DEVELOPMENT OF HIGH STRENGTH STEEL FOR COLD HEADED SCREWS

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lisi AUTOMOTIVE
LINK SOLUTIONS FOR INDUSTRY

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Outline

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- High strength steel development - History
- Requirements and results
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  - ➔ Heat treatment
  - ➔ Fatigue behaviour
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- Summary

1 business, 3 sectors of activity

925	66%	65	8,512
M€ Sales*	outside France*	M€ of investments*	Employees*

lisi AEROSPACE

Aerospace fasteners and assembly components

N° 3 in the world

16 sites

4,677 employees

407,6 M€ of sales

Customers: Airbus, Boeing, EADS Dassault, Embraer, Eurocopter, GEAE, Pratt & Whitney, Rolls Royce, Safran

lisi AUTOMOTIVE

Automotive fasteners and assembly components

N° 6 in the world

19 sites

3,312 employees

446,3 M€ of sales

Customers: BMW, Daimler, Ford, PSA, Renault-Nissan, VW-Audi, Autoliv, Bosch, Faurecia, TRW, Schneider

lisi MEDICAL

World class contractor for the medical device industry

4 sites

508 employees

74 M€ of sales

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LISI AUTOMOTIVE: 3 expertise units

Threaded Fasteners

Competitive and optimised factories in forging and metal working

Clipped Solutions

Continuous innovation – expert engineers in design and development

Safety Mechanical Components

Know-how – expert engineers in forging, machining and assembly

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History of high strength steel development

- **A new age of hydrogen embrittlement studies**

  - **Started by LISI AUTOMOTIVE to find the influent parameters of steels susceptibility to free hydrogen :**
    - **surface carburisation**
    - **phosphorus intergranular diffusion.**

  - **With ARCELOR-MITTAL : measurement of hydrogen input along the production process of screws :**

published in may 2006 in ‘’Traitement Thermique’’ revue.

Project

- **LISI AUTOMOTIVE / ARCELOR-MITTAL HS steel project**
  - ➔ **Project submitted by LISI AUTOMOTIVE in June 2004**
  - ➔ **Benchmarking and return of experience (10.9 and 12.9)**
  - ➔ **12 grades tested with laboratory casting (high and low carbon)**
  - ➔ **4 grades tested to finalise a solution :**

38CrMoNiB5-3

Industrialisation

- **First industrial cast of 38CrMoNiB5-3 in September 2008**
  - ➔ **Qualification on M7 conrod screw**
  - ➔ **Qualification on M10, M12, M14 screws**
  - ➔ **Test of bainitic quenching in lab. and industrial conditions**

High strength steel requirements

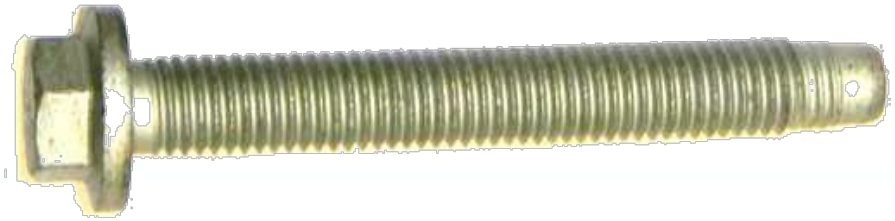
- **Mechanical properties (full size test)**

  - **Rm = 1500 MPa (equivalent to former 14.9 grade).**
  - **Elongation full size $Af_{1,2D}$ > 13% or test samples A5d > 8% (current specification for 12.9 grade).**
  - **Fatigue resistance: amplitude > 50MPa at 3.10^6 cycles under high preload.**
  - **Hydrogen embrittlement: Susceptibility to hydrogen brittle fracture at 1500 MPa not higher than 37Cr4 at 1250 MPa**

Transformation process

- Steel elaboration : continuous casting and hot rolling.
- Wire preparation : annealing, surface treatment, drawing.
- Cold heading, thread rolling, quenching and tempering (> 400°C)
- Surface treatments with low hydrogen input.

Target applications



- **Power train M6-M10 screws:**
  conrod,
  crankshaft bearing,
  cylinder head,
  fly wheel,
  differential ring gear

- **Suspension, transmission :**
  M10-M14 screws.

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Results : working 38CrMoNiB5-3 steel grade

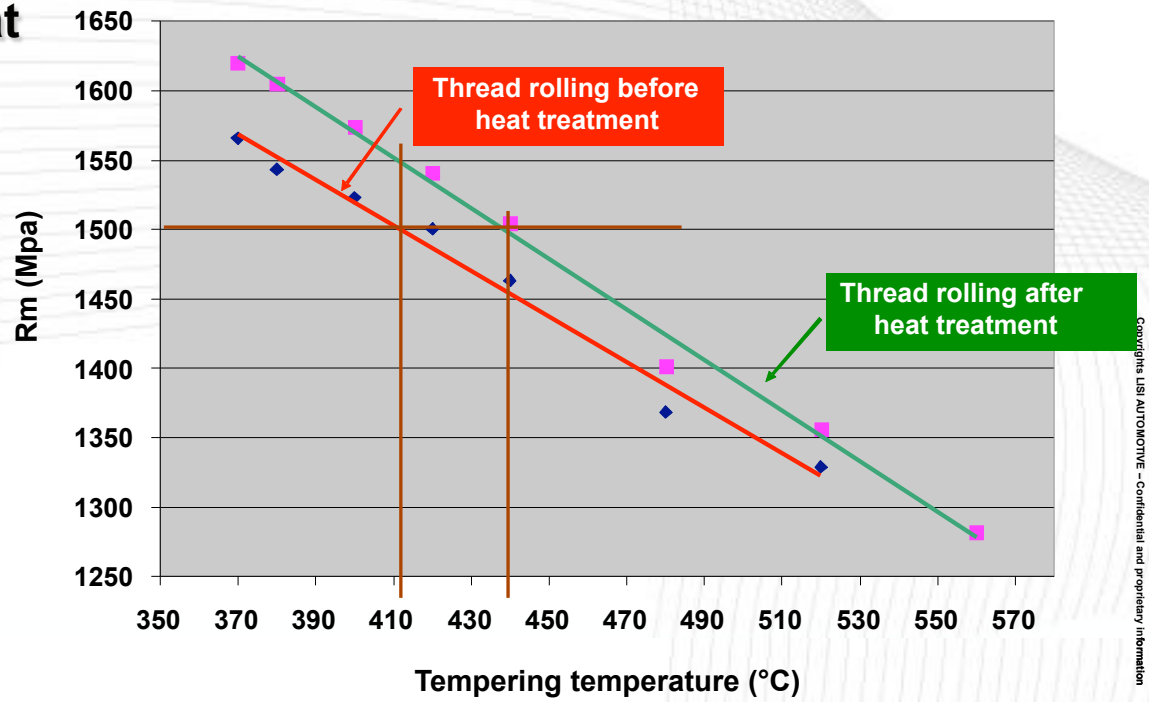
- **Cold forging ability**
  - ➔ **38CrMoNiB5-3 has the same forging ability as 37Cr4**
  - ➔ **Both steels have identical mechanical properties after annealing**

	Rm (MPa)		Z%	
	As rolled	Annealed drawn	As rolled	Annealed drawn
37Cr4	690	550	55	70
38CrMoNiB5-3	1 210	**580**	38	**72**

Results : working 38CrMoNiB5-3 steel grade

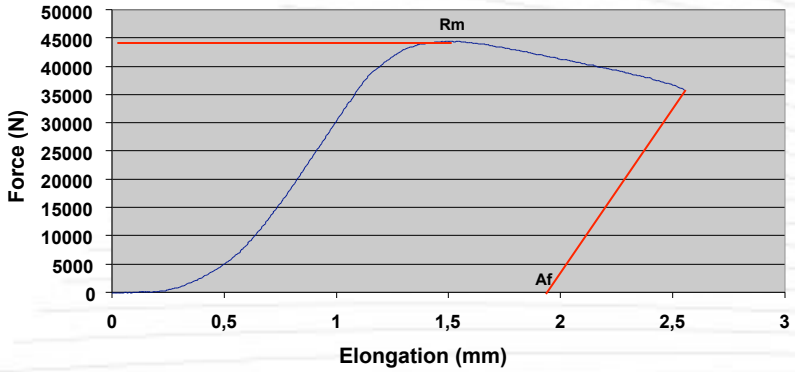
Heat treatment response

- Reference ISO 898-1 : tempering 12.9 grade T°> 380°C
- The new grade achieves 1500 MPa after oil quenching and tempering at T°>400°C

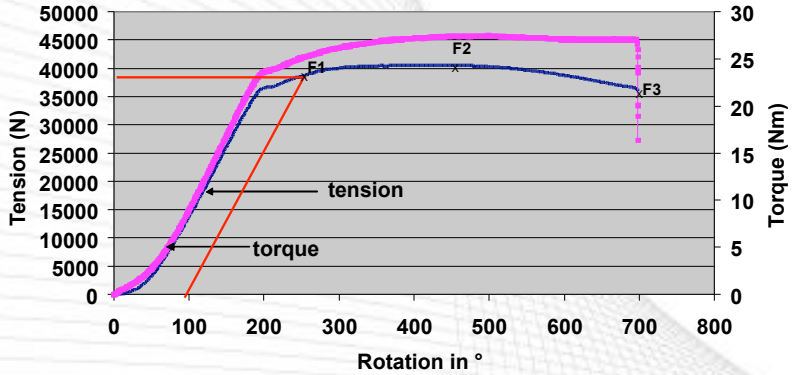


Characterisation of M7*100 conrod screw

Full size tensile test : 38CrMoNiB5-3
Thread rolled before heat treatment



Tightening test : 38CrMoNiB5-3
Thread rolled before heat treatment



		37Cr4 (sérial parts)	38CrMoNiB5-3	
			Rolling before HT	Rolling after HT
Tensile test	Rp 0,2 (MPa)	1 170	1 452	1 469
	Rm (MPa)	1 310	1 538	1 527
	Af%	19	19	15
Tightening	F1 (N)	33 370	39 140	39 800
	F2 (N)	34 340	40 590	40 590
	θ_3-θ_1 (°)	314	306	320

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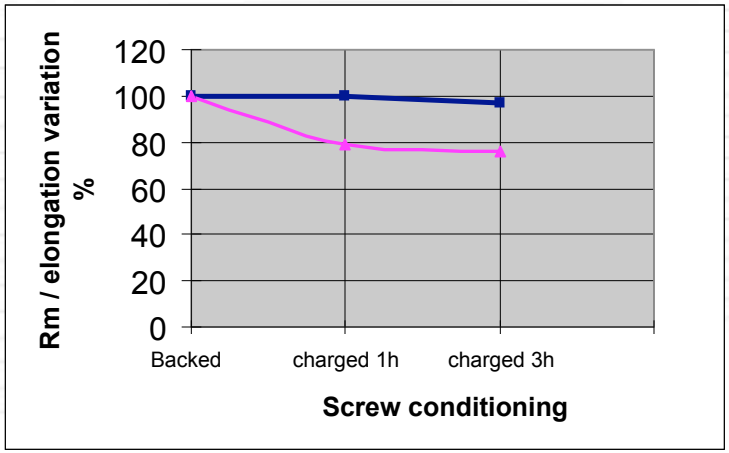
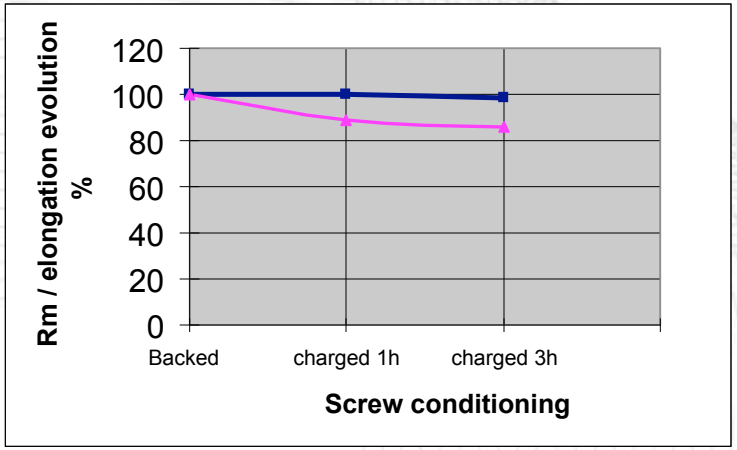
Susceptibility to hydrogen brittle fracture

- **Test have been carried at 3 hydrogen levels :**
  - **After backing : forecasted serial process.**
  - **Hydrogen charged : 1h in sulphuric environment, representative of industrial process before backing**
  - **Hydrogen charged : 3h in sulphuric environment.**

- **Slow tensile test results ($10^{-4}s^{-1}$) :**



37Cr4 / Rm = 1260MPa



38CrMoNiB5-3 / Rm =1500MPa

With higher mechanical resistance, the new grade offers a lower susceptibilyty to hydrogen brittle fracture than serial 37Cr4 steel grade

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Fatigue behaviour

- M7*100 conrod screws tested in alterned traction

	Average load	Thread rolling / heat treatment	Thread geometry	Endurance limit at 1M cycles
Serial parts : 37Cr4 Rm = 1300MPa	31 000 N	After HT	ISO M	1650 N
		After HT	ISO MJ	2300 N
New steel : 38CrMoNiB5-3 Rm = 1500MPa	36 000 N	After HT	ISO MJ	2300 N
		Before HT	ISO MJ	2400 N

- **Fatigue behaviour:**
  - ➔ **Similar between high strength steel and 37Cr4.**
  - ➔ **Similar between parts rolled after or before heat treatment.**

- **Endurance limit of M7 screw made from 38CrMoNiB5-3 steel grade:**
  - ➔ **2300 N, that means 80 MPa at 10^6 cycles.**

- **ISO MJ thread improves endurance limit drastically:**
  - ➔ **Thanks to an increase of thread bottom radius : ISO M = 0,11 / ISO MJ = 0,17**

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Conrod screws application

Conrod screw characteristics:

- ***M7 * 100***
- ***Length: 36 mm***
- ***Weight: 13 g***
- ***Rm: 1500Mpa***

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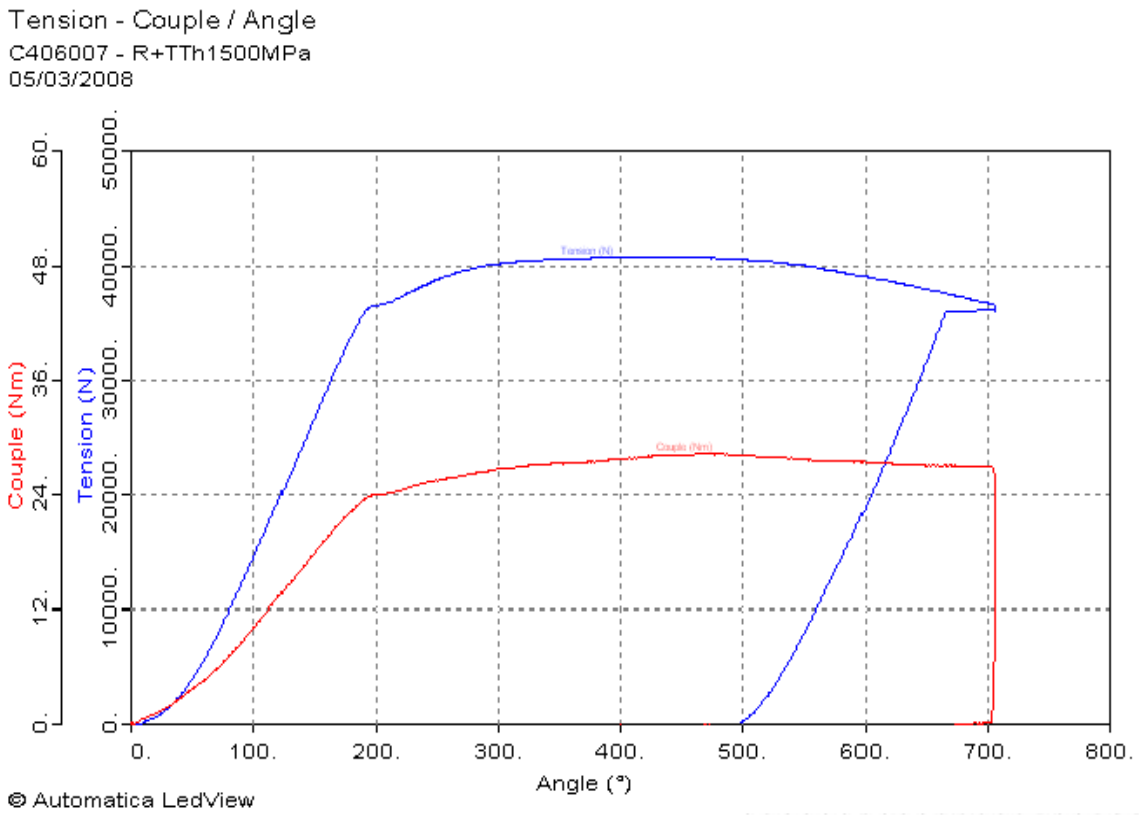
Tightening test graph:



Head cylinder screws application

Head cylinder screw characteristics:

- ***M12 * 150***
- ***Length: 134 mm***
- ***Weight: 126 g***
- ***Rm: 1500Mpa***

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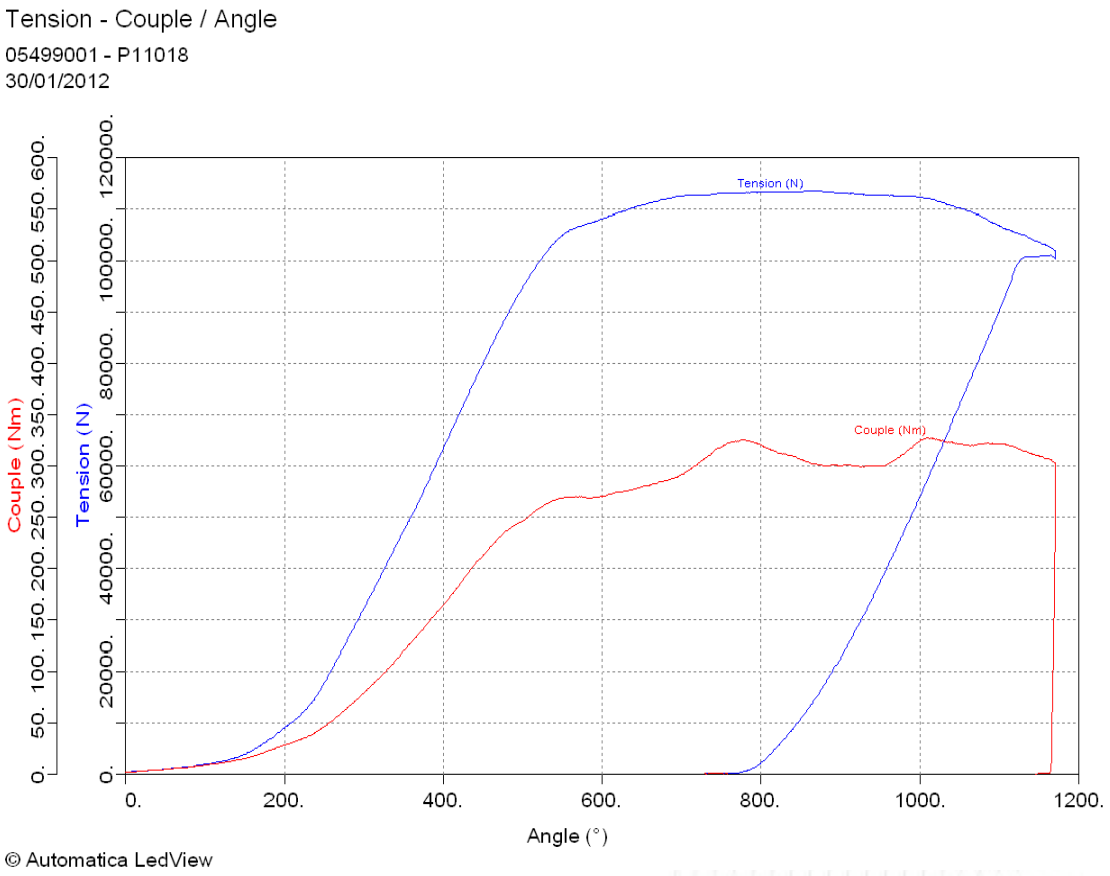
Tightening test tension graph:

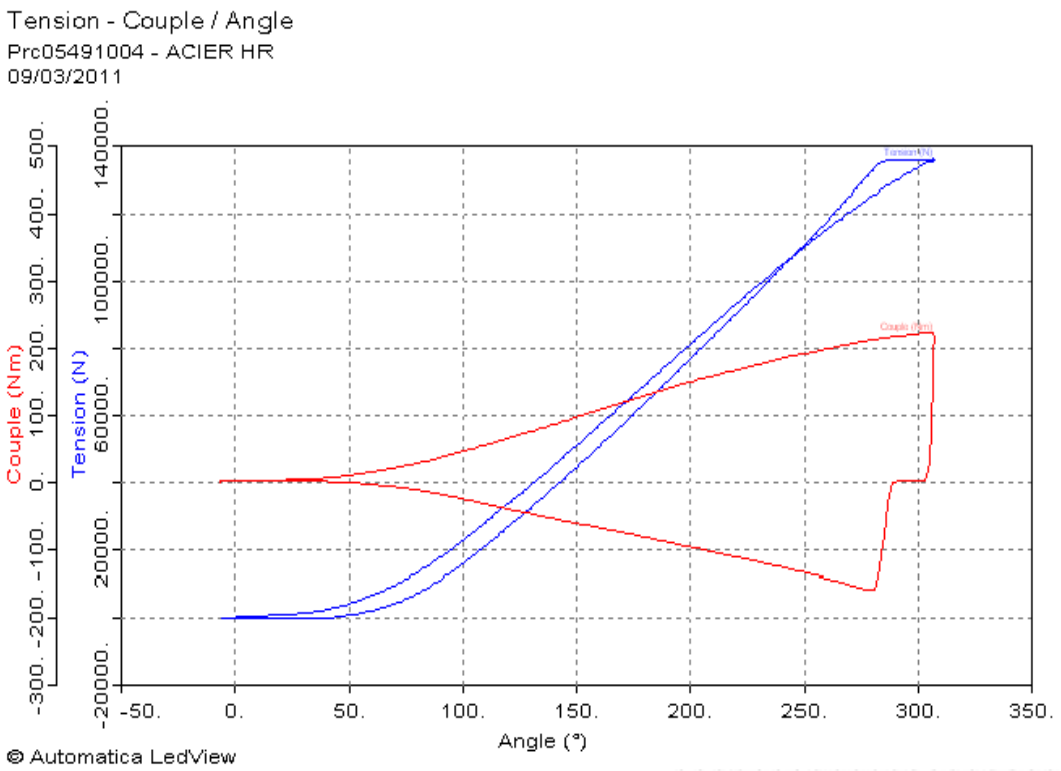


Chassis screws application

Characteristics:

- ***M12 * 150 / M12 * 125 / M14 * 175 / etc***
- ***Rm: 1300Mpa or 1500MPa***

Torque / Tension graph:



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Key success for global downsizing

- **Aim of a project should be weight reduction of all parts**
  - ➔ **Less place for install the bolts and other fastening items**
  - ➔ **More complicate design of the fasteners**
- **High strength steel gives you an opportunity for install smaller dimensions with same resistance**
  - ➔ **Coldforming ability of steel is a important factor**
  - ➔ **Mastering of tightening strategy**
- **Involving fasteners design in the early steps of the project.**

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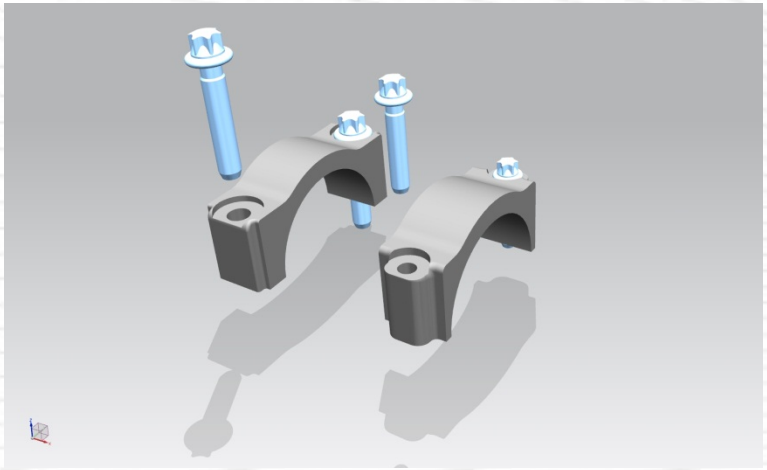
Advantages

- **The weight savings noticed on screws are multiplied by 5 to 10 taking their environment into account.**



- **Main advantage : The reduction of screw diameter allows downsizing of assembled parts, for example :**
  - ➔ **M6 or M7 conrod screws : reduction of con-rod weight**
  - ➔ **M8 crankshaft bearing screws : reduction of engine length**
  - ➔ **Suspension arm axle : reduction of linking rod dimensions**

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Summary

38CrMoNiB5-3

- High strength steel (1500 MPa) with good coldforming ability
- Heat treatment possibility acc. Iso 898-1
- Increased fatigue life
- Very good resistance against hydrogen embrittlement

- Weight reduction due to downsizing can be reached with the customer working together on the application

- We have to be embedded in the project in a very early stage

Thank you for your attention!