

The background of the slide features a large, stylized graphic of interlocking gears. The gears are rendered in shades of blue and white, with some areas appearing semi-transparent. The overall aesthetic is technical and industrial, consistent with the aerospace theme.

**AEROSPACE  
TESTING  
EXPO 2005**

**E U R O P E**

## **Permanent Mounted Transducer System**

Direct measurement of the clamp load on bolted joints using the ultrasonic technology within the series assembly and the maintenance

The winner of the NASA-Project “Smart Bolts” is now available for the series assembly process

### **The new standard in the bolted joint technology**



## **Achieving, assembling and maintaining the calculated minimum clamp load in a bolted joint“**

### **The central topic of the bolted joint technology**

#### **Highlights of the PMT Systems**

- Guaranty of the minimum clamp load
- Prevention of excessive clamp loads
- Independence of disturbance variables (friction scattering, settling behaviour, assembly mistakes)
- Evaluation and displaying the clamp load achieved
- Guarantees reliable online documentation for the quality of bolted joint connection
- Inspection of the still active clamp load in bolted joints without having to remove and to destroy the assembly parts
- Non-destructive bolt material inspection
- Potential for weight reduction and lower production costs due to optimization of assembly parts

- Great savings potentials in the field of maintenance/inspection and assembling
- No changes regarding „fit, form and function“ of bolted joints
- Increasing the availability of machines, equipment and assembling parts

## **The Permanent Mounted Transducer System**

- We all come across different kinds of bolted joints every day. They are actually one of the most important connecting objects at all. Alone in Germany more than 70 billion bolts are used in assembly processes every year. Whether in the aircraft and aerospace industry, in trains or in motor vehicles: bolted joints have to resist extreme operating forces.
- The engineers number one question is, is there sufficient clamp load in a bolted joint to resist any occurring operating force.

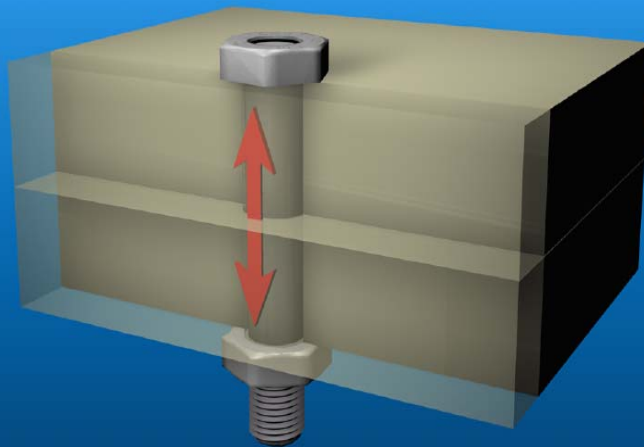
## What does “Clamp load” stand for?

During tightening process only a portion of the torque remains as an effective clamp load in the joint. It keeps the assembly parts together, the knowledge of its size is extremely significant for the design, assembly and maintenance.

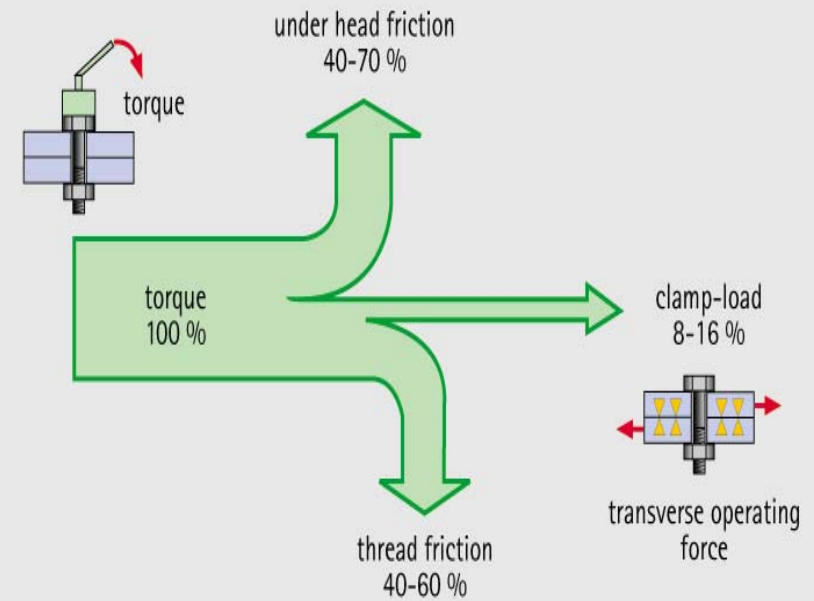
Incorrect assumptions of the clamp loads size can result in dramatic consequences, as loosening or even breaking the bolted joint. The calculation of the clamp load is an extreme complex process. For safety reasons greater numbers, larger size and partially higher grade materials are utilized.

Even if all structural rules are adhered to, we can never be sure that all bolted joints reach the calculated clamp load in the assembly process. Because the direct measurement of the clamp load in the production process was not possible yet.

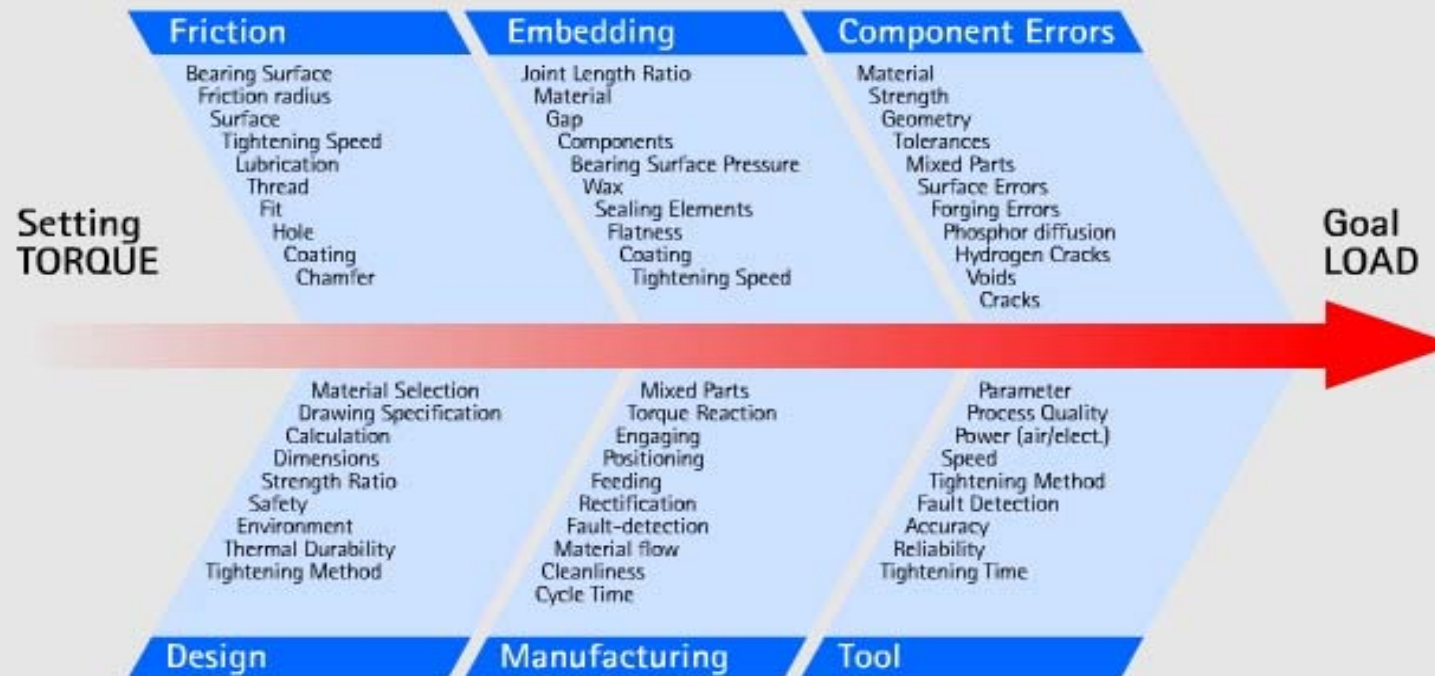
## Clamp load



## Friction scatter during the tightening process



## Cause-Effect Diagram in Fastening Technology



## **We have solved this problem**

The Permanent Mounted Transducer System measures the precise clamp load in bolted joints. This process takes place during the assembling and maintenance process. Furthermore it delivers reliable documentation and relevant quality assurance data.

**This is where the Permanent Mounted Transducer System becomes the new Standard in the bolted joint technology.**

### **It consists of three components:**

Any kind of customer bolt. The permanently mounted piezoelectric transducer and the accompanying PFW Technologies ultrasonic measurement technology.

The Permanent Mounted Transducer System combines numerous advantages. Cost reduction through improvement of regular bolts. Two work modes for the exact achievement of the targeted clamp load and the non-destructive control of the clamp load in bolted joints. Existing standard tools can be converted. Higher reliability with highly stressed bolted joints is given. Better material utilisation result in lighter designs. Work time reduction due to the omission of safety examinations, as for example the elongation limit of a bolt or other non-productive testing. Image and strengthening improvement of the market position by performance optimisation.

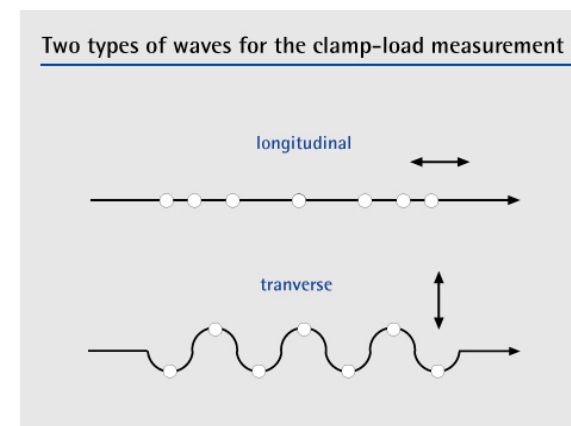
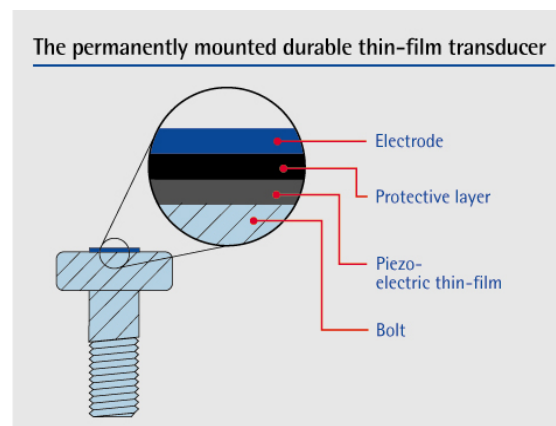
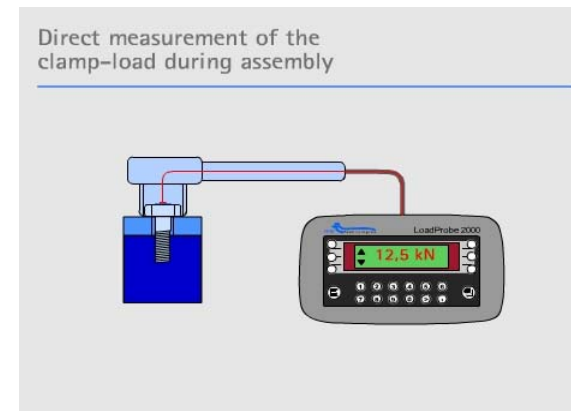
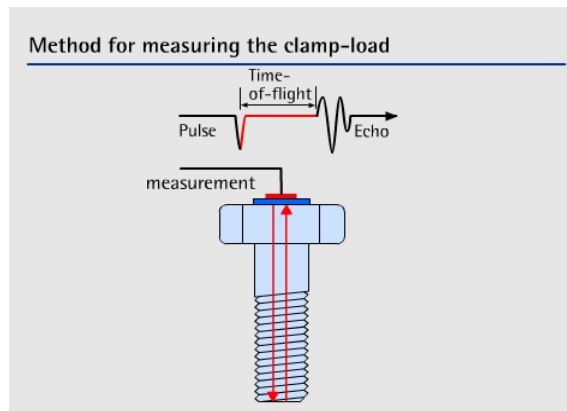
Summary: Worldwide there is presently no other method for the direct measurement of the clamp load in bolted joints during the assembly and maintenance process and in comparison of the preciseness, suitability and cost effectiveness of the Permanent Mounted Transducer System with other systems.

## **Functionality of the Permanent Mounted Transducer System**

Through the special application of the coating method the permanent mounted ultrasonic transducer becomes a real component of the bolt. This elegantly solves the old immanent system problem of the ultrasonic coupling. Result is a new, yet unknown accuracy of the ultrasonic measurement in the series assembly. In the series assembly we reach an accuracy of the target clamp load of +/- 3%.

The success of this system is based on the seamless connection of the ultrasonic measurement technology with the bolted joint technology. The transducer on the bolt head generates an ultrasonic impulse, which travels through the bolt and is reflected at the end of the bolt. From the changes of the "Time Of Flight" from an untightened to a tightened bolt the measurement device calculates an absolutely reliable height of the clamp load.

Through the new thin-film transducer the possibility is given to produce and measure longitudinal and transversal ultrasonic waves simultaneously in the bolt. This enables the measurement of the clamp load in tightened bolts. This technique is absolutely unique and ensures the Permanent Mounted Transducer System an unrivalled exceptional position within the ultrasonic measurement technology.



## Calibration of the measuring system

The respective assembly mode of the customer bolt is configured in certified load cells respectively tensile machines. The echoes ultrasonic Time Of Flight from untightened to tightened bolts are calibrated against the clamp load measuring value of the load cells and the tensile machines. The load cells respectively the tensile machines work on the strain gauge principle in order to reach the elongation coverage. This is independent of the time measurement of the ultrasonic echoes Time Of Flight changes.



## **Production**

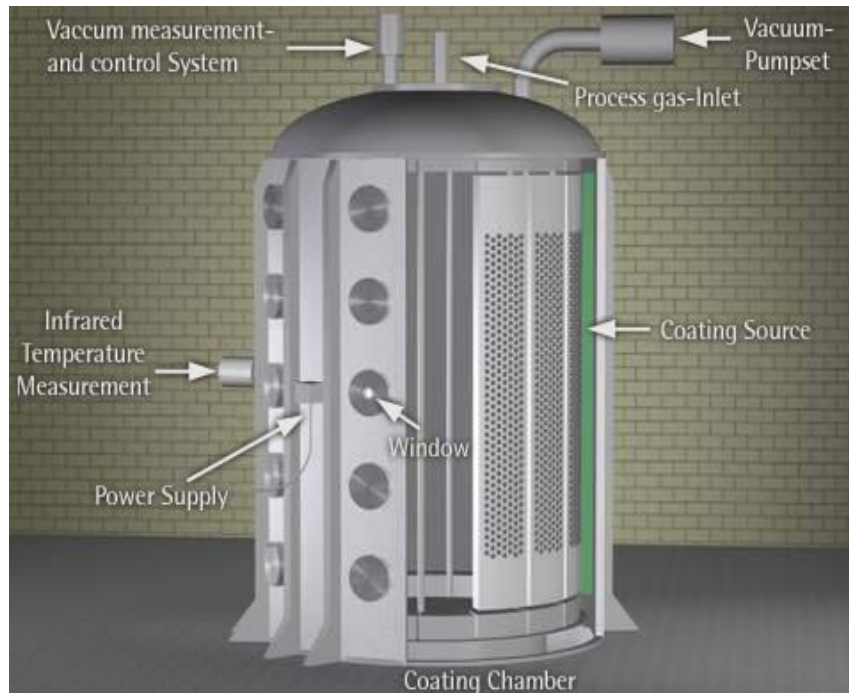
Let's now take a look at the production of the thin-film transducer. It takes place through the plasma coating process "Sputtering", which runs in a vacuum. Before the actual coating process, the bolts have to be prepared. After the cleaning in an ultrasonic bath the bolt heads are roughened in a barrel blaster, this improves the adhesion of the transducer. After the blasting the bolt heads go through a brushing process. Then the bolts are inserted in so called "sectors". A crane lifts the sectors to the bottom of the sputtering machine and transports them to the high vacuum chamber. Together with the sectors the bottom of the sputtering machine is lifted into the high-vacuum-chamber. Powerful pumps create a high vacuum in the chamber.

The vacuum-chamber is equipped with coating sources, the so called "Magnetrons". The coating materials are attached on the inside of the chamber. During the sputtering process the coating material is fired against the bolts using argon ions. Through the inserted impact energy atomic particles are injected from the solid body, building up a thin coating on the bolted joints.

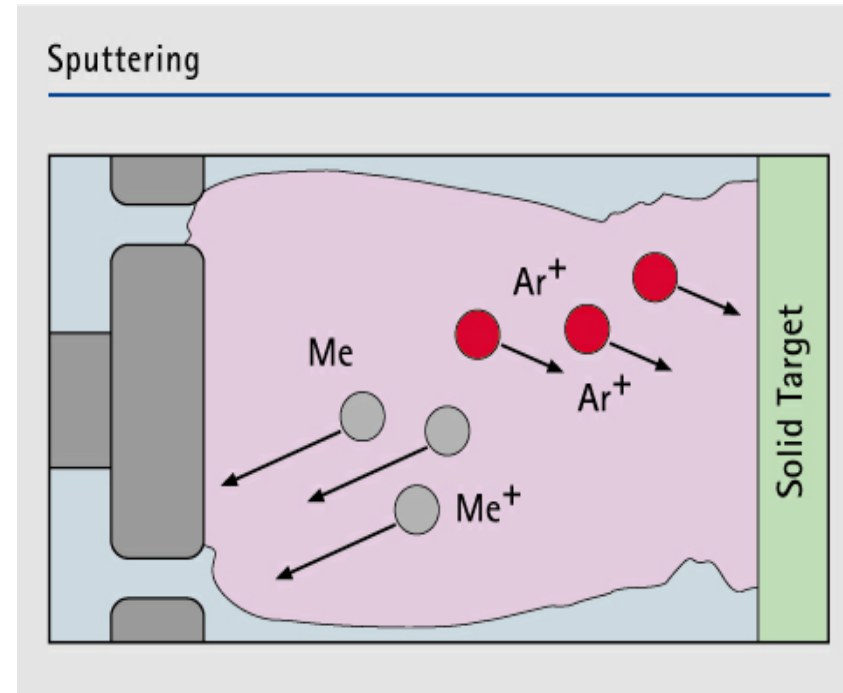
These particles hit the surface of the bolts with a high kinetic energy; this is the reason for the excellent adhesion of the sputtered coating. The reached coating, special polycrystalline with privileged direction, enables a simultaneous generation of longitudinal and transversal ultrasonic waves.

The first step applies a zinc oxide with the piezoelectric thin-film coating. Since the transducer has three layers the sputtering process is repeated twice. The final completion is the electrode of highly conductive tin (Sn). After this working process the coating of the bolt is completed. The transducer has a whole thickness of 0,035 mm and it resists mechanical forces, high temperature differences and many chemical influences.

### Sputtering Coating Chamber

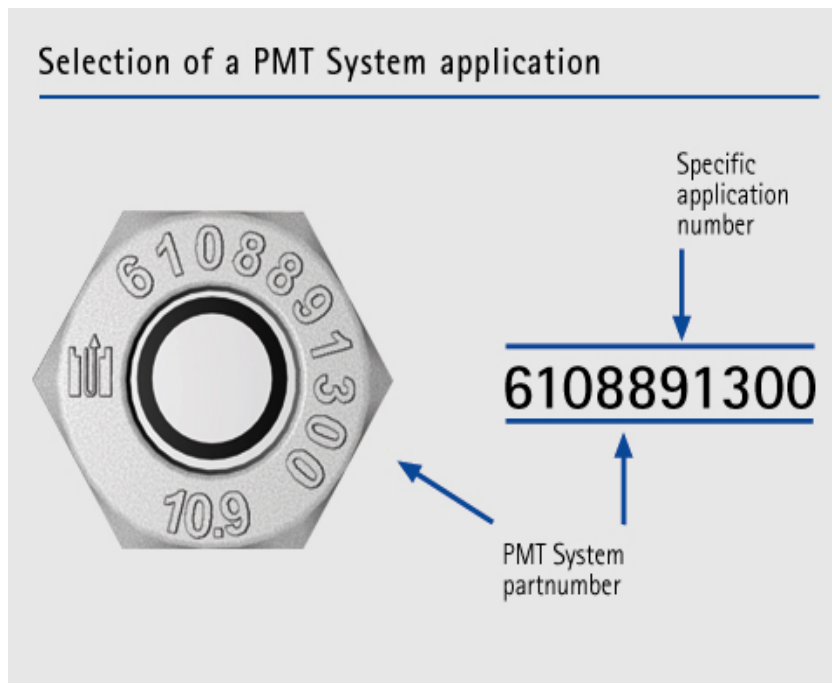


### Sputtering Process



## The selection of a PMT System application

Every particular application receives a special identification number (ID). The ID defines the qualification and specification parameters. Therefore the identification number is the only necessary information needed for an already defined Permanent Mounted Transducer System application.





## History

The Permanent Mounted Transducer System – High-tech for highest demands.

### **The PMT System, the winner of the NASA-Project “Smart Bolts”**

NASA is the main sponsor for the development of reliable joints for space stations within the Permanent Mounted Transducer Technology. In order to promote research and development projects the NASA supports selected companies with NASA-Development funds. This was the birth of the PMT System.

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