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OPTIMAL DESIGN AND ANALYSIS OF BALL CATCH MECHANISM IN REVERSO WATCH

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1. ABSTRACT

Usually watches can show standard time of a country. When we are in other country, suppose we need to know the time of our country, we have to calculate the time of other country by adding or subtracting from the time of that country. To overcome this trouble TITAN developed a new concept and implements it into the new product named as REVERSO. Reverso watches have two watch heads; one is on the topside, another is opposite to that. Each head having the capacity of showing different time and each can be controlled separately. Head can be changed whenever necessary by rotating it. Changing of head is possible by lock or unlock with the watchcase by pushing or pulling.

Keywords: Time, TITAN, Reverso, Pushing, Pulling, Capacity

2. INTRODUCTION

Ball catch is the functional component, which integrated with watch head in the Reverso watches. When watch head is locked, spring tension in the Ball catch pushes the ball head into a notched watchcase. Slip is avoided by the spring tension.

Ball catch is an important functional component of the Reverso watch, which integrated with watch head by press fit. The concept of the Reverso is carried out by the proper function of the Ball catch.

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If it fails it cause the failure of the Reverso model. Hence care must be providing for the design of Ball catch. Design of Ball catch is necessary to avoid the failure of the sleeve. Failure caused due to insufficient strength of the sleeve. So it is necessary to set the thickness of the sleeve based on the strength. This design is based on 'Developed Design', in which modifications provide in the existing designs into new idea.One of the design methodology used here is 'Empirical Design', depends on the Empirical Formulae based on the practice and past experience.

REVERSO WATCH MODEL

Figure-1

Figure-.2

2.1. ORGANISATION OF THE PROJECT

The total projected is completed in two stages. In first stage the theoretical design of ball catch is performed and in the second stage an Analysis of the ball catch is carried out. Initially through study of the Ball catch is made, which gives a clear idea of the ball catch and its functional

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importance. The design procedure is clearly stated in the initial chapters after which the calculation of required parameters is made. The analysis chapter includes the introduction of ANSYS and the analysis of sleeve. To get clear idea of analysis an introductory part on ANSYS is included in this chapter, from which an idea of general procedure and applications of the method are obtained.

3. LITERATURE SURVEY

3.1. TITAN INDUSTRIES- Manufacturer of Reverso Watches

Titan Industries Ltd. is a world-class manufacturer of wristwatches and jewelry. Titan with a turnover of Rs. 960 crores is the leader of watch business in India. With a product range of over 4500 variants to its credit, Titan has clearly redefined watch as a fashion accessory. A relentless pursuit of high quality standards, constant product innovation, customer focus and a drive to excel has made TITAN an undisputed market leader and most preferred brand in India.

As a joint venture between Tata and the Tamilnadu Industrial Development Corporation Ltd., a project of the Tamilnadu government, Titan Industries Ltd. was established in 1984. The company's corporate headquarters is located in Bangalore, Karnataka, although its registered office is in Hosur, an industrial town in Tamilnadu. Since 1987, the business has been involved in the production and sale of quartz timepieces. Over 2509 highly qualified and committed employees make up the company's workforce. The chance it has created for the employment of those who are physically disabled demonstrates the company's commitment to social responsibility.

The watch-making factory for Titan was established in 1987 with assistance from European and Japanese technological experts. The business has developed into the 6th largest watch producer in the world over the years and has built highly integrated production facilities. The business produces watch mechanisms, steel and brass watchcases, and solid and sheet steel bands. The manufacturing techniques used include stamping, hot forging, cold forging, metal injection moulding, micro precision operations (production of elements and sub assemblies), and tool fabrication. Particularly in the field of movement assembly and movement fabrication, there is a high level of automation.

The different departments and their functions of the reverse watch manufacturing are as follows:

- **Auto-turning**: The manufacturing of all cylindrical watch components.
- **Gears and sub-assembly**: The production of all gears required for watch manufacture.
- **Press shop**: The production of sheet metal components required for the manufacture of a watch module.
- **Ebauche**: The manufacture of the component main plate and its sub assemblies.
- **Case press shop**: Preparation of watchcases and case parts from raw material.
- **Case assembly**: Testing and assembling watch parts.
- **Assembly**: Planning and supervising the process of assembly for the manufacture of finished products.
- **Design & Development**: Design innovation and the preparation of standard technical designs incorporating manufacturing details for manufacturing and assembly departments.

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- **Tool room**: Tool engineering services to all departments.
- **Training**: To ensure that new employees are provided with appropriate training and information to enable them to perform their duties effectively. To continue further training to update each one's knowledge and skills from time to time.
- **Research and development**: Design of new movements, design of modification of movements, prototype assembly and evaluation of new movements, tool design for movement components, reliability testing and certification of movements.

3.2. Jaeger-Lecoultre Grand Reverso Duoface Watch-Development

For British polo players assigned to India in 1931, the first Reverso was created. The elite group was looking for a watch that would not be too susceptible to harm while being worn while playing the game. Watch crystals were made mostly of glass at the time and were quite delicate. The Reverso case is made of polished solid metal that can be turned over to expose the opposite side's crystal protection. Naturally, the flipped case mechanism has undergone some modernization, but it still uses the same fundamental design that was created roughly 80 years ago. With the introduction of several new designs, limited - edition, and a closer examination of the watch's history, Jaeger-LeCoultre ardently commemorated the Reverso's 80th anniversary last year. For review I had the pleasure of checking out one of the newer pieces - the Grande Reverso Duoface (also sometimes just called "Duo") timepiece

The sizes and designs of the Reverso vary. The oversized Reverso casings in Jaeger-most LeCoultre's expensive models, including the Gyrotourbillon II and the Triptyque, are the biggest contemporary watches. From there, the Grande Reverso is a step down. The more angular Squadra is an attractive, athletic alternative because of its well-designed, efficient case flipping feature. It has spring-loaded ball bearings that make it simple to move and enable it to lock into position. The Reverso's original caseback is made of simple metal. Early on, Jaeger-LeCoultre recognised the value of this area for personalised engravings, enamel paints, etc…
Jaeger-LeCoultre chose to treat each side as a separate time zone in this instance. As a result, this is a wonderful date and two timezone watch. To view the time zone in another country, simply turn the watch over. On one side, there is a date indicator and a time with supplementary seconds dial. Another time zone with a day/night sign is on the other side. Each dial has a striking resemblance to the original design of the Reverso. By offering the dials machine engravings and sharp printing, the manufacturer takes care to guarantee that the details is outstanding. The dial's black colour also has luminant for visibility at night. The Reverso design is very art deco in appearance, and the greatest thing is that it is also incredibly readable and practical. It is challenging to dislike Reverso. The style is ageless, flattering on the majority of individuals, and the flipping case idea is still entertaining today. Some have attempted to imitate the concept of a double-sided watch.

4. AIM AND SCOPE OF THE PROJECT

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The preliminary aim of the project is to design a Ball catch. Ball catch is an important functional component of the Reverso watch, which integrated with watch head by press fit. The concept of the Reverso is carried out by the proper function of the Ball catch. If it fails it cause the failure of the Reverso model. Hence care must be providing for the design of Ball catch.

Various parameters required are calculated for the design of the Ball catch. The designed part of the ball catch is sleeve, is then analysed with Ansys software to get the maximum stress values and the node at which the maximum values occurs. From the analysis result it is easier to identify where the failure starts and what kind of solution will stop the failure growth.

This design calculation can be used to design the Ball catches at various sizes. The design and analysis of ball catch is mainly to optimize the design parameters, through that effective utilization of resources and raw materials is possible.

5. CONSTRUCTIONAL DETAILS OF REVERSO WATCH

5.1. INTRODUCTION

Ball catch is a part, which integrated with the watch head of the Reverso model by press fit. Reverso watches have two watch heads; one is on the topside, another is opposite to that. Each head having the ability of showing different time and each can be controlled separately. Head can be changed whenever necessary by rotating it. Changing of head is possible by lock or unlock with the watchcase by pushing or pulling. When watch head is locked, spring tension pushes the ball head into a notched case.

5.2 WATCH HEAD

Figure 4.1.1 Shows the watch head, in which the ball catch is fitted into a slot provided for the ball catch by the application of power press. Due to the interference fit the movement of the ball catch is completely arrested.

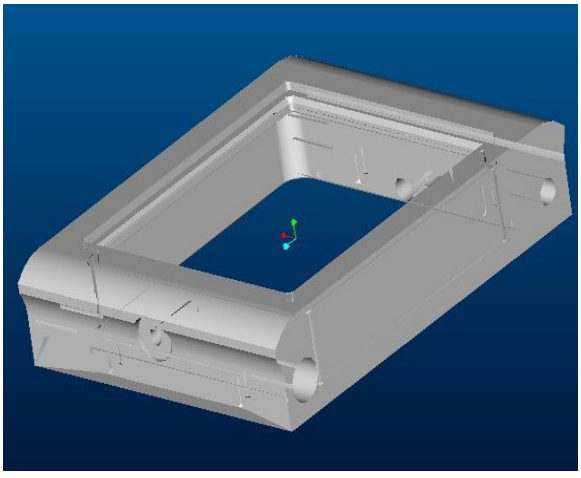

Figure 3

5.3 WATCH CASE

Figure 4.1.2 shows the watchcase. The ball head is locked by pressing the watch head, ball head compress the spring. When the ball head approaches the slot, spring pushes the ball head. So

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the ball head is seated by the spring tension with the slot. This is also called as frame.

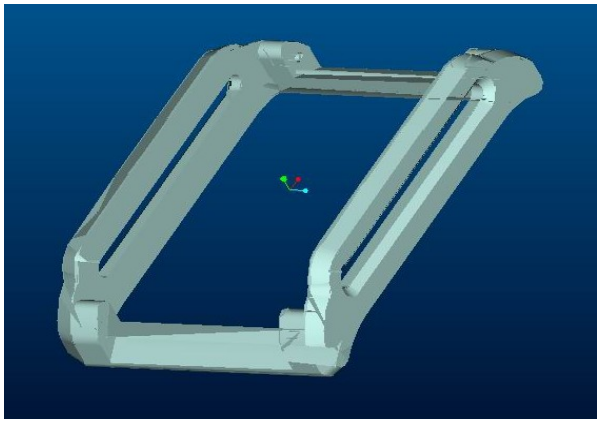


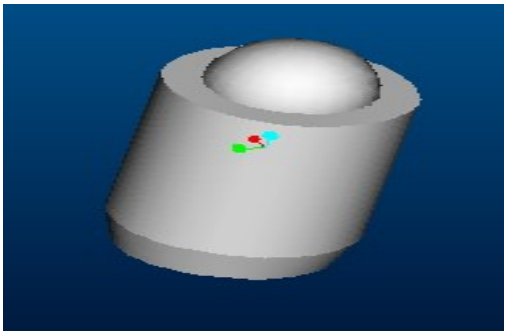
Figure 4.

5.4. CONSTRUCTIONAL DETAILS OF BALL CATCH

Ball catch is the modified form of the ball plunger

It consists

1. Ball head,
2. Spring
3. Sleeve



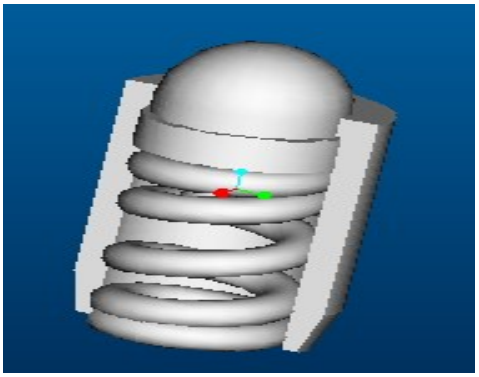
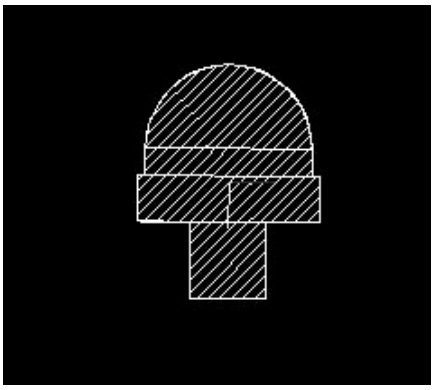


Figure 5

5.4.1. BALL HEAD



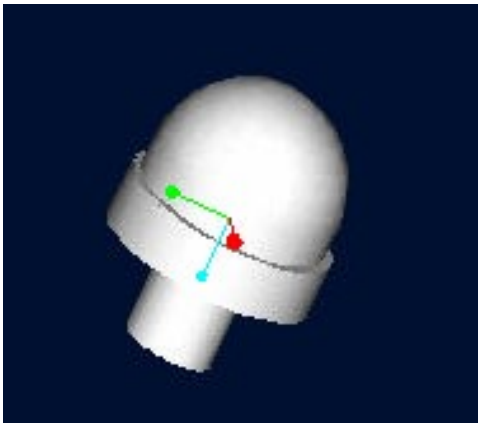


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Figure 6

Ball head is used to lock watch head with watchcase and to transfer load

5.4.2. SPRING

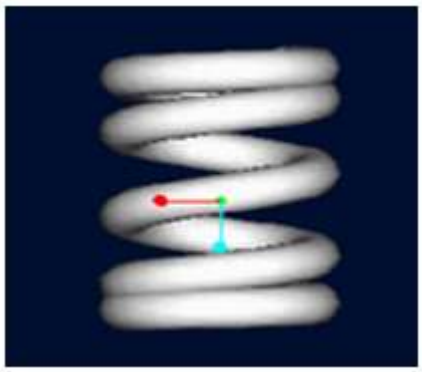

Figure 7

Spring is placed inside the sleeve in compressed form. This tension used to hold the watch head not to slip from the watchcase. In our problem spring should support two loads

- To carry weight of the watch head
- To carry the load applied to lock the watch head

5.4.3. SLEEVE

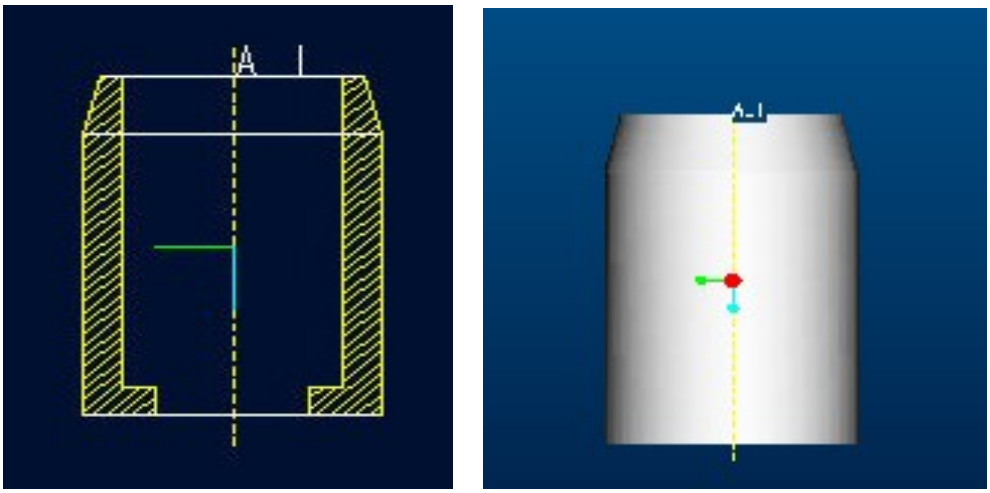

Figure 8

Sleeve is the heart of the ball catch. It is like a thin cylindrical part formed by deep drawing. One end of the sleeve edge is crimped to hold the spring in compressed form. Other end is used to arrest the movement of the ball head due to the spring tension. The ball movement is arrested by the extended edges of the sleeve. Hence it should strong enough to hold the forced ball head.

While designing sleeve it is must to consider the fixing method of the sleeve. Sleeve is fitted

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into the hole by pressing it. So one end is completely constrained hence there is no movement takes place. Another end of the sleeve carries Ball head. The energy absorbed by the spring pushes the back surface of the Ball head, when it released. The Ball head hits the edges of the sleeve.

6. BASIC DESIGN PROCEDURE

6.1. DESIGN

It is the creation of new and better products and improving the existing ones. From the through understanding of existing ideas new idea is to be generated. The new idea is then analysed for its commercial success and given shape and form in the form of drawings. While preparing these drawings care must be taken of the availability of resources in money, in men and in materials required for the successful completion of the new idea into an actual reality.

6.2. DESIGN METHODOLOGIES

New Design

From the results of the research work and the creative thinking new concept has generated. This concept is then convert for design.

Adaptive design
In this design modifications or adaptations are provide for the existing designs.

Developed design

By the thorough understanding and study of the existing designs, new idea has developed or adopting a new material or different method of manufacture to the existing designs to improve that.

The designs, depends upon the methods used, may be classified as

Rational design. -Design depends on the mathematical formula.
Empirical design -Design depends on the Empirical Formulae based on the practice and past experience.
Industrial design - Design depends on the production aspects to manufacture. any machine component in the industry

6.3. BASIC LOGIC STRUCTURE FOR BALL CATCH DESIGN

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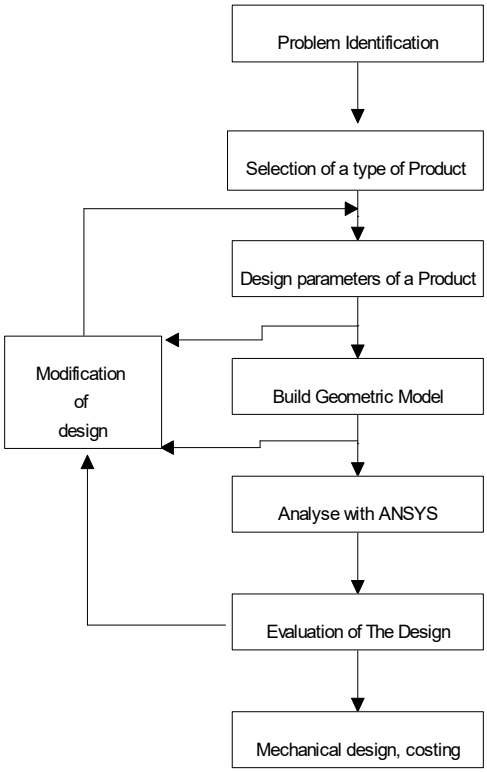


7. DESIGN OF BALL CATCH

7.1. DESIGN OF SLEEVE

Sleeve is like a thin cylindrical shell formed by deep drawing. Edges of one end of the sleeve is crimped to hold one end of the spring While designing sleeve it is must to consider the fixing method of the sleeve. Sleeve is fitted into the hole by pressing it. So one end is completely constrained hence there is no movement takes place. Another end of the sleeve carries Ball head. The energy absorbed by the spring pushes the back surface of the Ball head, when it released. The Ball head hits the edges of the sleeve. Since the pressure load due to the ball head hits the sleeve is consider as a Uniformly distributed load and the Load acting area of the sleeve is considered as a 'Flat circular annular plate' with edges are fixed as shown in figure. Hence the problem is simplified as a design of 'Flat circular annular plate' having uniformly distributed load with edges are fixed.

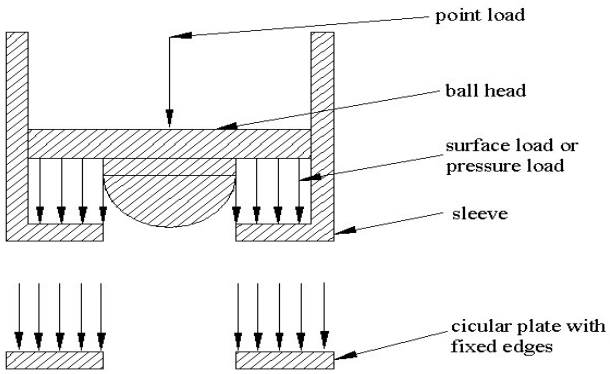
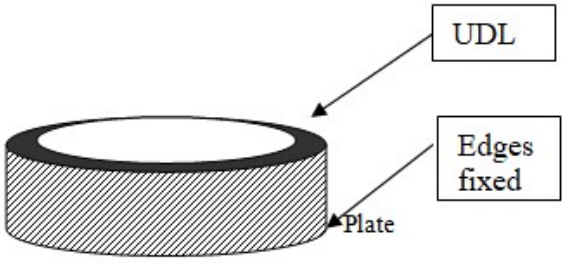


Figure- 9 Sleeve

7.1.1. Design of circular plate

The present design refers to circular metallic plates subjected to transverse loading. Our designs have to be based on the stress analysis. We have to find the maximum deflection of the plate as well. Do not be surprised if this deflection will exceed one-half the plate thickness. This means that the analysis should actually be performed using a nonlinear theory. However, we do not apply this theory in the project and usually, we do not recalculate the results in real engineering. The reason is that nonlinear effects actually reduce the maximum stress as compared to the result obtained from the linear solution. Therefore, by neglecting these effects, we actually incorporate additional safety into design.

When conducting the strength analysis you can use any theory you like. Choose among the maximum principal stress criterion, the Von Mises criterion and the Tresca criterion.



7.1.2. Design objective

Material selection
Setting up the thickness of the sleeve

7.1.3. Material selection

- Offer sufficient strength
- Should satisfies aesthetic needs
- Should resist corrosion and wear

So the material used for Sleeve is ‘STAINLESS **STEEL AISI 304**

* This is a **ductile** material

7.1.4. Material properties

Density ρ	$8.03 * 10^3$ kg/m^3
Elasticity modulus	$193.063 * 10^3$ N/mm^2
Poisson's Ratio	0.29
Yield Stress	268.896 N/mm^2
Ultimate Stress	613.633 N/mm^2
Factor of safety	2

Table-1

7.1.5. Setting up the thickness

To set the thickness we may use general plate equation base on the classical plate theory

$$\nabla^2\nabla^2 y = \frac{p}{D} \quad \text{.....(1)}$$

Solution for equation (1)

For circular plate we employ polar co-ordinates with origin at the center of the plate.

Circular plate of radius 'r' and thickness't'

Then the equation changes

$$\nabla^2\nabla^2 y=\left(\frac{\partial^2}{\partial^2}+\frac{1}{r}\frac{\delta}{\delta r}+\frac{1}{r^2}\frac{\partial^2}{\partial\theta^2}\right)\left(\frac{\partial^2 y}{\partial^2}+\frac{1}{r}\frac{\delta y}{\delta r}+\frac{1}{r^2}\frac{\partial^2 y}{\partial\theta^2}\right)=\frac{p}{D} \quad \text{----------(2)}$$

in the form of Boresi and Chong.

To obtain General solution of the equation (2) following cases are considered

1 Axis symmetry case

2 Plate is loaded and supported symmetrically with respect to 'z' axis

Then the equation reduces to

$$\nabla^2\nabla^2 y = \left(\frac{d^2}{dr^2}+\frac{1}{r}\frac{d}{dr}\right)\left(\frac{d^2 y}{dr^2}+\frac{1}{r}\frac{dy}{dr}\right)=\frac{p}{D} \quad \text{---------- (3)}$$

the form of Marguerre and Woernle.

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By integrating equation (3) we get

$$y = \frac{pr^4}{64D} + A_1 + A_2 \ln r + B_1 r^2 + B_2 \ln r \qquad \text{----------(4)}$$

By applying Boundary conditions the constant values are obtained
Writing equation for circular plate with hole at the center with fixed edges, and axis symmetric cases we should consider

$$A_2 = B_2 = 0$$

Apply $A_2 = B_2 = 0$ and solving it, we get

Maximum deflection $y_{\max} = \frac{k_1 pr^4}{Et^3}$ and

Maximum stress $\sigma_{\max} = \frac{kpr^2}{t^2}$

Where k_1 and k values are obtained by substituting the ratio of the outer radius and inner radius and are based on the boundary conditions corresponding to the poission's ratio.

Empirical co-efficient based on the type of material used and the type of constrained
Table.2

R/r	K	K_1
1.25	0.105	0.0025
1.5	0.259	0.0129
2	0.481	0.057
3	0.654	0.130
4	0.708	0.163
5	0.730	0.176

7.1.6. Design inputs

- Material used
- Geometry of the slot provided for the Ball catch

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i) Diameter of the slot
ii) Diameter of the slot is taken as an outer diameter of the 'Sleeve' i.e outer diameter of the 'circular annular plate'.
ii) Length of the slot
iii) Length of the stroke required
iv) Stroke length is taken as a inner diameter of the circular annular plate

From the inner and outer diameter of the circular plate design can be performed. And the Factor of safety based on the work requirement is taken as "2". The necessary material properties are taken from table.

7.1.7. Design rule

Design is acceptable only when the Design Stress should be greater than the Maximum allowable Stress

$[\tau_{max}] \prec [\tau]$

$[\tau]$- Design stress

Design stress is calculated from the Ultimate stress or by Yield stress
Yield stress is directly taken from the property table

7.1.8. Maximum shear stress theory

$$\text{Factor of safety} = \frac{\text{Ultimate Stress or Yield Stress}}{\text{Design Stress}}$$

Factor of safety is depends upon the utilization of the material.

For **Ductile materials**

Elongation exceeds 5%
Factor of safety based on Yield Strength or Endurance limit

For **Brittle materials**

Elongation is under 5%
Factor of safety based on Ultimate strength

7.1.9. Design calculation

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$$\text{Factor of safety} = \frac{\text{Yield Stress}}{\text{Design Stress}}$$

$$\text{Factor of safety} = 2$$

$$\text{Design Stress} = \frac{268.896}{2}$$

Design Stress = 134.448 N/mm^2

Since of the design rule

$$[\tau_{max}] \prec [\tau]$$

Hence the design stress is taken as a maximum allowable stress

Maximum allowable Shear stress $\sigma_{max} = \frac{kpr^2}{t^2}$

$$\sigma_{max} \succ \frac{0.259 * 30 * 0.55^2}{t^2}$$

$$t^2 \succ \frac{0.259 * 30 * 0.55^2}{\sigma_{max}}$$

$$t^2 \succ \frac{0.259 * 30 * 0.55^2}{134.448}$$

$$t \succ 0.134 \ \textbf{mm}$$

Hence plate thickness ‘t’ should be greater than the value obtained from the calculation. To withstand 30N, sleeve thickness should be greater than the value obtained above.

7.1.10. Maximum deflection

Maximum deflection $y_{max} = \frac{k_1 pr^4}{Et^3}$

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7.1.11. Results

Thickness of the sleeve =0.18 mm
Maximum shear stress =72.55 N/mm^2
Design stress =134.448 N/mm^2
Maximum deflection =3.15*10^{-5} mm

$$y_{max} = \frac{0.0129 * 30 * 0.55^4}{193.063 * 10^3 * 0.154^3}$$

7.3. DESIGN OF BALL HEAD

Ball head is the part, which directly contact with the watchcase. The load, which applied, to lock or unlock the watch head with watchcase is acting over the surface of the ball catch.

7.3.1. Design requirements

1. Strength
2. Resistance to wear & corrosion
3. Mirror like surface finish

7.3.2. Inputs to design

Material to be used
* Mainly based on the aesthetic needs
* Should withstand the spring force
* Resist to wear and corrosion

Geometry of the ball
* Space provide between the watch head and watchcase is taken as radius of the ball
* Ball movement based on the stroke during engagement

7.3.3. Material used

STAINLESS **STEEL AISI 304.** This is a **DUCTILE** material.

7.3.4. Material properties

Table- 3

Density ρ	8.03 * 10^3 kg/m^3
Elasticity modulus	193.063 * 10^3 N/mm^2
Poisson's Ratio	0.29
Yield Stress	268.896 N/mm^2

Ultimate Stress	613.633 N/mm^2
Factor of safety	2

8. RESULTS SUMMARY

8.1. FOR SLEEVE

Thickness of the sleeve=0.18 mm
Maximum deflection =3.15*10^{-5} mm
Maximum shear stress =72.55 N/mm^2

SLEEVE DIMENSIONS

Length of the sleeve = 2.20 mm
Outer Diameter = 1.60 mm
Inner Diameter = 1.20 mm
Wall thickness = 0.18mm

8.2. FOR SPRING

Wire diameter = 0.25 mm
Mean coil diameter = 0.95 mm
Free length = 2.08 mm
Solid length = 1.25 mm
Spring rate = 36.36 N/mm
Wire length required = 15.09 mm
Pitch of the coil = 0.53 mm
Mass of the spring = 6 grams
Spring index = 4
Helix angle = 10°
Number of active coils = 3
Number of inactive coil = 2

8.3. FOR BALL HEAD

Diameter of the ball head =1.10 mm
Diameter of the guide = 0.50 mm

9. CONCLUSION

The functional requirement of the ball catch is to lock or unlock the watch head with the watchcase. The total success of the Reverso model watches is based on the performance of the ball catch. Hence the design of ball catches is greater importance. Design is done for different sizes of Ball catches. These results are having good in agreement with the practical values, which are obtained during trials. The design of sleeve posed a great amount of mathematical complexity. But with the

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assumption of taking the load acting surface is as a ‘circular annular plate with thicknesses has made it possible to design the thickness of the sleeve. The results obtained during this project will be beneficial to optimize the design parameters, for effective utilization of resources and raw materials.

Finite element analysis of sleeve is to be done in next phase from which results obtained should match with both the theoretical values and practical values. The Finite Element analysis will also gives an idea about the real behavior of the material during the load applied.

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