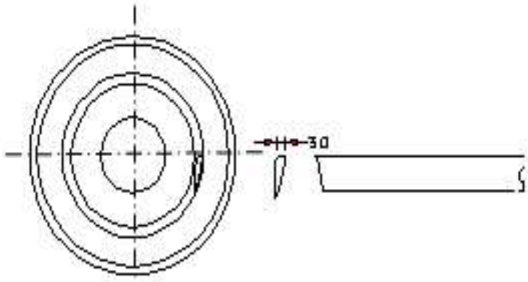

Fig.3: Trepanning Tool

with thin and costly face grooving inserts and tool holders. Since the ratio of groove width to depth (aspect ratio) required to be trepanned is quite high, frequent breakage of inserts was encountered due to production of continuous chip during grooving of annealed material and chip clogging. Thus a novel method of trepanning the groove using a simple grooving tool was attempted which was found very successful. The grooving tool developed in-house is shown in Fig. 3.

The trepanning operation is carried out by initially face grooving to a certain depth and parting off the required thickness of the rings. Then the parted ring is reversed & held in lathe and face grooving to the remaining depth is carried out thus separating the inner and outer rings. This method of trepanning is shown in Fig.4.

Fig. 4: Trepanning on a CNC lathe

After trepanning, the two rings were processed individually on CNC Lathes by developing suitable Mandrels. The raceway grooves are usually formed using form tools in production environment. But since the semi finishing operation was carried out in annealed state, the grooving operation using form tools was found to be unsuccessful. The surface finish could not be maintained due to excessive chattering due to higher contact area during forming. Also the ductile nature of the spherodite structure of the material leads to continuous chip production, burr formation in the tool exit point and to some extent formation of built-up edge on the tool face [2]. Thus the use of form tool for raceway grooving was suspended and resorted to standard single point tools.

During raceway form turning, the burr formation was noticed at tool exit point. Hence the cutting parameters were modified suitably. Initially, taking standard data from the standard metal cutting Data Handbook, the cutting conditions were set. But the data given in the books are particular to the ideal conditions; hence considering wall thickness and work piece clamping rigidity the cutting parameters were optimized by conducting several trials. The optimized cutting data is shown in Table-2. Tool built-up normally arises due to higher friction and contact pressure between the tool face and underside of the flowing chip. Increasing the cutting speed, reduction of temperature by administering sufficient coolant and judicial selection of turning insert, which is having low coefficient friction, can reduce this problem. Hence Titanium Nitride coated P30 grade cemented carbide copy turning insert, which is having positive rake geometry, was selected and used and thereby alleviated contact pressure and ensured clean cutting during form turning.

Table-2: Optimized cutting parameters

Cutting conditions		
Operation	Speed (rpm)	Feed mm/rev
Roughing	500 rpm	0.05
Finishing	700 rpm	0.03

Even with all these efforts the required circularity could not be maintained owing to the slim wall thickness and annealed condition (soft state) of the work piece. To obviate this problem, it was resorted to clamp the components using hydraulic chuck in a CNC Lathe. As the contact pressure on the jaw points is the primary candidate for problems like ovality, it was decided to use collet type holding arrangement wherein more area could be brought into contact with chucking surface. Thus a collet type special holding arrangement, which is in the softer state, was devised and used to clamp the external surface of the ring inner and to clamp the ring inner a close toleranced parallel type mandrel was used. The soft state of the collet type chuck jaws acted like soft jaw thus close tolerance could be achieved and also speed of operation could be enhanced. The hydraulic clamping helped to control the contact pressure. The Special collet type arrangement and mandrels are shown in Fig. 5&6.

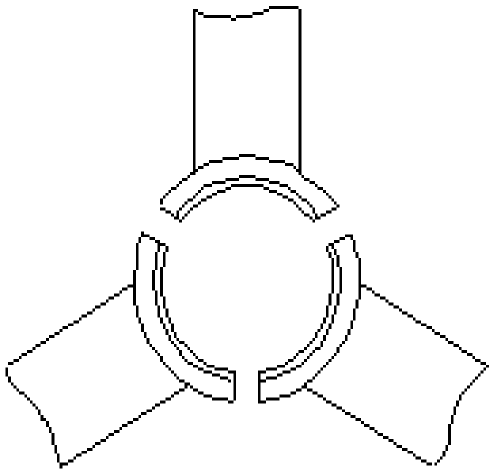

Fig. 5: Collet type holding Device

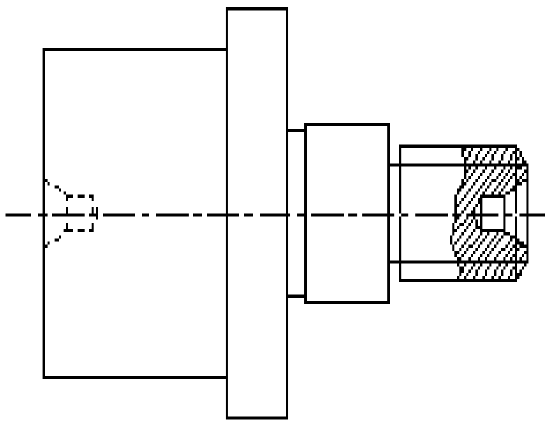

Fig. 6: Mandrel

The raceway profile was inspected using contour checking instrument and the radii of the grooves were inspected using custom-built ball type Go and NoGo gauges. With these efforts the Inner and Outer rings of the ball bearings were successfully machined to the required dimensional and geometrical parameters.

V. CONCLUSION

1. Method of manufacturing bearing rings from high quality M50 HSS was established.
2. Collet type holding arrangement in combination with hydraulic chucking was found to be successful for reducing problems like ovality.

3. Single point insert with Positive rake geometry was found to be successful to reduce the contact pressure between tool and work piece and tool built-up between tool face and the chip.

REFERENCE

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[2.] Miguel C. Avila, The effect of kinematical parameters and tool geometry on burr height in face milling.