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DESIGN, ANALYSIS AND MANUFACTURING OF STUFFING BOX

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Abstract

Mechanical sealing systems known as packed stuffing-boxes are widely utilized in pressurized valves and pumps. However, there is currently no established procedure for verifying their mechanical integrity and leak tightness. This study aims to address this issue by designing a stuffing box and creating a 3D model with NX UNIGRAPHICS 10. To evaluate the strength and durability of the model, structural and modal analyses are conducted using different materials, including Stainless Steel, Brass, and Grey Cast Iron. Additionally, a structural analysis of the packing gland and bush is performed for validation purposes. Finally, a comparison is made among the dissimilar materials to identify the optimal material for the stuffing box. The modelling is completed using NX UNIGRAPHICS 10, while the analysis is conducted with ANSYS, and the manufacturing process is accomplished using NX CAM

Key words : modelling, analysis, manufacturing, packing gland, bush

1. Introduction

A gland package or stuffing box is a component that encloses a gland seal and prevents fluid leakage, such as water or steam, between the sliding or rotating parts of a machine. In the case of a pump that handles suction lift and operates below atmospheric pressure, the role of stuffing box is to prevent air leakage into the pump. Conversely, if the pressure is above atmospheric, its function is to prevent liquid from leaking out of the pump.

Description

The Stuffing Box is composed of a packing chamber equipped with an external nut or hydraulic chamber. Additionally, it features a swivel bracket and sheave that guides the wireline through the packing chamber. The Stuffing Box sheave's radius is changeable, enabling it to accept larger sheaves for accommodating larger wireline sizes. The Stuffing Box is a crucial device in mechanical engineering that plays a significant role in preventing

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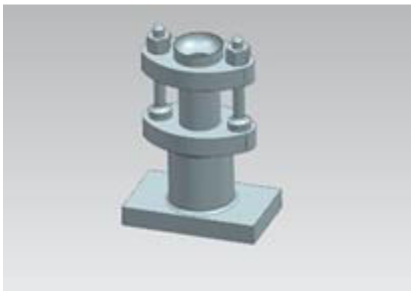
fluid leakage around a moving part, such as a connecting rod, that passes through a hole in a vessel, such as a cylinder, containing oil, water, or steam. This device is constructed by enlarging the hole and incorporating a gland to compress the packing material contained inside the box or chamber.

Explanation

A stuffing box is a device engineered to prevent fluid leakage around a moving component, such as a connecting rod, that passes through a hole in a container, like a cylinder, that contains oil, water, or steam. It consists of a chamber or box created by enlarging the hole and a gland that compresses the packing material inside. In case a stuffing box starts leaking significantly, the recommended course of action is to tighten the packing nut until the leak stops. It is important to note, however, that each tightening of the nut will result in further compression of the packing material around the shaft. This compression can cause the packing material, typically made of flax, to wear away over time, increasing the risk of damage to the shaft. In fact, the hardened packing material can ultimately create a groove on the shaft's surface, making it impossible to achieve a proper seal.



STUFFING BOX

Function and Working Principle

The stuffing box is primarily responsible for preventing fluid leakage from a rotating shaft. The entire packing assembly is positioned over the rotating shaft, and once the gland packing is tightened, the packing rings inside the stuffing box assembly compress to prevent fluid leakage. Due to continuous friction, the assembly may generate heat, and therefore, the entire packing assembly is lubricated by introducing lubricant through a lantern ring.

Furthermore, all stuffing boxes work based on the same fundamental principle. Rings of specially treated flax packing material are tightly wrapped around the prop shaft and inserted into a hollow packing nut screwed to the outside of the stuffing box housing. Tightening the packing nut squeezes and compresses the packing material around the shaft, creating a watertight seal, even while the shaft is rotating. The seal is practically watertight, except for a slow drip. To prevent the packing nut from loosening due to vibration, a lock nut is screwed around the housing and tightened against the packing nut.

Overall, the stuffing box is a crucial component in ensuring proper machinery function by preventing fluid leakage from the rotating shaft. Its unique design and operation ensure that the packing material remains adequately lubricated

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and cooled, preventing excessive wear and tear.

Advantages of stuffing box

Here are the advantages of using a stuffing box, summarized in points:

- Simple and compact design
- Cost-effective sealing device
- Packing rings can be easily replaced in case of an emergency
- Minimal leakage losses
- Easy and straightforward maintenance
- Simple to flush and lubricate
- Sturdy and durable structure

Disadvantages of stuffing box

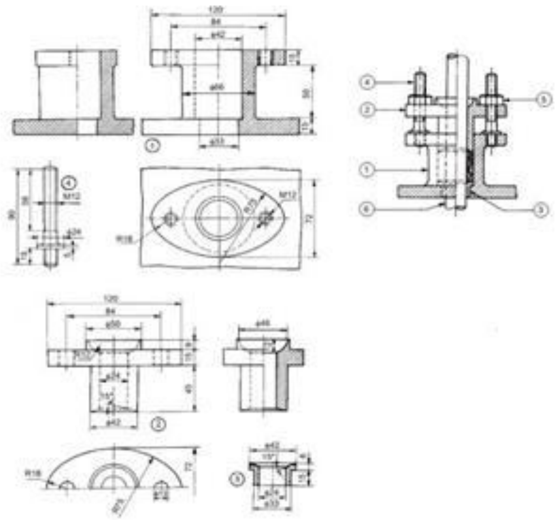
- Overheating and thermal stress can cause cracking.
- Excessive friction in packing rings can result from shaft deflection
- Stuffing box failure can occur in pumps due to friction and vibration.
- Wear in the shaft sleeve can be caused by radial and axial moment.
- Special sealing system designs are required to handle toxic and flammable liquids like liquid fuels, liquid ammonia, liquid CO_2, etc., as the stuffing box design is not suitable for such liquids.

Applications of stuffing box

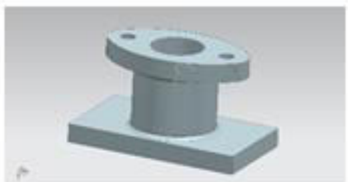
- It is primarily used in water pumps and slurry pumps, but not in pumps that handle toxic and flammable liquids.
- It is used in boat propellers to prevent seawater from entering.
- It is used in large centrifugal pumps.

Design of stuffing box using NX UNIGRAPHICS

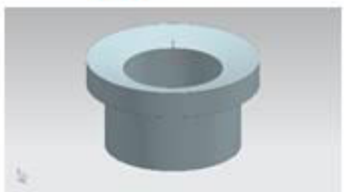
Our team utilized NX software to create a 3D model of a stuffing box. NX, previously known as "Unigraphics," is a sophisticated CAD/CAM/CAE software. Siemens Digital Industries Software has owned the software since 2007. In 2000, Unigraphics acquired SDRC I-DEAS and embarked on a project to integrate features of both software packages into a unified product, which is now known as Unigraphics NX or NX 2D diagram of stuffing box



Parts of stuffing box



BASE



BUSH

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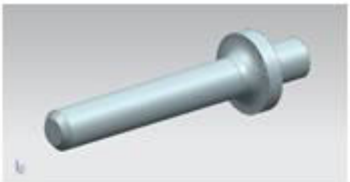
PACKING GLAND



STUD

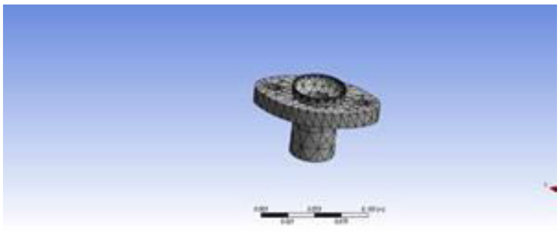
ANALYSIS OF STUFFING BOX PROCEDURE

- Open the software and select the static structural tool from the toolbar.
- Assign the proper material from the Engineering data module.
- Create a geometry or import one from the Geometry module.
- Create a mesh from the Model module.
- Apply boundary conditions from the Setup module.
- Perform the solving process in the Solution module.
- View the results in the Results module

MESH GENERATION IN ANSYS

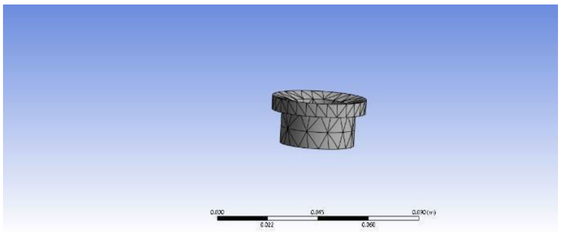
Mesh generation involves dividing a continuous geometric space into discrete geometric and topological cells, forming a simplicial complex that partitions the input domain. Ansys offers an intelligent, high-performance meshing software that automatically produces a suitable mesh for accurate and efficient Multiphysics solutions. The software has built-in smart defaults that make meshing easy and intuitive, providing the necessary resolution to accurately capture solution gradients and ensure reliable results. Whether through automatic meshing or highly tailored mesh, Ansys' software allows for efficient and accurate analysis of complex engineering problems

Mesh generation for packing gland



Nodes = 3271
Elements= 1506

Mesh generation for bush



Nodes = 880
Elements = 384

Results of packing gland Material used: grey cast iron

Object Name	Total Deformation	Directional Deformation	Equivalent Elastic Strain	Equivalent Stress
State	Solved			
Scope				
Scoping Method	Geometry Selection			
Geometry	All Bodies			
Definition				
Type	Total Deformation	Directional Deformation	Equivalent Elastic Strain	Equivalent (von-Mises Stress
By	Time			
Display Time	Last			
Separate Data by Entity	No			
Calculate Time History	Yes			
Identifier				
Suppressed	No			
Orientation		X Axis		
Coordinate System		Global Coordinate System		
Results				
Minimum	0. m	-2.2029e-008 m	1.984e-008 m/m	1328.4 Pa
Maximum	7.7414e-008 m	2.1935e-008 m	5.1963e-007 m/m	55692 Pa
Average	1.9618e-008 m	-5.4001e-011 m	2.0539e-007 m/m	19576 Pa

Material used: stainless steel

Object Name	Total Deformation	Directional Deformation	Equivalent Elastic Strain	Equivalent Stress
State	Solved			
Scope				
Scoping Method	Geometry Selection			
Geometry	All Bodies			
Definition				
Type	Total Deformation	Directional Deformation	Equivalent Elastic Strain	Equivalent (von-Mises Stress
By	Time			
Display Time	Last			
Separate Data by Entity	No			
Calculate Time History	Yes			
Identifier				
Suppressed	No			
Orientation		X Axis		
Coordinate System		Global Coordinate System		
Results				
Minimum	0. m	-1.2604e-008 m	1.116e-008 m/m	1325.4 Pa
Maximum	4.4047e-008 m	1.2567e-008 m	2.9097e-007 m/m	54469 Pa
Average	1.1163e-008 m	-2.9244e-011 m	1.1654e-007 m/m	19508 Pa

Material used: brass

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Object Name	Total Deformation	Directional Deformation	Equivalent Elastic Strain	Equivalent Stress
State	Solved			
Scope				
Scoping Method	Geometry Selection			
Geometry	All Bodies			
Definition				
Type	Total Deformation	Directional Deformation	Equivalent Elastic Strain	Equivalent (von-Mises) Stress
By	Time			
Display Time	Last			
Separate Data by Entity	No			
Calculate Time History	Yes			
Identifier				
Suppressed	No			
Orientation		X Axis		
Coordinate System		Global Coordinate System		
Results				
Minimum	0. m	-503.06 m	436.85 m/m	26411 Pa
Maximum	1748.3 m	502.4 m	11379 m/m	1.0641e+006 Pa
Average	443.09 m	-1.0882 m	4619.6 m/m	3.8904e+005 Pa

<u>Results of bush</u>

Material used: grey cast iron

Object Name	Total Deformation	Equivalent Elastic Strain	Equivalent Stress
State	Solved		
Scope			
Scoping Method	Geometry Selection		
Geometry	All Bodies		
Definition			
Type	Total Deformation	Equivalent Elastic Strain	Equivalent (von-Mises) Stress
By	Time		
Display Time	Last		
Separate Data by Entity	No		
Calculate Time History	Yes		
Identifier			
Suppressed	No		
Results			
Minimum	0. m	9.8255e-008 m/m	8276. Pa
Maximum	1.5303e-008 m	5.8481e-007 m/m	51442 Pa
Average	5.6924e-009 m	3.1484e-007 m/m	24946 Pa

Material used: stainless steel

Object Name	Total Deformation	Equivalent Elastic Strain	Equivalent Stress
State	Solved		
Scope			
Scoping Method	Geometry Selection		
Geometry	All Bodies		
Definition			
Type	Total Deformation	Equivalent Elastic Strain	Equivalent (von-Mises) Stress
By	Time		
Display Time	Last		
Separate Data by Entity	No		
Calculate Time History	Yes		
Identifier			
Suppressed	No		
Results			
Minimum	0. m	5.4356e-008 m/m	8892.9 Pa
Maximum	8.5647e-009 m	3.2801e-007 m/m	51520 Pa
Average	3.1812e-009 m	1.7772e-007 m/m	24797 Pa

Material used: brass

Object Name	Total Deformation	Equivalent Elastic Strain	Equivalent Stress
State	Solved		
Scope			
Scoping Method	Geometry Selection		
Geometry	All Bodies		
Definition			
Type	Total Deformation	Equivalent Elastic Strain	Equivalent (von-Mises) Stress
By	Time		
Display Time	Last		
Separate Data by Entity	No		
Calculate Time History	Yes		
Identifier			
Suppressed	No		
Results			
Minimum	0. m	112.78 m/m	9326.8 Pa
Maximum	18.001 m	692.4 m/m	51642 Pa
Average	6.6762 m	377.52 m/m	24645 Pa

MANUFACTURING OF STUFFING BOX USING NX CAM

NX CAM: NX CAM is a highly versatile and efficient software that offers a wide range of advanced functionalities, such as multi-axis machining and high-speed cutting, making it capable of addressing various tasks. Its advanced programming

Operation Type Cavity
Milling Gouge Check Status Not checked Order Group NC_PROGRAM

application-specific programming such as volume-based milling for faster programming of prismatic parts. This not only saves time but also enhances the precision of the machining process.

One of the significant benefits of NX CAM is that any job can be programmed using a single software, providing comprehensive and integrated NC programming capabilities in one system. This allows for consistent use of 3D models, data, and processes to seamlessly connect planning and shop floor operations with a digital thread. The software's ability to integrate multiple processes streamlines operations, reduces downtime and errors, and improves overall efficiency.

Moreover, NX CAM provides powerful, application-specific tools for streamlining and automating NC programming, resulting in reduced cycle time. The software offers numerous features such as adaptive milling, feature-based machining, and custom macros that improve programming speed, quality, and accuracy. With its advanced capabilities, the software is ideal for machining complex parts, including simultaneous 5-axis milling, high-volume production, and mold manufacturing.

Overall, NX CAM enables the use of one CAM software to create better parts in a shorter time. Its advanced features and capabilities make it a valuable tool for precision manufacturing, especially in the aerospace, automotive, and medical device industries.

Operation information for packing gland

Operation Name CAVITY_MILL

Tool info for packing gland Tool Name: BALL_MILL
Tool Type: Milling Tool-Ball Mill
Holding System: not specified

(D) Diameter = 6.0
(R1) Lower Radius = 3.0
(L) Length = 75.0

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(B) Taper Angle = 0
(FL) Tool Flute Length = 50.0
Number of Flute = 4
Direction = CLW

Operation information for bush Operation Name CAVITY_MILL Operation TypeCavity Milling Gouge Check Status Not checked Order Group NC_PROGRAM
Method Group MILL_FINISH Tool information for bush
Tool Name: BALL_MILL
Tool Type: Milling Tool-Ball Mill
Holding System: not specified

(D) Diameter = 6.0
(R1) Lower Radius = 3.0
(L) Length = 75.0
(B) Taper Angle = 0
(FL) Tool Flute Length = 50.0
Number of Flute = 4 Direction = CLW

CONCLUSION

- In this project, the stuffing box was designed and modelled using NX UNIGRAPHICS 10.
- To determine the strength of the design, structural analysis was conducted on the packing gland and bush using ANSYS software.
- The analysis was performed using various materials, including stainless steel, grey cast iron, and brass.
- Based on the results of the analysis, it was found that stainless steel had the least deformation value when compared to the other materials.
- Therefore, it was concluded that stainless steel is the most suitable material for the stuffing box.
- Additionally, it was determined that the packing gland and bush can be manufactured using a CNC machine.

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