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OptiFastening II
Optimized assembly of lightweight screw joints - Open Final Report

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Program	FFI – Sustainable production technology

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1. Executive summary

This project is a direct continuation of the FFI project OptiFastening, No. 2009-00299, which ended 2011-03-31. The project intends to translate the new information into improved procedures and processes in the automotive industry. The project focuses on optimized design and production of weight-optimized bolted joints.

Bolted connections are a key technology for the assembly of cars, trucks and other vehicles. A modern car has about 2,000 bolts of which about 100 are classified. The total value of the bolted joints produced annually within the Swedish automotive industry is estimated at about 10 billion.

In order to reduce the weight of the bolted joints in itself, there are two ways:
1) lighter screws or 2) fewer joints. The screws can be made lighter by a higher utilization of smaller screw sizes (yield strength mounting) or by switching to stronger screw steel. Fewer joints can be used if the life-cycle load and the setting of the joints are known. This saves costs even for assembly. In both cases, a more sophisticated assembly technique is needed in order to reduce the influence of variation in e.g. mounting friction.

Ultrasound guided assembly to just below the yield strength and ultrasound supervised assembly to just above the yield strength of the screw are technologies that the project will demonstrate. Non-destructive inspection using ultrasound will also be developed in the project.

The developed processes and information will give product development, manufacturing engineering, and production tools, including user-friendly models, needed to produce lightweight, safe and economical screw joints.

Budget: 8 million, support from VINNOVA: 4 million
Period: 2012-01-01 - 2014-12-31

Participants: Volvo Car Corporation (PL), Scania CV, Volvo Powertrain, Vicura, bolt Sweden, Atlas Copco Tools, KIMAB, Swerea IVF.

2. Background

Bolted connections are a key technology for the assembly of cars, trucks and other vehicles. A modern car has about 2,000 bolts of which about 100 are classified. A truck has about the same number but as the screw dimension is larger the total weight of the screws is about 200 kg while it is about 25 kg for a passenger car. The total value of the bolted joints produced annually within the Swedish automotive industry is estimated at 10 billion.

Increased focus on CO2 emissions and better fuel efficiency along with safer and better equipped vehicles with good performance is an equation that is difficult to solve. The main track is to reduce vehicle weight. This highlights the use of lightweight materials and exploiting the properties of the materials in full.

Lightweight construction will increasingly be based on designs with components of different materials. When different materials are to be joined a screw joining is one of the available technologies, along with other mechanical joining and adhesive bonding. Bolted connections with mixed materials set high demands on process, choice of surface pressure, galvanic corrosion, different friction coefficients and thermal expansion coefficients, etc.

In order to reduce the weight of the bolted joints there are two tracks: lighter screws or fewer joints. The screws can be made lighter by using smaller dimensions with higher strength and also by utilizing the whole strength of the screws.
High strength bolts where the entire clamping force is utilized requires more of the mounting technology. The influence of variation in friction values must be minimized and screwdrivers have to be very precise in order to achieve the desired clamping force with high precision and repeatability.

3. Objective

The aim of the project was to develop reliable and easy to use tools to achieve the best possible installation of weight-optimized bolted joints. This has been achieved by developing models that provide mounting parameters without testing, as well as models that can predict setting in the clamping force for critical joints. Along with the developed tools for ultrasound-based yield strength assembly the screw joints can be optimized, which can provide significant savings in weight and cost. For the models user-friendly interfaces were developed and published on the network's website.

The aim of the project was that all the information compiled must be readily available. It has been fulfilled by the handbook and calculation tools available freely on the website, www.sfnskruv.se.

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The objectives for the different work packages are shortly presented:

WP1
To develop a pedagogic user interface to SFN's homepage in which the relationship between the clamping force and ultrasonic time-of-flight provided by a FE model when joint geometry is known, see Figure 1. Also the stiffness of the whole and parts of the joint shall be easily reproduced.

WP2
Ultrasonic technology offers opportunities for production efficiency, including by having accurate clamping force control to reduce weight and cost of bolted joints but also by better and easier be able to verify and assure the quality of processes and equipment for yield point assembly. The project intends to show this by two demonstrations. The project utilizes achievements from previous MERA / FFI/ VINNOVA work in the field FE modeling of bolted joints and so-called dry couplants.

WP3
The project group has in the previous project evaluated EMAT and Bi-wave techniques for ultra-sound measurement of clamping force and seen that it works in the lab environment. The aim now was to investigate the possibility to also use the technologies in production. Since weight and performance optimized bolted joints require exploiting yield strength mounting, the influence of plastic flow on the bi-wave technology needs to be clarified. Other factors that are not understood are the impact of and requirements for surface roughness and surface treatment on the screw end faces and for which screw sizes an ultrasound probe can be adapted and used.

WP4
To develop a user-friendly interface that enables designers and others to predict clamping force losses with relatively high accuracy for different types of joints. This will provide information for which dimension and assembly method that is appropriate for a specific component. The setting in dynamically loaded screw joints with different materials and surfaces will be mapped and analyzed.

WP5
Those from testing and simulation work developed user interfaces for the calculation and prediction of bolted joints are uploaded to the SFN website (www.sfnskruv.se).
The goal of the handbook is that it will eventually provide guidance in the majority of the issues that arise in the design, preparation, production and maintenance of bolted joints. The handbook is addressed primarily to the automotive industry and its suppliers. Other industries also have a lot of information in the handbook.

This package also includes the implementation of an international conference.

4. Project realization

The work was divided in five work packages with a WP-leader for each package.

WP1
Production of the FE model in which one can see how the forces develope in the joint as it is tightened. The model will be extended to be modular based so that for example the selection of screw head and the length of the threads may be included. This allows any standard screw to be modeled.

With an accurate picture of the stress distribution in this area the calculation of ultrasound answer used to control / monitor the equipment into the yield strength range of different screw types. Furthermore, the influence of thread friction in yield point tightening is analyzed so that proper care can be given with respect to the relationship between the clamping force and "Time-Of-Flight" ultrasonic response.

Elastic properties of an arbitrary joint are calculated with detailed FE models so simpler models of joints can be produced with a more accurate stiffness in the joint. Today hand calculation, partly based on experience, from a few samples, is used. The work package includes addressing simulation results and development of a simplified algorithm and user interface suitable for the handbooks´ web application.

WP2
Tightening of screws over the yield strength of the material maximizes the utilization of the screws. Clamping force variation is also relatively small (≤ 10%) and depends on variations in material yield strength and variations in thread friction. Installation is either a torque + angle assembly or as a so-called gradient controlled assembly where the assembly is determined by the slope of the torque-angle curve.

The project will identify a number of actual yield strength assembled applications at AB Volvo, Volvo Cars, Saab and Scania and some applications will be selected. Demonstration of ultrasound guided assembly is the ultimate goal but initially the ultrasound is used to verify that the correct clamping force is reached.

Earlier VINNOVA project has apart from FE-modeling treated so-called "dry couplants", membrane that replaces using glycerin as acoustic coupling agent. Glycerin is obviously not practical in current production. Atlas Copco has developed a conceptual parallel bolt tightening system with spindle, electronics and control systems. This is now available for tightening of bolts under production conditions.

WP3

EMAT (ElectroMagnetic Acoustic Transducer) is a technique to generate ultrasound in the surface of the material with electro-magnetism. This means that the method is non-contact and it is thus no need for a coupling medium between the probe and the screw head. To not be dependent on a coupling medium is a big advantage for production adapted ultrasound measurement of screw joints.

Bi-wave is a technique that uses both transversely and longitudinally ultrasound. As the speed of these sound waves is changed differently when the screw is stretched it is possible to measure the stresses and thus the clamping force of mounted screws without these having been measured before they were mounted. This is of great interest both for direct control and analysis of assembly of bolted joints and subsequent monitoring of residual clamping force.

The project team has surveyed the EMAT and Bi-wave techniques and seen that they work in the lab environment. There are questions that need to be answered before it can be considered for inclusion in production.

WP4

Each screw joint will lose clamping force with time. Initially this takes place in connection with tightening as an adjustment of the opposing surfaces in contact. Between 1-10 % of the clamping force is lost only by static load. For dynamic high-strength joints, e.g. chassis joints, further clamping force reduction occurs when using the vehicle. Between 10-20 % is normal but sometimes much more. In this work package setting in dynamically loaded screw joints with different materials and surfaces is mapped and analyzed with the goal to fill up a regression model (MODDE).

The results are analyzed and formulated in a regression model that adequately describes the setting in an optional screw joint. Setting curves for the various experiments are generated. A user-friendly interface for the regression model will be developed. This will be web-based with access through SFN Handbook website.

WP5

Those from testing and simulation developed user interfaces for the calculation and prediction of bolted joints are uploaded to the SFN website (www.sfnskruv.se).
The goal of all activities within OptiFastening II is that they result in information that is introduced in the handbook for the benefit of the Swedish automotive industry.
SFN's website and handbook will also include models and interactive tools for the design and production of screw joints.

5. Resultats and deliverables

5.1 Delivery to FFI-goals

The project will contribute to reduced fuel consumption and reduced CO2 emissions from vehicles. This is made possible by the project has developed improved processes for design, control and monitoring of bolted joints so their properties can be fully utilized. Today many bolted joints are utilized only at half capacity or less. The project will result in that the number and size of screw joints can be reduced, which allows a weight reduction of screw joints and thus a reduction in weight of the vehicle.

The project will also lead to a more efficient design and preparation of bolted joints by the developed models that can be used to calculate the ultrasonic response for a certain clamping force to be achieved. This then becomes independent of variations in friction values.

Monitoring of the resulting and also the remaining clamping force after use will be simplified considerably and become completely non-destructive, since the measurement of ultrasonic signal does not require disassembly or other physical contact with the joint. This may eventually increase the competitiveness of the industry.

By being able to predict the setting a certain joint will get, it will be easier to choose the right size and type of joint and thus to optimize the design.

Screw joining is a core technology for the assembly of vehicles. By developing technology, we help to improve the ability to maintain and expand advanced industrial production in Sweden. It has previously been few research activities in this field.

The project will improve the skills of the Swedish automotive industry and its suppliers and to help automotive companies to stay in the international front. The information that has been developed is freely available on the project website, which means that other industries can benefit greatly from it. The information presented in this handbook can also be used for education materials, both for technical training in engineering and training at universities, colleges and research institutes.

The network (SFN = Swedish Fasteners Network) which was initiated from the automotive industry and developed through the OptiFastening project is very important for contacts and exchange of experience between the companies. By working for consensus in bolted joint technology, we form a good basis for improved and accelerated development in Sweden.

5.2 Summary of the 5 work packages

WP1: FE analysis of bolted joints with the goal to provide simple user interface to the results. Also input to WP5.

A parametric FE model representing a screw joint has been developed. It is a three-dimensional model. This means that all stress components are included when the stress distribution is studied. The coefficient of friction was assumed to be 0.1. Figure 1 shows a picture of one of the units studied.

A variety of simulations were performed to create a base for the interactive user interface. The parameters that were varied were, thread size, material in the parts and the threads, different types of head and various types of nuts.

The simulations have been used to provide the stress distribution in the center of the screw. The goal was to describe the time an ultrasonic pulse spend in the screw as a function of achieved clamping force. Since the speed of the ultrasonic pulse in the screw material is strongly dependent on the stresses in the material, the stress distribution gives necessary information for the time calculation. Below is the speed of sound as a function of stresses.

$$\frac{v_0 - v}{v_0} = \frac{A}{C}\sigma_{\mathrm{i}} + \frac{B}{C}\left(\sigma_{\mathrm{j}} + \sigma_{\mathrm{k}}\right)$$

$$A = 2(\lambda + \mu)(4m + 5\lambda + 10\mu + 2l) - 2\lambda(2l + \lambda)$$
$$B = 2(2l + \lambda)(\lambda + \mu) - \lambda(2l + \lambda) - \lambda(4m + 5\lambda + 10\mu + 2l)$$
$$C = -4\mu(\lambda + 2\mu)(3\lambda + 2\mu)$$

All constants (λ, μ, l, m) for calculation of A, B & C are elastic material constants. FE-simulations will give a more exact joint stiffness then if the empirical models in e.g. VDI-2230 are used.

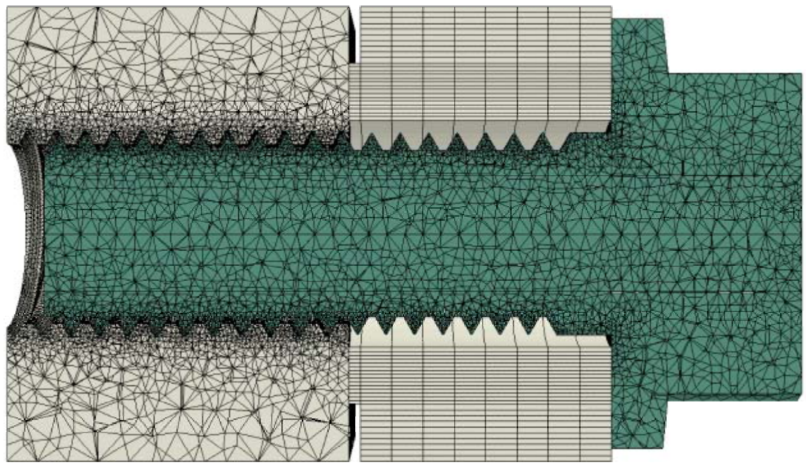


Figure 1. FE-model of one of the studied screw joints.

In the project the elastic constants of 10.9 screw material from two different manufacturers were measured. The mean constants of these measurements were used to describe the relationship between the clamping force and ΔTOF. Special equipment was used to measure *l* & *m*, which can only be determined when the material is under load. Poisson's ratio and Young's modulus were measured in the traditional way.

By combining materials measurements with the results of FE simulations it is possible to calculate the duration of an ultrasonic pulse in a screw with 10.9 quality and to determine the extra time (ΔTOF), when tightened and under load, see Figure 2.

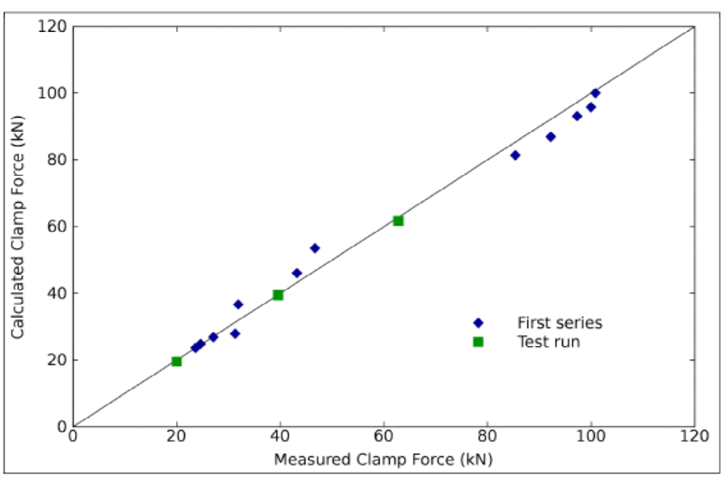


Figure 2. After analysis of the FE-based stress image and an average value of all measured elastic constants of 10.9 materials.

WP2 Demonstration of control and monitoring of bolted joints using ultrasound technology. Even input to WP1.

Ultrasound Controlled tightening of bolted joints at Scania CV.

What controls the clamping force in a bolted joint is the extension of the screw. Ultrasound is used to measure ToF (Time-of-flight), the time it takes for the ultrasonic signal to go through the screw and bounce back. The project's goal has been to control the assembly using ultrasound technology with 100 % approved verifications and with a spread of less than 10% of the actual clamping force.

An assembly equipment has been developed together with Atlas Copco Industrial Technique AB for mounting the counterweights on Scania crankshafts in production. The test rig at Atlas Copco included a load cell to measure the true clamping force, a nut thread and a spacer with the same clamping length as for the mounting of the counterweights on the crankshaft at Scania, see Figure 3.

Figure 3. Atlas Copco’s test rig for the development of ultrasonic assembly.

In a production environment at Scania, see Figure 4, after 10,000 mountings the outcome was 99.9 % with an approved ultrasonic signal and in lab environment was the number of approved mountings 100 % and the spread in clamping force less than ± 2.5 % for the screws used in the field test. This error includes errors in the entire measurement and control system, but also errors due to tolerances in the screw material and dimensions.

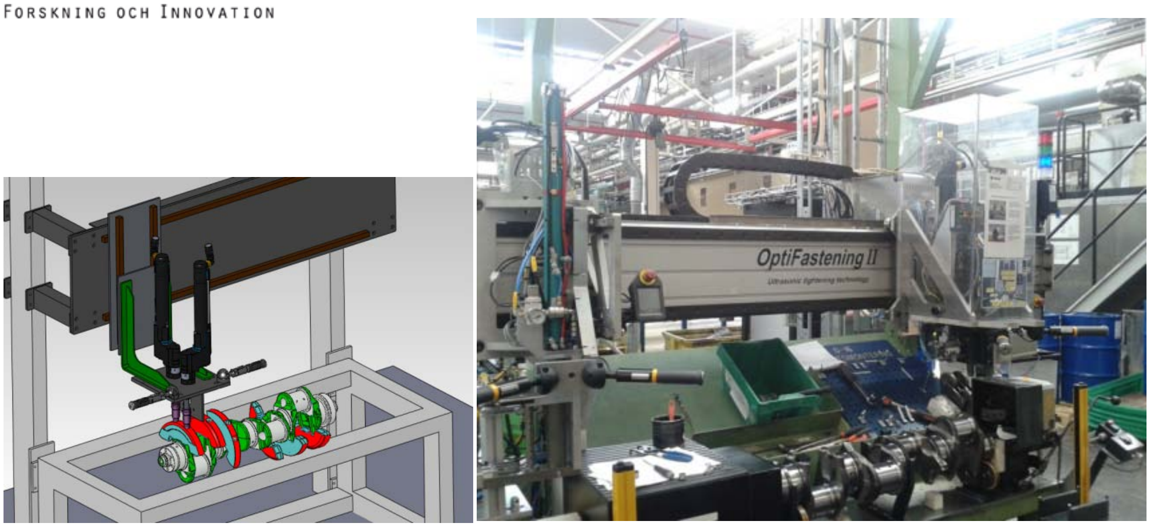


Figure 4. Ultrasound verified yield point tightening of crank shaft weights
LEFT: Schematic illustration; RIGHT: Production equipment at Scania CV.

Ultrasound technology at Volvo Cars

Yield point assembly is used in power transmission units to achieve the highest possible strength with the least number of screws of smallest possible dimension, also when the product has been used. Yield point tightening currently has a relatively tedious verification. Verification using ultrasound represents a very interesting alternative since this method is non-destructive.

Today's method (see Figure 5, left)
Mechanical measurement is performed by:

1. Measure the length of the screw before assemble
2. Assemble
3. Disassemble
4. Measure the removed screw
5. Reassemble with a new screw

Tomorrow's method (see Figure 5, right)
With ultrasound, the following mätschema used:

1. Measure the length of the screw before assemble
2. Measure the assembled screw

Figure 5. Equipment for mechanical length measurement (left) and ultrasound (right).

Because we will measure on yield strength assembled screws it is appropriate to develop a calibration curve. That means to measure the screw length both mechanically and ultrasonically and translate the mechanical requirements into ultrasound values.
The screw joint is assembled to different levels of permanent screw elongation. The ultrasonic signal is measured on the assembled units. Mechanically measured permanent screw elongation is set as a function of ultrasound elongation on mounted units, see Figure 6.

In the example below the ultrasound limit is set to min 1.3 and max 1.7.

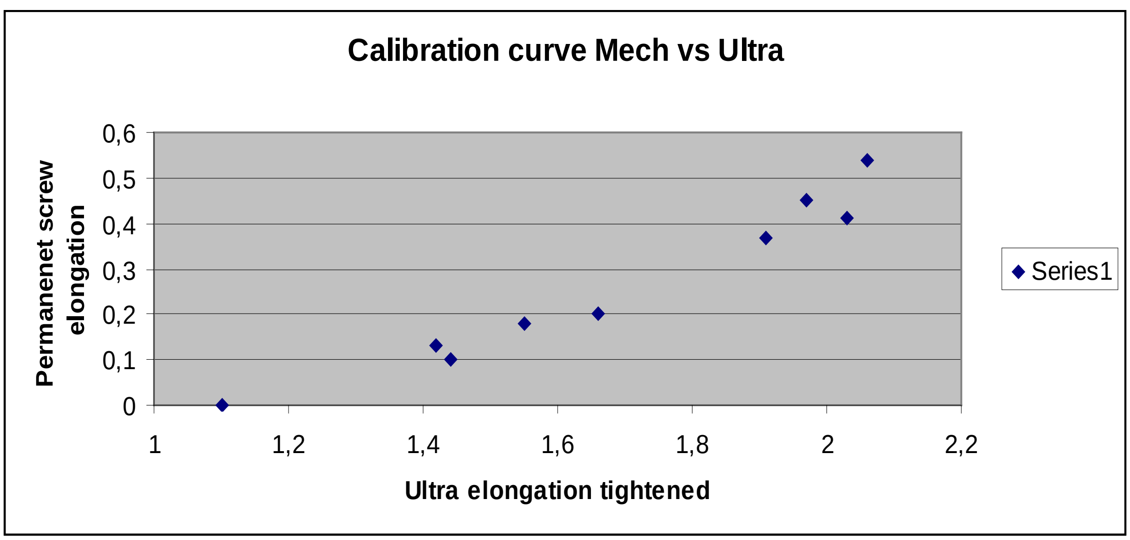


Figure 6. Calibration curve for ultrasound elongation relative to permanent mechanical screw elongation.

Special screws must be used, with an additional cost of about 5 %. The end surfaces must be smooth and plane-parallel and amply of glycerin must be applied to get good contact and signal. The glycerin must be handled carefully, so you do not lubricate the threads of the screws / nuts and cause lower mounting friction.
The measurement method has the potential to be much faster than today's method because it avoids disassembly and reassembly. The method requires trained personnel and a stationary station to provide relevant results. Overall, the current method and equipment is not yet sufficiently stable and developed for production environments.

WP3 Evaluation of alternative ultrasound techniques (EMAT/Bi-wave) for production applications. Also input for WP2.

EMAT (Electromagnetic Acoustic Transducer) is a technique in which electro-magnetism generate an ultrasonic pulse in the surface of the material to be examined. This is a technique that does not require direct contact between the screw and transducer since the ultrasound is generated directly in the screw head. This means that the method is in principle non-contact and it is thus no need for a coupling medium between the probe and the screw head, which is the case with traditional ultrasound technology. To not be dependent on a coupling medium would be a great advantage for production adapted ultrasound measurement of screw joints.

The project’s intention was:

1. Inventory and evaluation of suitable equipment available.
2. Investigation of the possibilities and limitations of the EMAT technology.
3. Investigation of bi-wave technology capacity of yield point assembly.
4. Production adapted evaluation among Atlas Copco and Vehicle Manufacturers.

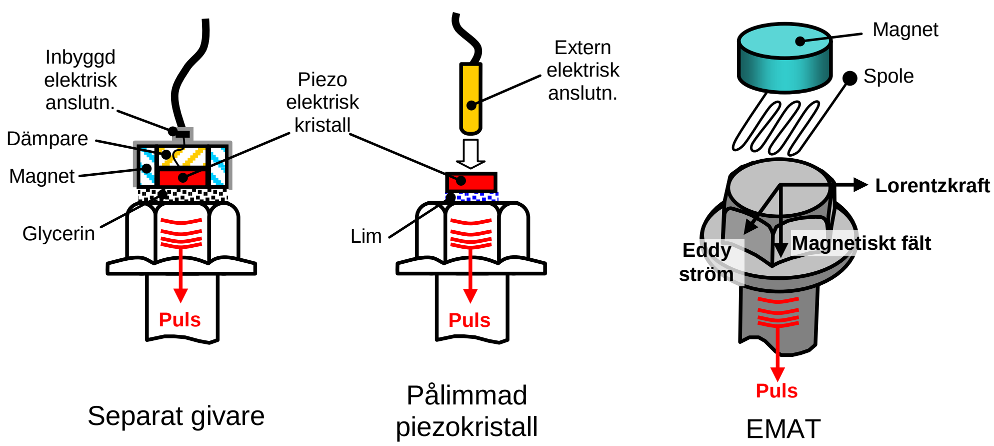
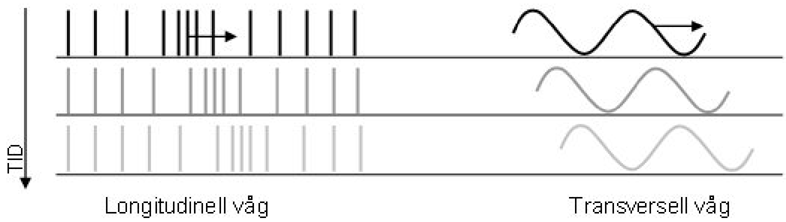


Figure 7. Left: Separate probe for longitudinal waves. Glycerin cannot transmit transverse waves. Middel: Glued piezo crystal. Right: Principal EMAT-probe. Can generate both transverse and longitudinal waves.



Figur 8. Longitudinal and transverse waves.

Another technique that has been evaluated is "bi-wave". This is based on that both the longitudinal and transverse waves are used. These two waves propagation velocity is affected differently by stresses in the material and this can be used to calculate the clamping forces. This means that the clamping force can be measured directly without the screws have been measured before installation.

EMAT and bi-wave have been evaluated in lab environment at the research institute CETIM in France and we follow Inner Spec Technologies development of a production adapted equipment. When this is available, which was announced for the fall of 2011, it would be evaluated within the project. It has, however, not yet appeared autumn 2014. Alternative suppliers with commercially available systems have not been found.

The project team decided in the spring of 2013 that EMAT technology is still interesting but with the limited resources in the project, it was decided that we should not pursue own development of measuring equipment. The work package (WP3) was terminated and the resources transferred to the other work packages.

WP4 User interface for design of clamping force critical screw joints.

Also input for WP5.

Typical screw joints where the clamping force losses may be considered were identified; power transmitting chassis and powertrain joints in sizes M8 to M14. Normally occurring screw lengths (clamping lengths) and with representative materials; painted steel, aluminum and untreated steel were specified. The geometry of the test samples (Figure 9 left) was adapted for dynamic testing in a MTS machine.

Parameters that we wanted to study were: the initial force, assembly speed, size of contact area, surface effects (different materials and painting), diameter of the screw and clamp length, see figure below. To limit the number of specimens, statistical design of experiments was employed, using the software Modde. The evaluation of the tests was done with the same software.

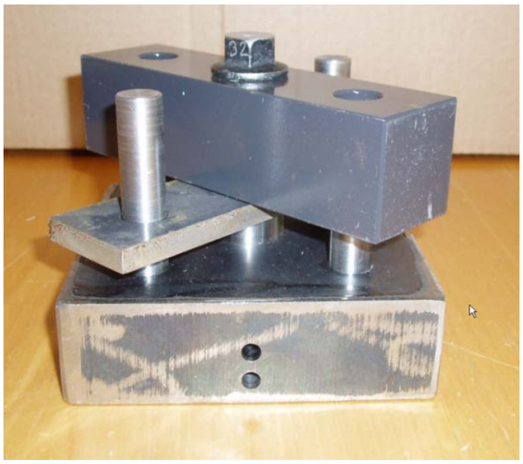


Figure 9. Left: Geometry of the test samples and fixture. Right: Assembly equipment.

The next stage of the test was to expose the units for heat exposure similar to field conditions. The screw joints were placed in the oven, equipped with welded thermocouples to monitor the temperature. Some joints were excluded from the test, and they are referred to as RT (room temperature), while the steel and aluminum joints were exposed to 90 and 120 ° C and the painted joints were subjected to 60 or 90 ° C for 24 hours. The screw length was measured before and after the test.

The dynamic load experiments mimic a low cycle fatigue, like when you run into a pit, and not thousands of small vibrations but relatively large loads on the order of hundreds of cycles. Special equipment was built to perform the test, see Figure 10.

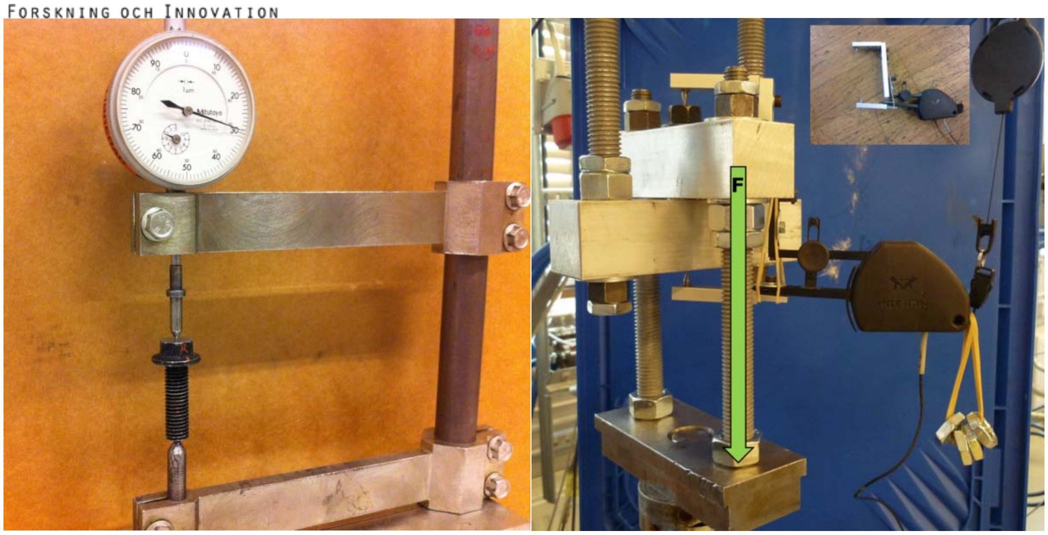


Figure 10. Fixture for length measurement of screws and equipment for dynamic load of the screw joints.

After each step, the screws elastic elongation was measured. In that way, changes in clamping force could be followed. After testing, the joint was dismantled and the screw's zero level of elastic extension was verified (the screw was also measured before mounting at the beginning of the test).

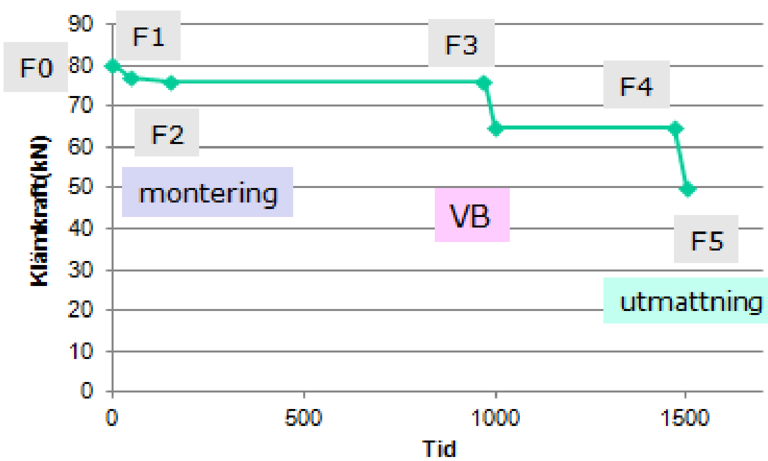


Figure 11. Illustration of the setting evaluation.

The test results were then fed into the Modde model and the model's accuracy could be estimated. With the aid of the regression model "Modde", the setting for different combinations of materials, clamping lengths, assembly torque levels and loads can be predicted. The model is based on physical samples. A user-friendly interface was developed and is now published on the project website, see "Calculation Utilities" on www.sfnskruv.se. The setting in the form of clamp load loss can now with relatively good precision be predicted for a number of chassis and powertrain screw joints. This enables optimization of the joints geometry and the assembly technology.

Initial setting

- The initial setting for the screw joints showed no clear effect of tightening speed.
- Increased clamping length showed most effect of all tested variables and reduces setting in all cases.
- Increased contact pressure increases setting. To get a specific residual clamping force, it must therefore initially be increased more than just by what will be lost.
- For steel, about 2 % of the force is lost initially, slightly more for smaller screws.
- Powder coatings lose most initially, around 4.5 %, followed by aluminium and ED-coatings with around 3.5-4%.

Influence of temperature

- Increased temperature increases setting.
- Increased clamp length has no evident effect.
- Increased contact pressure has little effect, except for aluminium for which the setting increases.
- Steel joints show no or very low sensitivity in the tested range, about 2 % setting.
- ED-painted joints showed low sensitivity, about 5 % setting.
- Aluminium and powder painted joints showed high sensitivity, about 20 % setting.

Influence of dynamic load

- The contact pressure is the most important parameter for dynamic load. Increased contact pressure increases the setting, about 25% difference between low and high contact pressure.
- Steel and ED-coated samples show low sensitivity, about 5 % setting, while the setting for aluminium is about 15 % and for powder coated samples may be about 30 %.
- Longer clamping length gives a reduced tendency to setting. For aluminium and powder coated samples, the difference is about 20 % in the setting between short and long clamp length.

WP5 Further development of SFN's homepage with new web applications, see WP1 and WP5, and expansion and refinement of the handbook

Handbook in screw joint technology

The goal of all activities within the project has been that they should result in new and improved information made available through the handbook. SFN's website and handbook in screw joints are freely accessible at www.sfnskruv.se . The handbook contains updated knowledge about most things needed to design and produce optimized bolted joints. The handbook is compiled by the project team's leading experts from the Swedish automotive industry. Our hope is that it will serve as a natural aid and assistance in the design and production of screw joints, primarily for the automotive industry and its suppliers but also for other industries. Our hope is also that we can continue to develop its content and usability through new development projects about screw joint technology.

The handbook has achieved 19 new chapters during the project.
The handbook now has 55 chapters.

The new chapters are:

1. Process Monitoring
2. Ultrasound in production
3. Ultrasound in lab
4. Insert threads
5. Special fasteners
6. Composite laminates
7. Electrically conductive joints
8. Ultrasonic introduction
9. Washers
10. Hole making
11. Aluminium screws
12. Lubrication
13. Threaded fasteners for plastics
14. Thread forming high strength joints
15. Weld nuts and screws
16. Press nuts
17. Simplified screw joints calculation
18. Failure analysis
19. FAQ

In addition to the new chapters, all previous chapters have been revised and many chapters have been supplied with improved and expanded information and new pictures.

Calculation tools
Two calculation tools have been introduced at the homepage. One is to calculate the ultrasonic response when measuring the assembledscrews in the clamps and the other is to calculate the remaining clamping force as a result of static load, dynamic load and temperature influence. The information for the calculating tools is developed within WP1 for the ultrasonic response and within WP4 for the setting calculation. The tools are presented in more detail there. The calculations are not exact because the relationships are very complex. They should be seen as a good indication of the actual outcome.

6. Dissemination and publications

6.1 Knowledge and results dissemination

The homepage of the handbook is freely available online under www.sfnskruv.se . When searching for screw joint related information it comes up as an early alternative.

The screw joint experts at the companies can recommend the handbook for many of the questions of a general nature that are asked. This frees time for more specific problems while the handbook helps with knowledge transfer to designers, production engineers and production, and also creates an increased interest and focus on screw joint technology.

Details and results of the project have been presented internally at the companies and at various conferences and meetings such as VINNOVA FFI conferences and meetings within LIGHTer. Examples of presentations are:
- What opportunities are provided by future screwdrivers, FFI Katrineholm, 2012, Erik Persson, Atlas Copco Tools.
- Simulation of screwdriving, FFI Katrineholm, 2012, Niclas Stenberg, KIMAB.
- Digital handbook for screw joints, FFI Katrineholm, 2012, Jan Skogsmo, Swerea IVF.
- New opportunities to optimize bolted connections - the correct clamping force despite lower weight, FFI Katrineholm, 2013, Thomas Hermansson, Volvo Cars.
- Measurement of screw clamping forces, FFI Katrineholm, 2013, Jan Skogsmo, Swerea IVF.
- Ultrasound for quality-assured screw assembly at Scania CV and Volvo Cars, FFI Katrineholm, 2014, Lars Oxelmark, Scania CV, Thomas Hermansson, Volvo Cars.

Through the development of a common set of requirements for fasteners, design of screw joints, and assembly technology, standardization can be driven further increasing competitiveness. To develop a Swedish consensus on smart assembly which is displayed internationally will also increase our international credibility as talented and ambitious automotive producers.

Modern screw joint technology - Internationell konferens

The project organized an international conference "Modern screw joint technology". It was a two-day conference, held in Stockholm on 18-19 September 2013. The meeting rooms were partly Quality Hotel Nacka and partly The Mine at Atlas Copco in Nacka. The conference brought together 62 participants, mainly from the Swedish automotive industry but also other industries and international participants. The conference was held in English. The presentations were sent to the participants with a link in PDF format.

6.2 Publications

A robust algorithm to find the relation between clamp force and Ultrasonic Time of Flight in a bolted joint, Niclas Stenberg, Chunhui Luo, Peter Lundin, Submitted for publication, 2014.

Skruva med ultraljud – och få ner bilens vikt, Ny Teknik, 110921.
Minskad vikt tar skruv, VINNOVA-nytt 1, 2012
Lättviktsförband och förband med aluminiumskruv, Aluminium Scandinavia, 5, 2012.
Skruvmontering till rätt klämkraft, IVF-publikation_ Teknik och Tillväxt, 2013

The following reports have been prepared and sent to the participants:
1. Report Optifast modeling 140423 description of the development of modeling
2. Article ULbolt_JAMT. Article about the modeling of ultrasound
3. Report Atlas Copco 140822 Description of Development at Atlas Copco.
4. Report Scania 140815 Summary of ultrasound in production at Scania.
5. Report Volvo Cars 140821 Summary of ultrasound in production at Volvo Cars.
6. Report Screw joint weight reductions 140416 Ultrasound in production at Volvo Cars.
7. Report Experiments and modeling of setting in bolted joints.

7. Conclusions and further research

Screw joint technology is a very complex area with a great need for continued research and development. There are great gains with improved screw joints technology:

- Lighter screw joints
- Less number of fasteners
- Faster and easier design
- Faster testing
- Faster and more secure assembly
- Better quality assurance
- Fewer breakdowns
- Allows constructions in mixed materials

There is a clear need for a pedagogic sequence for how the screw joints are designed and dimensioned. Some of the parameters needed is not known exactly, but they must be estimated, but how? A tutorial can be organized in blocks where each block explains how to generate the information needed, such as friction value, need for clamping force, choice of screw size, etc.
This design instruction would be pedagogically and accessible through the website. In this section would also updating and completing the handbook with extended information and new chapters be included.

8. Participating parties och contact person

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