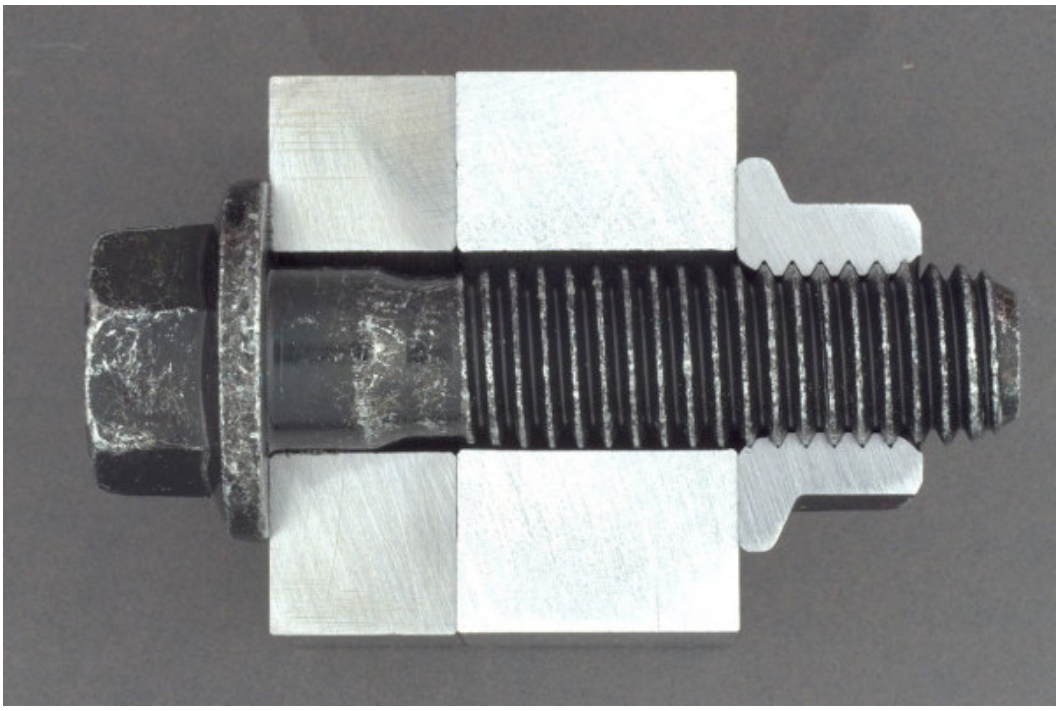
OptiFastening – Optimized assembly of light weight screw joints



Screw joints: Screw, nut and clamped parts

Authors Thomas Hermansson – Volvo Car Corporation
Jan Skogsmo – Swerea IVF

Date 31 May 2011

Project within Sustainable industrial engineering

Content

FFI in short

FFI is a partnership between the Swedish government and automotive industry for joint funding of research, innovation and development concentrating on Climate & Environment and Safety. FFI has R&D activities worth approx. €100 million per year, of which half is governmental funding. The background to the investment is that development within road transportation and Swedish automotive industry has big impact for growth. FFI will contribute to the following main goals: Reducing the environmental impact of transport, reducing the number killed and injured in traffic and Strengthening international competitiveness. Currently there are five collaboration programs: **Vehicle Development, Transport Efficiency, Vehicle and Traffic Safety, Energy & Environment and Sustainable Production Technology.**

For more information: www.vinnova.se/ffi

1. Executive summary

The project OptiFastening started in 2009 and was finished 31 May 2011. OptiFastening is a project concerning optimized construction, preparation and assembly of light weight screw joints in the vehicle industry.
The participants are SFN(Swedish Fasteners Network)with Swedish vehicle industry: Volvo Cars, AB Volvo, SAAB Automobile and Scania CV: distributors of fasterners and assembly equipment: Bulten Sweden and Atlas Copco: as well as the research institute Swerea with the subsidaries Swerea IVF and Swerea KIMAB.

The project's objective has been to produce instructions, calculation models and other tools to facilitate optimized construction and production of screw joints. The focus of the project has been light weight screw joints. Screw joints in a vehicle can be made lighter by reducing the number of screw joints and/or reduce the dimensions of the screw joints. This means that the strength of the screw joints is utilized to a higher degree. In order to increase the level of utilization of the screw joints in multiple production, a more sophisticated assembly technique is needed, to reduce the influence from e.g. scattering in assembly friction. Better control of how the clamping force in screw joints act towards different materials and load is also needed.

A Swedish web based handbook on screw joints has been produced and published; it is available for everyone at www.sfnskruv.se . Simulation models for screw joints have been developed. They form the basis for the calculation programs for ultrasonic measurements and control of the clamping force and prediction of relaxation which are available on SFN's website. The possibility of using ultrasonics for control and follow up of assembly even at the yield strength, which gives maximum utilization of the screw, has been prepared in the project and will be developed in the continuation project OptiFastening II (OFII).

The result objective of the activities in the project has been practical, applicable information which is made available at SFN's website and the handbook

2. Background

SFN (Swedish Fasteners Network) was founded in 2006 to coordinate the development of screw joint technology in the Swedish vehicle industry. Participants from Swedish vehicle industry: Volvo Cars, AB Volvo, SAAB Automobile and Scania CV. Distributors of fasteners and assembly equipment: Bulten Sweden and Atlas Copco as well as the research institute Swerea and its subsidiaries Swerea IVF and Swerea KIMAB.

Screw joints are a key technology for the assembly of cars, trucks and other vehicles. A modern car has about 2000 screw joints, of which about 100 are security classified. The total value of the screw joints that are produced annually in the Swedish vehicle industry is estimated at SEK 10 billion.

There are two ways to reduce the weight of the screw joints:

1) Lighter screws or
2) Fewer joints

Screws can be made lighter by a higher utilization level of existing screw dimensions (yield piont assembly) or by switching to stronger steel.
This way the joints can be reduced by one dimension and the weight be reduced by about 40 grams per joining point in a typical joint. Fewer joints can be used if the life cycle strain and the relaxation of the joint are known. To fully be able to utilize the screw joints, optimized assembly technique and full control of important parameters like friction, speed, moment, vibration and clamping force are required. The information must be easily available to staff within construction, preparation and production.

3. Objective

The objective of the project has been to provide instructions and other tools to constructors, those who prepare and mechanics to support optimized construction and assembly for increase utilization degree and thus reducing weight of the screw joints in vehicles. To be able to utilize ultrasonics for control and follow up of clamping force, simulation models for the distribution of the stresses in the screw joints needed to be developed. They form the basis for the calculation programs for ultrasonic measurements and control of the clamping force and prediction of relaxation which are available on SFN's website. The possibility of using ultrasonics for control and follow up of assembly even at the yield strength, which gives maximum utilization of the screw, has been prepared in the project and will be developed for production in the continuation project OptiFastening II (OFII).

The result objective of the activities in the project has been practicle, applicable information which is made available on SFN's website and in the handbook.

4. Project realization

The Handbook
The handbook has been produced by a main author and co-authors from the project team, who have written chapters respectively. These chapters have then been sent to the whole project team for proof reading. Swerea has adapted the contents to a uniform web format. When everyone has approved the contents it has been published online, see www.sfnskruv.se and choose "Handbook". The information which is presented is therefore mutually agreed by Swedish vehicle industry. Information is added and refined on a regular basis.

Figure 1. Handbook on screw joints, www.sfnskruv.se .

Model for calculation of distribution of the stresses and ultrasonic ToF

Ultrasonics are used as a form of echo sound. You measure the screw's length by measuring the time it takes for an ultrasonic pulse to travel back and forth through the screw, see figure 2.

The ultrasonic ToF (time of flight) is mainly affected by a) the length of the screw and b) the screw's stress condition. The stress condition has even bigger impact than the change of length. Temperature affects ToF as well. The stress in the screw is not evenly distributed but varies depending on length and cross-section, depending on what the joint looks like and how it has been assembled. Manufacturing engineers can use the ultrasonic model to calculate the ToF which is equivalent to the desired clamping force of a particular joint.

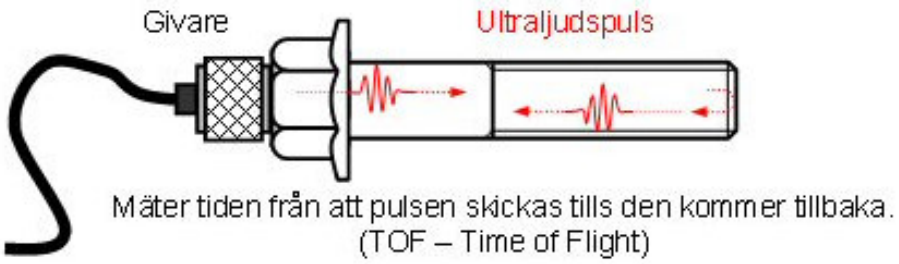


Figure 2. Principle of ultrasonic measuring of a screw

The simulation technology, with an FE-model for distribution of stresses in order to get clamping force in screw joints as a function of ultrasonic ToF, has been developed to a useful tool to construct optimized screw joints. The intention is to develop the model further to give better support at advanced calculation and to improve simple calculation models.

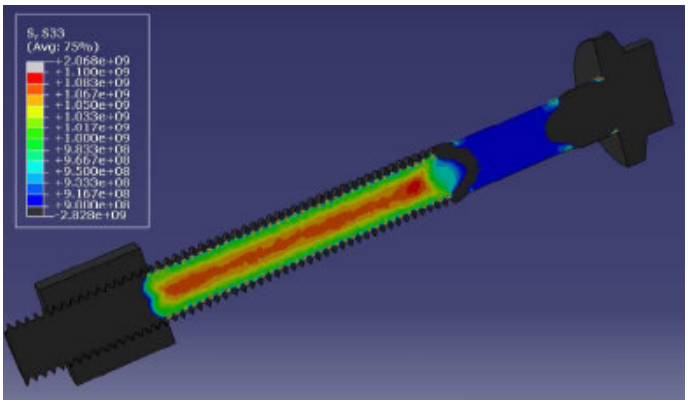
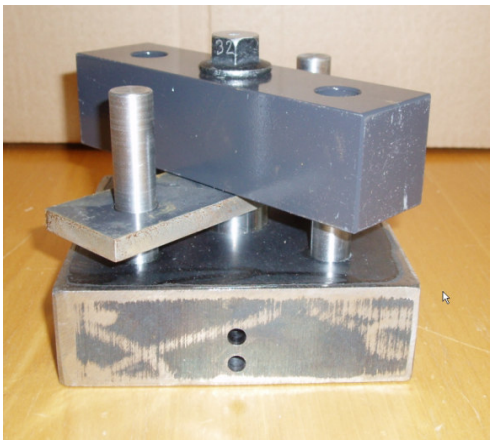


Figure 3. Simulated stress picture in an assembled screw.

Test series to predict relaxation in screw joints

A large number of test specimens has been produced to represent different types of joints. The main objective with this test series was to generate information to better evaluate relaxation. Relaxation, or loss of clamping force, is one of the most important aspects for screw joints. These different types of screw joints have been subjected to increased temperature to generate relaxation. The clamping force has been investigated with the developed ultrasonic technology right after assembly and after different storage times and temperatures. A regression model has been developed from the tests to predict relaxation as a function of heat and outer loads. It has been observed that more test specimens are needed to get a good significance of predicting the remaining clamping force. The test specimens are shaped in a uniform way, se figure 4, to fit a test rig in order to apply external loads in dynamic tests.



Figur 4. Assembled test specimen in a fixture

Alternative ultrasonic technologies

Other interesting alternative ultrasonic technologies have been analysed, see figure 5 for one of them: EMAT = Electro Magnetic Acoustic Transducer. This is a technique which does not require direct contact between the screw and transducer; instead ultrasonics is generated directly in the screw head. Therefore, no coupling medium is required between the transducer and the screw head, which is of great value for production measurements.

Another technique which has been assessed is the bi-wave. This is based on the use of both longitudinal and transversal waves. The two waves are affected by different stresses in the material and this can be used to measure the stresses. This means that the clamping force can be measured directly without requiring the screw to be measured before assembly.

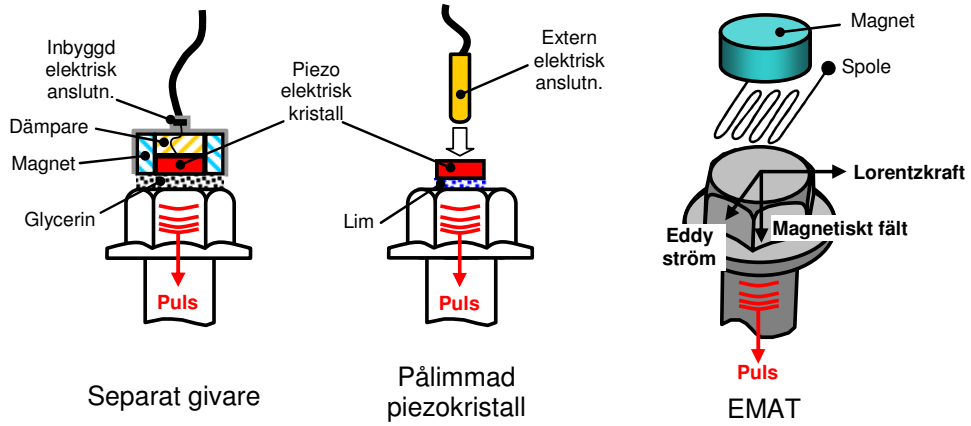


Figure 5. Left: Separate transducer for longitudinal waves. Glycerin cannot transfer transversal waves. Centre: Glued on piezo crystal, can basically be used even for tranversal waves. Right: Principle for EMAT-transducer. Can generate both transversal and longitudinal waves.

It is possible to combine EMAT and bi-wave technology. To measure the clamping force directly without measurement of the ultrasonic signal from the unloaded screw, and to be able to do it without using sticky glycerin as a coupling medium, is of great value; not only to the vehicle industry but also for aeroplanes, ships, wind power, masts, bridges and other constructions with crucial screw joints. If the method can be used for stable assembly to or near a yield strength, there will be increased opportunities of obtaining optimized screw joints, lighter construction and simplified follow-up and guarantee of quality.

Ultrasonic follow-up of clamping force crucial joints in production
The follow-up of clamping force in crucial screw joints has been conducted with ultrasonics in the production at the vehicle companies. The intention was to select appropriate joints for production follow-up and to give a preview of practical carry through and specification of requirements of the equipment.

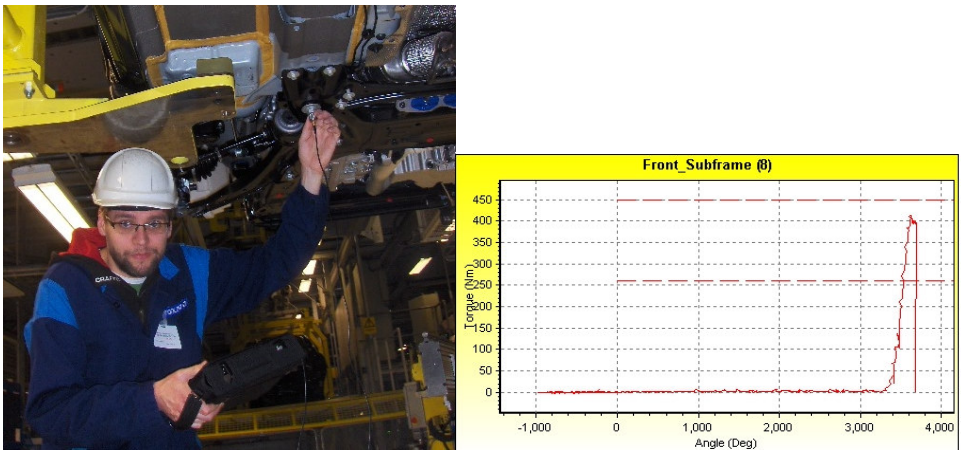


Figure 6. Follow-up of clamping force in the production at Volvo Cars with ultrasonic measurement and moment-angle graph for the assembly process..

5. Results

5.1 Delivery to FFI-goals

The project has contributed to many of the objectives that are set for the programme:

- Lighter screw joints result in lighter vehicles and therefore decreased emissions
- Development of screw joint technology gives increased possibilities of introducing light weight constructions and constructions put together of different materials.

- The project has resulted in close contacts between the vehicle companies and important distributors.
- The exchange of experience which has happened has been very valuable to increase knowledge, create consensus and strengthen Swedish vehicle industry and its distributors
- The project contributes directly to development of technology and skills at all levels in industry, not just the vehicle industry, due to the fact that the information is easily available on the website and in the handbook
- The handbook can be used as a basis for training in industrial engineering
- The objective of the project has been that all activities will give applicable information which is presented on the website and in the handbook
- Programs for simulation of screw joints have been produced. They can be used to construct optimized screw joints and to predict the ultrasonic result which is equivalent of a set clamping force which is of great value to industry.
- The handbook and the produced calculation programs facilitate construction and production of optimized screw joints which is important to strengthen competitiveness
- The SFN network, which represents Swedish vehicle industry, is a forceful research partner with excellent international competitiveness.

6. Dissemination and publications

6.1 Knowledge and results dissemination

The handbook is available on www.sfnskruv.se .
Apart from the 50 informative chapters in the handbook there are calculation programs for calculating ultrasonic results from assembled screws and calculation of level of relaxation of screw joints.

Use of the handbook as a source of information is being marketed by the project participants at their respective companies and externally through articles and references.

6.2 Publications

An international seminar at Swerea IVF , 6 October 2009
IVF report ”Ultrasonic testing for determination of clamping force”, Swerea IVF, 2009.

The usage of ultrasonic testing for determination of clamping force – measuring ToF
Summary of presentations, International meeting, Report Swerea IVF (2009)

FEM simulation of tightening into the plastic region of an M12, ISO 10.9 screw joint, Nathaniel Chia, Report KIMAB-2008-138 (2009).

”Simulation based calibration for clamping force prediction in bolted joints with use of ultrasonic measurement”, Chunhui Luo, Niclas Stenberg Swerea KIMAB, Carl Carlin, Arne Roloff, Atlas Copco Tools and Assembly Systems, a paper from Swedish Fasteners Network. To be submitted to scientific journal, 2011.

”Introduktion till klämkraftsmätning i skruvförband med hjälp av ultraljud”, Compilation of State-of-the-Art, SFN, May 2011.

7. Conclusions and future research

Screw joints are and will continue to be important components when assembling vehicles. Today, the utilization of the screw joints' performance is barely 50%. By increasing the level of utilization the screw joints will be made safer and lighter. In order to achieve this, stable assembly methods, better control of included parameters and further knowledge of how the screw joints act during assembly and use are required.

- The project has developed simulation models where stresses in screw joints can be calculated. This can be used to optimize construction.
- The models can be used to predict which ultrasonic result equals a particular clamping force. This provides the opportunity to use ultrasonics for follow-up and control of clamping force.
- The evaluations show that there are good possibilities to introduce ultrasonics for clamping force measurements in production.
- The handbook has developed into an important tool which is now used at companies.
- The calculation models for which ultrasonics result equals a particular clamping force and calculation of relaxation have been added to the website

Screw joints are complex constructions which are affected by many different factors, materials and loads. During the project it has become clear that the developed models need to be refined and the number of tests needs to be increased and carried out. What mainly needs to be done in the continuation project OptiFasteningII is:

- Interactive calculation aid for supervision limits of ultrasonics will be produced and put on the SFN website
- The simulation model for distribution of the stresses needs to be developed for yield strength assembly

- A user interface which gives constructors the possibility to calculate the rigidity and analysis of distribution of the stresses of screw joints will be developed
- The test series for production of models for relaxation will be increased to provide more accurate predictions for different materials and dynamic loads. A test cycle for relaxation based on a life cycle perspective also needs to be produced
- Evaluation of production of ultrasonics equipment, including EMAT and bi-wave, will be carried out.
- Additional chapters and information will be added to the handbook.

8. Participating parties and contact person

Kurt Andersson, Screw joints specialist, Bulten Sweden AB,
kurt.andersson@bulten.com, tel: +46705691356

Lars Oxelmark, Skills manager, Åtdragningsteknik, Scania CV AB,
lars.oxelmark@scania.com , tel:+ 46702900035

Göran Toth, screw joints technical specialist, Saab Automobile AB/VICURA AB,
goran.toth@vicura.se , tel: +46701678217

Filip Bergman, Materials – and screw joints specialist, Volvo Powertrain Corporation,
filip.bergman@volvo.com , tel: +46313223362

Carl Carlin, General Manager, Atlas Copco Tools AB,
carl.carlin@se.atlascopco.com , tel: +46706336690.

Niclas Stenberg, Senior researcher, Swerea KIMAB AB,
niclas.stenberg@swerea.se , tel: +46734169838

Jan Skogsmo, Project manager, Swerea IVF AB,
jan.skogsmo@swerea.se , tel: +46707806042.

Thomas Hermansson. Screw joints specialist, Volvo Personvagnar,
therma14@volvocars.com , tel: +46313252387.

Notice 1
Carl Carlin will be replaced in the continuation project as he recently retired.
Projektgruppen would like to thank ”Calle” for his valuable contribution and team-work.

The new Atlas Copco contact person is:
Erik Persson, Team leader tightening technique, Atlas Copco Tools AB
erik.persson@se.atlascopco.com , tel: +46706199425

Notice 2
SAAB‘s part of the continuation project will be divided between SAAB Automobile AB and VICURA AB.

The new contact person for SAAB is:
Peter Lidman, SAAB Automobile AB
peter.lidman@saab.com , tel +4652084511

Göran Toth will continue to be the contact person at VICURA AB.

FORDONSSTRATEGISK
FORSKNING OCH INNOVATION

Adress: FFI/VINNOVA, 101 58 STOCKHOLM
Besöksadress: VINNOVA, Mäster Samuelsgatan 56, 101 58 STOCKHOLM
Telefon: 08 - 473 30 00