To develop the model for improving the surface texture of deep groove ball bearing to optimize cutting parameter, by using the methodology of Design of Experiment

Shraddha Arya[1], M.P. Singh[2], Manish Bhargava[3]
(Research Scholar, Department of Mechanical Engineering, Jagannath University, Rajasthan, India.)[1]
(Professor, Department of Mechanical Engineering, JECRC College, Rajasthan, India.)[2]
(Principal, Maharishi Arvind Institute of Engineering and Technology, Rajasthan, India.)[3]

Abstract:-

The main purpose of this paper is to describe about the modelpreparation for the improvement of the surface texture of ball bearing by using the methodology of Design of Experiment.Ball Bearings are used as multifaceted part, self-retaining bearing with solid outer rings, inner rings, balls and cage assemblies. They are of a simple design, robust in nature, easy to maintain. Due to raceway geometry and the use of balls, deep groove ball bearing can support the axial forces in both direction as well as radial force. Use of Design of experiment (DOE) to investigate most significant responsive factor which is contributing in improving surface texture by using fishbone diagram. The main problem in the Ball Bearing is noise, and to eliminatethis problemimprovement in the surface texture of inner and outer track of the bearing is essential. Now a day poor surface texture has become a sizable problem especially for automobile industry so to eliminate this problem and to identify the major optimum solution, DOE tool is used.

The significance of the factors on overall quality characteristics of the burnishing process has also been evaluated quantitatively with the variance method (ANOVA). Optimal results were verified through confirmation experiments. This shows application feasibility of the Grey relation analysis in combination with Taguchi technique for continuous improvement in product quality in manufacturing industry.

Keywords: *ANOVA, DOE, Fishbone diagram,optimal result, Taguchi method.*

INTRODUCTION:-

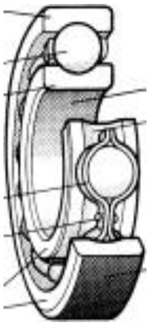
Ball bearing is the most common type of bearing that can handle both radial and thrust loads. Ball bearings are also known as deep-groove single row or Conrad bearings. The inner ring is typically fastened to the rotating shaft and the groove on the outer diameter provides a circular ball raceway. The outer ring is mounted onto the bearing housing. The ball bearings are housed in a race and when the load is applied, it is transmitted from the outer race to the ball and from the ball to the inner race. The raceway grooves have typical curvature radii of 51.5% to 53% of the ball diameter. Smaller curvature raceways can cause high rolling friction due to the tight conformity of the balls and raceways. Higher curvature raceways can shorten fatigue life from increased stress in the smaller ball-race contract area.

Surface roughness parameters are widely used in modern mechanical engineering for the assessment of the operational characteristics of the machine components especially wear resistance, contact stiffness, and hermeticity. When analyzing the surface layer processes, which are comparative to initial surface roughness, it is strictly necessary to understand the processes of asperity forming, strengthening, and interacting taking into account all the complex surface geometry.

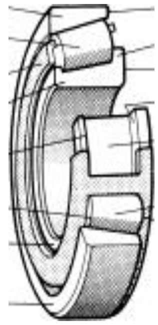
Classification of Bearings:-

Ball bearings are bearings that use spherical balls for separation between inner and outer races. The contact points between the ball and the outer race is very small due to the spherical shape of the bearing. This also helps the ball spin very smoothly. Since the contact point is so small, the bearing can become overloaded at a specific point causing the ball bearing to become deformed. This will ruin the bearing. Therefore it is used in small load applications.

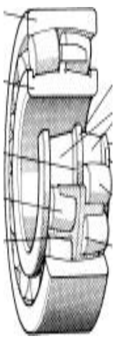
Fig1: Types of roller bearing



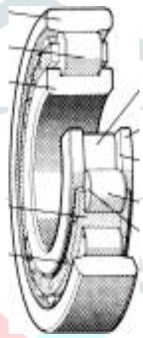
(a) Deep groove ball bearing



(b) Tapered roller bearing



(c)Cylindrical roller bearing



(d) Spherical roller bearing

A deep groove ball bearing (fig1) is simple in design and non-separable hence therefore it is most widely used for high speeds. A tapered roller bearing (fig 2) have tapered inner and outer races as well as tapered bearings so as to accommodate load on either sides and are used in engine motors, gear boxes and in differential etc. Cylindrical roller bearing has two ribs among one ring and single rib on the other ring (fig 3). They are capable to accommodate heavy loads at high speeds. Spherical roller bearings (fig 4) are self-aligning bearings that has very high load carrying capacity. Rollers are spherical in shape so can align in either direction easily. These types of bearings are used in locomotives.

Problem identification in the surface of Ball Bearing:-

For problem identification, BRAIN STORMING is the initial and major factor to be discuss, in which the main reason and parameters are to be discussed through which the problem is occurs. So for identify the various reason DOE is the main tool, in which the complete operations of Ball Bearing will have be discussed. ISHIKAWA DIAGRAM (Fish Bone diagram) in which following factor(s) is recognized.

GRINDING: - The grinding is a manufacturing process which uses a grinder made up of abrasive material and is often used to remove surface material.The quality of a surface generated by grinding determines many work piece characteristics such as the minimum tolerances, the lubrication effectiveness and the component life, among others. A typical surface is characterized by clean cutting paths and plowed material to the sideway of some grooves. However, many other marks can be found, such as cracks produced by the thermal impact, back-transferred material and craters produced by a grain fracture.

HONING: - Honing is a low velocity abrading process in which stock is removed from metallic or non-metallic surfaces by bonded abrasive sticks. It is a finishing operation employed not only to produce high finish but also to correct out-of-roundness, taper and axial distortion in work piece. In honing, since a simultaneous rotating and reciprocating motion is given to the stick, the surface produced will have a characteristic cross-hatch lay pattern.. It is used to increase the surface texture. Stone pressure, work head RPM, stone oscillation frequency and honing time (cycle time) which affects surface texture of the bearing.

Factors affecting bearing life:-

The bearing life depends upon its usage and maintenance factor. Wear and tear of bearing mainly occurs because of an oil film of minute thickness. However the contact of rotating part also increases the friction between the parts and leads to failure. Besides this there are many factors that affect the life of a bearing are:

1. Corrosion: The main cause of damage to any moving part is corrosion. Bearing parts get corroded over a period of time and thus the problem of leakage, entry of foreign particle and friction factor increases and finally leads to breakage or seizing of bearing.
2. Abnormal Load: This type of failure is caused because of poor or improper mounting on a housing. Special care should be taken to balance the loads of either side. The other failure of similar types are Faulty Loading, Abnormal temperature etc.
3. Lubrication: it is the most important factor and plays a major role in the life of a bearing. Lubrication is done to prevent direct metal to metal contact between the rolling parts raceways and cages. Lubrication also protects bearing from corrosion and make it heat resistant too, thus a proper knowledge of bearing lubrication is important. Excessive lubricant, insufficient lubricant, improper lubrication, incorrect selection of Greece or oil or the use of Greece where condition demands oil, too much or too little quantity of oil, poor quality of oil increases friction, wear and tear, leads to corrosion thus results in the reduction of life of bearing.
4. Foreign Particle: These are caused because of improper sealing, improper mounting, poor quality of oil and corrosion, damaged protrusion of edges on the abutment faces of shaft and housing shoulders, dirt trapped between abutment shoulder machined out of square with axis of rotation and misalignment between pair of housing spaced and incredibly.
5. Other reasons include over loading, improper bearing selection, faulty bearing installation , electric erosion etc.

TOOL USED

Design of Experiment-

Design of experiment is a method of finding how the input affects the output or in simple terms it is the method of building relationship between input and output. In DOE we use static methods to investigate the effect of input on output. A predetermined pattern is followed to change the input setting. There are several terms used in DOE i.e. Factor, Response, Level, Treatment, Ram, Replicates.

The input whose effect on the response is investigated is the factor and the output that is interested to the experimenter is response. Level is the setting of a factor used in experiment. Treatment is the combination of levels of factor while replicates are the experiment runs corresponding to the same treatment that are conducted.

Why DOE

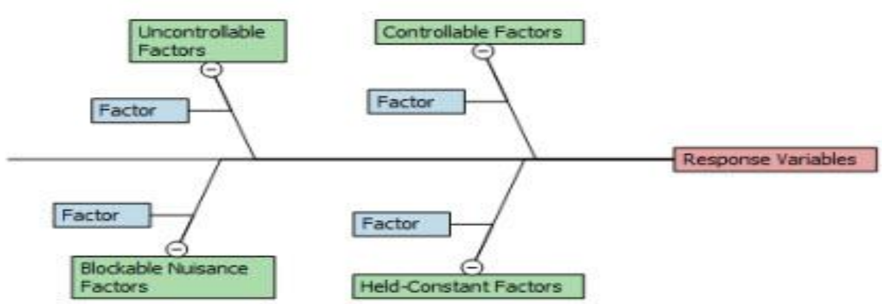
Design of experiment is a tool used to increase the complexity with limited resources. A organized test plan is needed. DOE also provide a systematic approach to solve a problem and also a very useful and helpful tool in decision making. Thus we can say that DOE tool can save time and cost. It makes our life easier.

What DOE can do?

DOE is widely used mainly in the fields with broad application across all the natural and social sciences. Thus DOE can help to compare different designs and also can identify the key factors that affect the performance. It also identifies the relationship between the output and key factors. With DOE we can also optimize the product process and robustness.

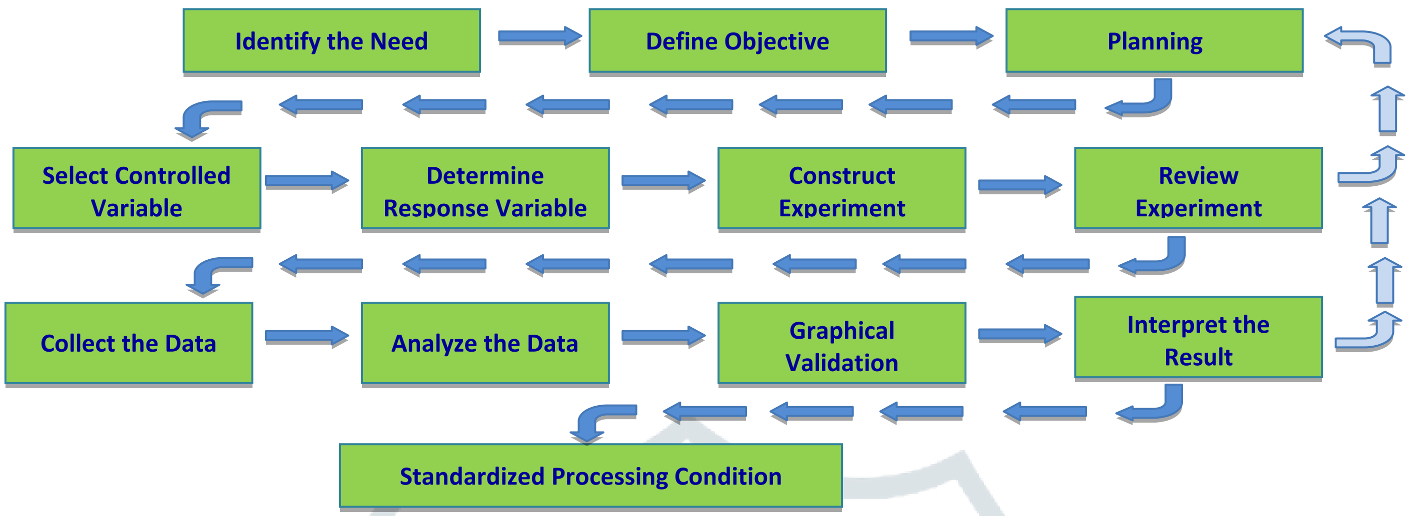
Fishbone Diagram

Fig 2 Fishbone diagram for DOE



Phases of DOE

Fig.2 Phases of DOE



Design of Experiment for Outer part of bearing-

Table 1 Select controlled variable factor for grinding process

Factor	Name	Unit	Low Level	High Level	Current
A	Work RPM	RPM	375	535	417~489
B	Grinding Feed Rate (Fine)	mm/sec.	0.008	0.010	0.012
C	Dress compensation	Mm	0.010	0.020	0.030
D	Dress feed rate	mm/sec.	0.008	0.010	0.012
E	Grinding Feed Rate (Rough2)	mm/sec.	0.042	0.045	0.048
F	Spark out time	sec.	0.5	1	0.5

Table 2 Select controlled fixed factor (Process Condition) for grinding process

Factor	Name	Unit	Value
1	Total Feed Amount	Mm	0.570
2	Quick Feed Amount	Mm	0.05
3	Fine Feed Amount	Mm	0.04
4	Quick Feed Rate	mm/sec	0.2
5	Rough-1 Feed rate	mm/sec	0.09
6	Dress Ratio	-	0.32
7	Wheel Surface Speed	m/min	2300
8	Machine Idle Time	Sec	4.7

The Standard values of RA and talyrond is 0.5 and 0.5 µm respectively.

Construct Experiment Design

Table 3 Level full Factorial Design

Number of factor (K)	Number of Level (L)	Replication	Number of Runs ($n=L^K$)	Total Degree of Freedom (n-1)
6	2	1	64	63

Table 4- Design Matrix and data collection for outer race

Std Order	Run Order	Variable Parameter						Response	
		Work RPM	Grinding Feed Rate (Fine)	Dress compensation	Dress feed rate	Grinding Feed Rate (Rough2)	Spark out time	Ra	Talyrond
43	1	375	0.010	0.01	0.010	0.042	1.0	0.2813	0.53
33	2	375	0.008	0.01	0.008	0.042	1.0	0.2588	1.58
17	3	375	0.008	0.01	0.008	0.045	0.5	0.2599	1.42
40	4	535	0.010	0.02	0.008	0.042	1.0	0.2602	1.48
55	5	375	0.010	0.02	0.008	0.045	1.0	0.2670	1.55
6	6	535	0.008	0.02	0.008	0.042	0.5	0.2844	1.90
25	7	375	0.008	0.01	0.010	0.045	0.5	0.3282	1.35
52	8	535	0.010	0.01	0.008	0.045	1.0	0.2830	1.32
18	9	535	0.008	0.01	0.008	0.045	0.5	0.2632	1.95
60	10	535	0.010	0.01	0.010	0.045	1.0	0.2863	1.48
44	11	535	0.010	0.01	0.010	0.042	1.0	0.2727	1.28
9	12	375	0.008	0.01	0.010	0.042	0.5	0.3015	1.43
2	13	535	0.008	0.01	0.008	0.042	0.5	0.2761	1.55
8	14	535	0.010	0.02	0.008	0.042	0.5	0.2720	1.35
28	15	535	0.010	0.01	0.010	0.045	0.5	0.2818	1.35
23	16	375	0.010	0.02	0.008	0.045	0.5	0.3026	1.47
59	17	375	0.010	0.01	0.010	0.045	1.0	0.2776	1.62
24	18	535	0.010	0.02	0.008	0.045	0.5	0.3074	1.53
22	19	535	0.008	0.02	0.008	0.045	0.5	0.3223	1.20
19	20	375	0.010	0.01	0.008	0.045	0.5	0.2941	1.35
16	21	535	0.010	0.02	0.010	0.042	0.5	0.3088	1.43
42	22	535	0.008	0.01	0.010	0.042	1.0	0.2951	1.25
36	23	535	0.010	0.01	0.008	0.042	1.0	0.2848	1.50
35	24	375	0.010	0.01	0.008	0.042	1.0	0.3030	0.87
47	25	375	0.010	0.02	0.010	0.042	1.0	0.3042	0.98
57	26	375	0.008	0.01	0.010	0.045	1.0	0.2844	0.98
41	27	375	0.008	0.01	0.010	0.042	1.0	0.2739	0.97
26	28	535	0.008	0.01	0.010	0.045	0.5	0.3347	1.10
54	29	535	0.008	0.02	0.008	0.045	1.0	0.3023	0.97
62	30	535	0.008	0.02	0.010	0.045	1.0	0.2954	1.30
14	31	535	0.008	0.02	0.010	0.042	0.5	0.2852	1.27
32	32	535	0.010	0.02	0.010	0.045	0.5	0.3052	1.30

Table 4- Design Matrix and data collection for outer race Contd.

Std Order	Run Order	Variable Parameter						Response	
		Work RPM	Grinding Feed Rate (Fine)	Dress compensation	Dress feed rate	Grinding Feed Rate (Rough2)	Spark out time	Ra	Talyrond
39	33	375	0.010	0.02	0.008	0.042	1.0	0.3085	1.27
64	34	535	0.010	0.02	0.010	0.045	1.0	0.2822	1.82
48	35	535	0.010	0.02	0.010	0.042	1.0	0.2894	1.72
56	36	535	0.010	0.02	0.008	0.045	1.0	0.3026	1.50
1	37	375	0.008	0.01	0.008	0.042	0.5	0.2909	1.48
38	38	535	0.008	0.02	0.008	0.042	1.0	0.2939	1.00
37	39	375	0.008	0.02	0.008	0.042	1.0	0.2947	1.23
49	40	375	0.008	0.01	0.008	0.045	1.0	0.2945	1.53
13	41	375	0.008	0.02	0.010	0.042	0.5	0.3087	1.02
45	42	375	0.008	0.02	0.010	0.042	1.0	0.3152	0.95
21	43	375	0.008	0.02	0.008	0.045	0.5	0.3265	1.27
15	44	375	0.010	0.02	0.010	0.042	0.5	0.3068	1.32
7	45	375	0.010	0.02	0.008	0.042	0.5	0.3124	1.03
12	46	535	0.010	0.01	0.010	0.042	0.5	0.3111	0.97
4	47	535	0.010	0.01	0.008	0.042	0.5	0.2806	0.92
63	48	375	0.010	0.02	0.010	0.045	1.0	0.2861	0.85
31	49	375	0.010	0.02	0.010	0.045	0.5	0.2899	0.98
50	50	535	0.008	0.01	0.008	0.045	1.0	0.2938	1.23
61	51	375	0.008	0.02	0.010	0.045	1.0	0.2973	1.00
5	52	375	0.008	0.02	0.008	0.042	0.5	0.2936	1.25
53	53	375	0.008	0.02	0.008	0.045	1.0	0.2913	1.45
46	54	535	0.008	0.02	0.010	0.042	1.0	0.3100	1.47
3	55	375	0.010	0.01	0.008	0.042	0.5	0.2935	1.37
51	56	375	0.010	0.01	0.008	0.045	1.0	0.3198	1.25
27	57	375	0.010	0.01	0.010	0.045	0.5	0.3169	1.03
11	58	375	0.010	0.01	0.010	0.042	0.5	0.3149	1.08
29	59	375	0.008	0.02	0.010	0.045	0.5	0.3202	1.03
58	60	535	0.008	0.01	0.010	0.045	1.0	0.3147	1.13
10	61	535	0.008	0.01	0.010	0.042	0.5	0.2789	1.22
30	62	535	0.008	0.02	0.010	0.045	0.5	0.2935	1.48
20	63	535	0.010	0.01	0.008	0.045	0.5	0.3144	1.43
34	64	535	0.008	0.01	0.008	0.042	1.0	0.3058	1.38

Design of Experiment for Inner part of bearing-

Table51 Select controlled variable factor for grinding process

Factor	Name	Unit	Low Level	High Level	Current
A	Work RPM	RPM	710	914	800
B	Grinding Feed rate (Fine)	mm/sec.	0.008	0.010	0.012
C	Dress compensation	mm	0.020	0.030	0.05
D	Dress feed rate	mm/sec.	0.008	0.01	0.010
E	Grinding Feed rate (Rough-2)	mm/sec.	0.04	0.043	0.045
F	Spark out time	sec.	1.0	1.5	1.0

Table 6 Select controlled fixed factor (Process Condition) for grinding process

Factor	Name	Unit	Value
1	Total Feed Amount	mm	0.500
2	Quick Feed Amount	mm	0.020
3	Fine Feed Amount	mm	0.050
4	Quick Feed Rate	mm/sec	0.200
5	Rough-1 Feed rate	mm/sec	0.100
6	Dress Ratio	-	0.20
7	Wheel Surface Speed	m/min	3600
8	Machine Idle Time	sec	3.5

Determine Response Variable

The Standard values of RA and talyrond is 0.5 and 0.5 µm respectively.

Note- While conducting the experiments, above limits will be taken as Standard limits and any value beyond this will be treated as negative response

Table 7 Level full Factorial Design

Number of factor (K)	Number of Level (L)	Replication	Number of Runs ($n=L^K$)	Total Degree of Freedom (n-1)
6	2	1	64	63

Table 8- Design Matrix and data collection for inner race

Std Order	Run Order	Variable Parameter						Response	
		Work RPM	Grinding Feed rate (Fine)	Dress compensation	Dress feed rate	Grinding Feed rate (Rough-2)	Spark out time	Ra Avg.	Talyrond Avg.
60	1	914	0.010	0.020	0.010	0.043	1.5	0.4642	1.00
34	2	914	0.008	0.020	0.008	0.040	1.5	0.4504	0.82
52	3	914	0.010	0.020	0.008	0.043	1.5	0.4637	0.83
42	4	914	0.008	0.020	0.010	0.040	1.5	0.4889	0.73
16	5	914	0.010	0.030	0.010	0.040	1.0	0.4214	0.87
8	6	914	0.010	0.030	0.008	0.040	1.0	0.4361	0.77
1	7	710	0.008	0.020	0.008	0.040	1.0	0.4332	0.67
2	8	914	0.008	0.020	0.008	0.040	1.0	0.3567	0.60
15	9	710	0.010	0.030	0.010	0.040	1.0	0.3549	0.83
9	10	710	0.008	0.020	0.010	0.040	1.0	0.3795	0.97
27	11	710	0.010	0.020	0.010	0.043	1.0	0.3812	0.82
61	12	710	0.008	0.030	0.010	0.043	1.5	0.3921	0.68
57	13	710	0.008	0.020	0.010	0.043	1.5	0.3843	0.40
31	14	710	0.010	0.030	0.010	0.043	1.0	0.4043	0.37
41	15	710	0.008	0.020	0.010	0.040	1.5	0.3818	0.38
33	16	710	0.008	0.020	0.008	0.040	1.5	0.2720	0.75
58	17	914	0.008	0.020	0.010	0.043	1.5	0.3699	0.82
23	18	710	0.010	0.030	0.008	0.043	1.0	0.3826	0.70
36	19	914	0.010	0.020	0.008	0.040	1.5	0.3879	0.65
7	20	710	0.010	0.030	0.008	0.040	1.0	0.3715	0.60
5	21	710	0.008	0.030	0.008	0.040	1.0	0.3771	0.73
30	22	914	0.008	0.030	0.010	0.043	1.0	0.3669	0.67
63	23	710	0.010	0.030	0.010	0.043	1.5	0.3899	0.57
49	24	710	0.008	0.020	0.008	0.043	1.5	0.3704	0.67
6	25	914	0.008	0.030	0.008	0.040	1.0	0.3633	0.43
19	26	710	0.010	0.020	0.008	0.043	1.0	0.3832	0.72
50	27	914	0.008	0.020	0.008	0.043	1.5	0.2557	0.73
37	28	710	0.008	0.030	0.008	0.040	1.5	0.3585	0.73
45	29	710	0.008	0.030	0.010	0.040	1.5	0.3670	0.65
22	30	914	0.008	0.030	0.008	0.043	1.0	0.3558	0.67
20	31	914	0.010	0.020	0.008	0.043	1.0	0.3875	0.65
47	32	710	0.010	0.030	0.010	0.040	1.5	0.3832	0.87

Table84- Design Matrix and data collection for inner race Contd

Std Order	Run Order	Variable Parameter						Response	
		Work RPM	Grinding Feed rate (Fine)	Dress compensation	Dress feed rate	Grinding Feed rate (Rough-2)	Spark out time	Ra Avg.	Talyrond Avg.
35	33	710	0.010	0.020	0.008	0.040	1.5	0.3468	0.85
28	34	914	0.010	0.020	0.010	0.043	1.0	0.3661	0.53
53	35	710	0.008	0.030	0.008	0.043	1.5	0.3322	0.47
11	36	710	0.010	0.020	0.010	0.040	1.0	0.3834	0.88
32	37	914	0.010	0.030	0.010	0.043	1.0	0.3763	1.03
64	38	914	0.010	0.030	0.010	0.043	1.5	0.4338	1.37
43	39	710	0.010	0.020	0.010	0.040	1.5	0.3694	0.73
18	40	914	0.008	0.020	0.008	0.043	1.0	0.3853	1.05
59	41	710	0.010	0.020	0.010	0.043	1.5	0.3480	0.87
17	42	710	0.008	0.020	0.008	0.043	1.0	0.2865	0.68
44	43	914	0.010	0.020	0.010	0.040	1.5	0.2686	0.63
13	44	710	0.008	0.030	0.010	0.040	1.0	0.2576	0.73
21	45	710	0.008	0.030	0.008	0.043	1.0	0.2663	0.60
12	46	914	0.010	0.020	0.010	0.040	1.0	0.2679	0.82
29	47	710	0.008	0.030	0.010	0.043	1.0	0.2628	0.57
54	48	914	0.008	0.030	0.008	0.043	1.5	0.2764	0.68
46	49	914	0.008	0.030	0.010	0.040	1.5	0.2615	0.88
25	50	710	0.008	0.020	0.010	0.043	1.0	0.2596	0.68
38	51	914	0.008	0.030	0.008	0.040	1.5	0.2549	0.77
10	52	914	0.008	0.020	0.010	0.040	1.0	0.2774	0.67
40	53	914	0.010	0.030	0.008	0.040	1.5	0.2666	0.95
62	54	914	0.008	0.030	0.010	0.043	1.5	0.2814	0.82
39	55	710	0.010	0.030	0.008	0.040	1.5	0.2938	1.05
48	56	914	0.010	0.030	0.010	0.040	1.5	0.2726	1.03
24	57	914	0.010	0.030	0.008	0.043	1.0	0.2627	0.95
26	58	914	0.008	0.020	0.010	0.043	1.0	0.2756	0.97
56	59	914	0.010	0.030	0.008	0.043	1.5	0.3414	1.82
3	60	710	0.010	0.020	0.008	0.040	1.0	0.2871	0.77
14	61	914	0.008	0.030	0.010	0.040	1.0	0.2540	0.60
55	62	710	0.010	0.030	0.008	0.043	1.5	0.2610	0.42
51	63	710	0.010	0.020	0.008	0.043	1.5	0.2627	0.65
4	64	914	0.010	0.020	0.008	0.040	1.0	0.2920	1.20

Construct Experimental Design

Number of factor (K)	Number of Level (L)	Replication	Number of Runs ($n=L^K$)	Total Degree of Freedom (n-1)
6	2	1	64	63

Taguchi Method

Robust product design is a concept from the teachings of Dr. Genichi Taguchi, a Japanese quality guru. It is defined as reducing variation in a product without eliminating the causes of the variation. In other words, making the product or process insensitive to variation. This variation (sometimes called noise) can come from a variety of factors and can be classified into three main types: internal variation, external variation, and unit to unit variation. Internal variation is due to deterioration such as the wear of a machine, and aging of materials. External variation is from factor relating to environmental conditions such as temperature, humidity and dust. Unit to Unit variation is variations between parts due to variations in material, processes and equipment. (Lochner and Matar, 18). Examples of robust design include umbrella fabric that will not deteriorate when exposed to varying environments (external variation), food products that have long shelf lives (internal variation), and replacement parts that will fit properly (unit to unit variation). The goal of robust design is to come up with a way to make the final product consistent when the process is subject to a variety of "noise".(1)

ANOVA

The ANOVA stand for analysis of variance, ANOVA is basically a technique for testing the difference among different groups of data for consistency. The core meaning of ANOVA is that the total amount of variation in a set of data is shatteredinto two types, that amount which can be accredited to chance and that amount which can be attributed to specific causes. There may be variation between samples and also within sample items. ANOVA consists splitting the variance for analytical purposes here ANOVA can be done for surface roughness (Ra). Hence, it is a technique of analyzing the variants to which a response a subject into its various components corresponding to various sources of variation. Through this technique one can explain whether various factors and there different value varies and give different results significantly so that a policy decision could be taken accordingly. Similarly, the differences in various types of bearing components prepared for a particular class or various types of bearing manufactured for improving the surface texture of ball bearing may be studied table 8, 9 and 10 and similarly the graphical representation of RA response, talyrond response for inner and outer race, with the help of MINITAB are given below and judged to be a significant or nit through the application of ANOVA technique.

ANOVA table for Ra response:- outer race

Table 8 ANOVA table for RA response

Analysis of Variance for Surface Roughness (Ra), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Work RPM	1	0.0002490	0.0002214	0.0002214	0.78	0.382
Grinding Feed rate (Fine)	1	0.0000715	0.0000873	0.0000873	0.31	0.582
Dress Compensation	1	0.0004493	0.0004118	0.0004118	1.44	0.235
Dress feed rate	1	0.0005858	0.0005429	0.0005429	1.90	0.173
Grinding Feed rate (Rough 2)	1	0.0007557	0.0008114	0.0008114	2.84	0.097
Spark out time (Fine)	1	0.0010335	0.0010335	0.0010335	3.62	0.062
Error	57	0.0162687	0.0162687	0.0002854		
Total	63	0.0194135				

Fig 3- Graphical Representation of RA response

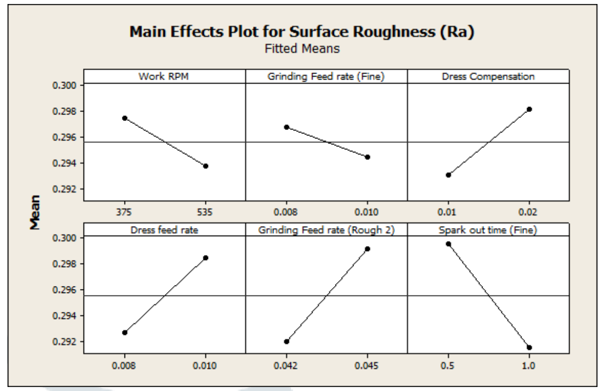
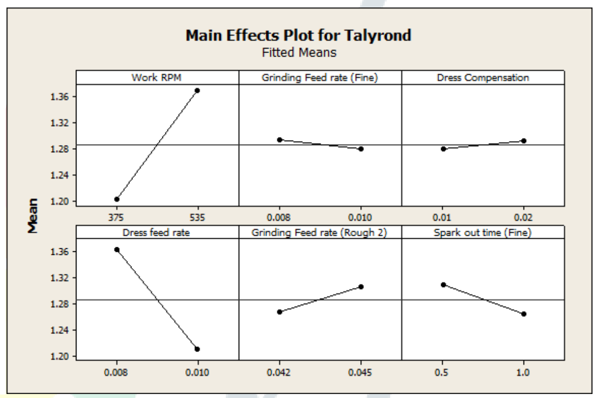


Table 9- ANOVA table for Talyrond response

Analysis of Variance for Talyrond, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Work RPM	1	0.43615	0.44204	0.44204	6.91	0.011
Grinding Feed rate (Fine)	1	0.00271	0.00323	0.00323	0.05	0.823
Dress Compensation	1	0.00316	0.00265	0.00265	0.04	0.839
Dress feed rate	1	0.37261	0.37809	0.37809	5.91	0.018
Grinding Feed rate (Rough 2)	1	0.02154	0.02319	0.02319	0.36	0.549
Spark out time (Fine)	1	0.03154	0.03154	0.03154	0.49	0.485
Error	57	3.64498	3.64498	0.06395		
Total	63	4.51270				

Fig 4 Graphical representation for talyrond response



ANOVA table for Ra response :- inner race

Table 10 ANOVA table for RA response

Analysis of Variance for Ra Avg., using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Work RPM	1	0.000000	0.000000	0.000000	0.00	0.999
Grinding Feed rate (Fine)	1	0.006736	0.006736	0.006736	1.57	0.216
Dress compensation	1	0.005753	0.005753	0.005753	1.34	0.252
Dress feed rate	1	0.001644	0.001644	0.001644	0.38	0.539
Grinding Feed rate (Rough-2)	1	0.000135	0.000135	0.000135	0.03	0.860
Spark out time	1	0.000285	0.000285	0.000285	0.07	0.798
Error	57	0.245100	0.245100	0.004300		
Total	63	0.259653				

Fig 5- Graphical Representation of RA response

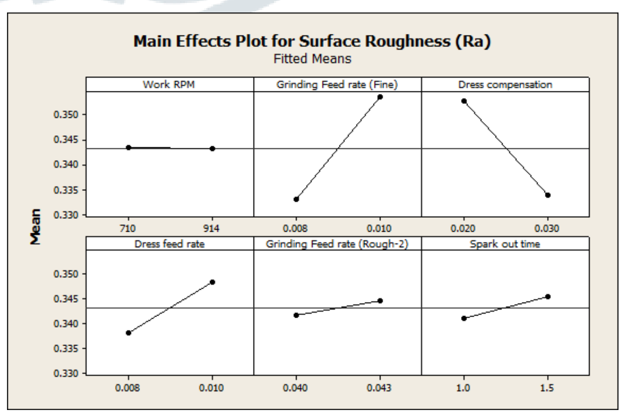
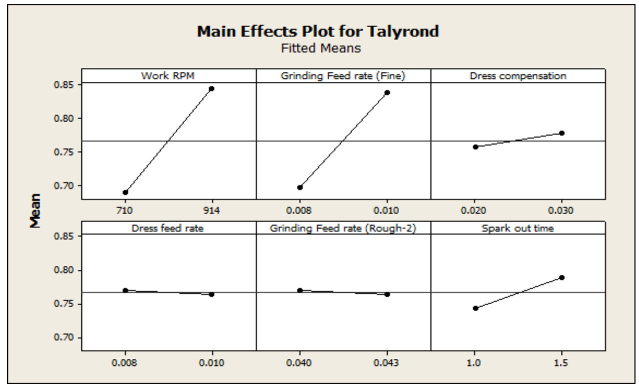


Table 9- ANOVA table for Talyrond responseFig 4 Graphical representation for talyrond response

Analysis of Variance for Talyrond Avg., using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Work RPM	1	0.38285	0.38285	0.38285	8.17	0.006
Grinding Feed rate (Fine)	1	0.31875	0.31875	0.31875	6.80	0.012
Dress compensation	1	0.00730	0.00730	0.00730	0.16	0.695
Dress feed rate	1	0.00053	0.00053	0.00053	0.01	0.916
Grinding Feed rate (Rough-2)	1	0.00053	0.00053	0.00053	0.01	0.916
Spark out time	1	0.03438	0.03438	0.03438	0.73	0.395
Error	57	2.67039	2.67039	0.04685		
Total	63	3.41472				



Result and Conclusion:-

By using ANOVA to numerically simulate and analyze on improvement of surface texture of ball bearing, the ANOVA solution got the sources affects the surface roughness at different labels**.**

It should be mandatory that all the above critical values (P) are more than 0.05 and Critical value (P) should be less than 0.05 for significant factor selection.

- After the experiment conducted and Analysis the ANOVA table-8 ,

On the basis of above Results, we can come to conclusion that none of the sources affects the surface roughness (Ra) value at this level.

Hence machining Conditions are already at optimum level for surface texture & no scope of further improvement.

- After the experiment conducted and Analysis the ANOVA table-9,

Two out of six critical values (P) are less than 0.05. and Critical value (P) should be less than 0.05 for significant factor selection.

After analyzing, the above given results, we can come to conclusion that two factor Work RPM & Dress Feed Rate affects the Talyrond value.

But all these sources are not affects on the surface texture of the product.

- After the experiment conducted and Analysis the ANOVA table-10,

On the basis of above Results, we can come to conclusion that none of the sources affects the surface roughness (Ra) value at this level.

Hence machining Conditions are already at optimum level for surface texture & no scope of further improvement.

- After the experiment conducted and Analysis the ANOVA table-11,

After analyzing, the above given results, we can come to conclusion that two factor Work RPM & Grinding feed rate (fine) affects the Talyrond value.

But all these sources are not affects on the surface texture of the product.

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