

Engine Downsizing – Trends and Optimization Technologies



A CASE STUDY ON STANDARDIZATION AND DOWNSIZING VARIANTS OF FASTENERS IN CONTEMPORARY DIESEL ENGINES

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OVERVIEW

- INTRODUCTION OF FASTENERS
- CASE STUDY – BACKGROUND
- CHALLENGES TO OVERCOME
- OBJECTIVES OF FASTENERS STUDY
- CASE STUDY – OVER VIEW
 - STANDARDIZATION & DOWNSIZING
- RESULTS ACHEIVED

INTRODUCTION OF FASTENERS

What

- Fastener system is used to transfer load. Fasteners are the parts used to join 2 or more parts

Where

- Permanent/semi permanent(vehicle chassis)
- Temporary (Engine).

When

- Disassembly for inspection & repair
- Modular design, where a product consists of a no. of subassemblies

Why

- To ease of assembling & disassembling of the entire system

INTRODUCTION OF FASTENERS

(Contd.)

- Fasteners are using from 1812.
- The invention of the screw thread is attributed to Archimedes in the 3rd century BC.
- Sir Joseph Whitworth, the British mechanical engineer, was well known for his work on engineering standards.
- In 1841 he proposed the introduction of standard fastener sizes to the Institution of Civil Engineers.
- These comprised a universal set of specifications for the angle and pitch of screw threads.
- The Whitworth thread became the first standard thread system in the world.

INTRODUCTION OF FASTENERS

(Contd.)

- Normal Population of fasteners in contemporary diesel engines (Range 1.5L to 3.0L) are 40~45% of total no. of parts
 - “The Boeing 747” uses about 2.5 million fasteners
- 50% of production time is spent on assembly/fastening.
- Fasteners are critical to product performance and reliability
- Selection of proper fastener is an important part of product design

INTRODUCTION OF FASTENERS

(Contd.)

No. of variety

Discrete Fasteners
(separate connector from the part)

THREADED

screws
nuts & bolts
studs
hooks
spring toggle
bolts
turnbuckles

NON-THREADED

nails, tacks
retaining rings
rivets
keys
pins
clips, staples
snaps

Integrated Fasteners
(molded into the part)

LOCATORS

stop
lug
pin in hole
wedge in slot

LOCKS

cantilever hook
trap
snaps
ball & socket

COMPLIANT

cantilever spring
crush rib feature

Bonding

energy bonding
welding
brazing
solvent bonding

Other

Velcro
crimping
seaming



Lug



Cantilever Hook



Wedge-in-Slot



Trap



Annular Trap



Pin-in-hole

Selecting the right type of fasteners for the right application can enhance the environment attributes of a product

CASE STUDY – BACKGROUND

- As major/minor system components responsible for function/reliability, fasteners are often neglected since start of design
- More so critical fasteners are called because of this negligence
- But they play vital role as major dynamic components in place.
- A need of attention will save a lot in product development

CASE STUDY – BACKGROUND

(Contd.)

- Localization of fasteners against imported fasteners used in our current engines, so that target cost can be met.

➡ **LOCALISATION**

- To downsize number of varieties and standardize the fasteners with current Indian products.

➡ **STANDARDISATION**

- To optimize the tools required for assembling and disassembling of the parts (Ex: M6, M8, M10 & M12 Bolts & nuts are used) So that assembling & disassembling can be possible with only 4 spanners.

➡ **OPTIMIZATION**

- To optimize the time required for assembling & disassembling of entire engine.

➡ **COST REDUCTION**

CHALLENGES TO OVERCOME

While Benchmarking...

- **Technical Challenge**

Difference in physical & chemical properties of local (Indian) product against parts equivalent in elsewhere.

Stringent standards followed by foreign counter part other than international standards (IS,etc..)

- **Cost**

No cost advantage in short term perspective.

Risk to cost factor is very high.

- **Time**

Product validation & verification test will take more time.

TECHNICAL CHALLENGE

Chemical property of fasteners

- Differences in Chemical properties of raw material

Japanese Material

MATERIAL SPEC	C	Mn	Si	Cr	Ni	S	P	B
MnB123H	0.2 - 0.26	0.7 - 1.0	0.15 - 0.35	0.07 - 0.3	0.25 max	0.03 max	0.03 max	0.001 - 0.003

Indian Material

MATERIAL SPEC	C	Mn	Si	Cr	Ni	S	P	B
19 MnB4	0.2 - 0.25	0.8 - 1.1	0.15 - 0.3	0.3 - 0.4	0.2 max	0.03 max	0.03 max	0.0008 - 0.003

Raw material procurement constraints in home country.
But no impact on life of the fasteners.

TECHNICAL CHALLENGE

(Contd.)

Mechanical properties of fasteners

Specifications for mechanical properties of fasteners are different from Indian specifications.

For example:

specification (JIS)	Indian specification (SAE / DIN / IS)
7T	8.8
9T	9.8
10T	10.9
12T	12.9

Even if there are some differences in Hardness(2 HRC but mean remains same) & Tensile strength in Raw material, the final product will satisfy all the specifications and recommendation specified in JIS standard

CHALLENGE ON COST

- The cost is higher than local cost in long run.
- Inflation of exchange rate (USD to INR, INR to RMB, INR to EURO, INR to YEN)
- Higher inventory cost.
- Not suitable for smaller batch (Proto samples) quantities. Freight charges is not economical.
- Import duties.
- Inflation of logistics cost.

FAILURES OF FASTENERS

- Subject to static loading (overload) or dynamic fatigue loading
- Static loading may be tension, shear, bending or torsion - either singly or in combination
- Dynamic forces may result from impact or from cyclic fatigue loading, including vibration
- In addition to fatigue and overload, other common causes of fastener failures include environmental effects, manufacturing discrepancies and improper use or incorrect installation.

FAILURES OF FASTENERS

(Contd.)

- Fastener failure during assembly operation.
- Dimpled fracture features indicated head cracks caused by overload.
- Chemical analyses, hardness tests, and micro structural examination of the fastener should be within specification.
- Over torque of the fasteners cause nut-thread stripping.

FAILURE MODES

Fretting

- Very small movement of one highly loaded surface over another
- Fretting can be prevented by minimizing clearance in bolt holes & using high-strength fasteners properly tensioned – prevent relative motion of contacting surfaces

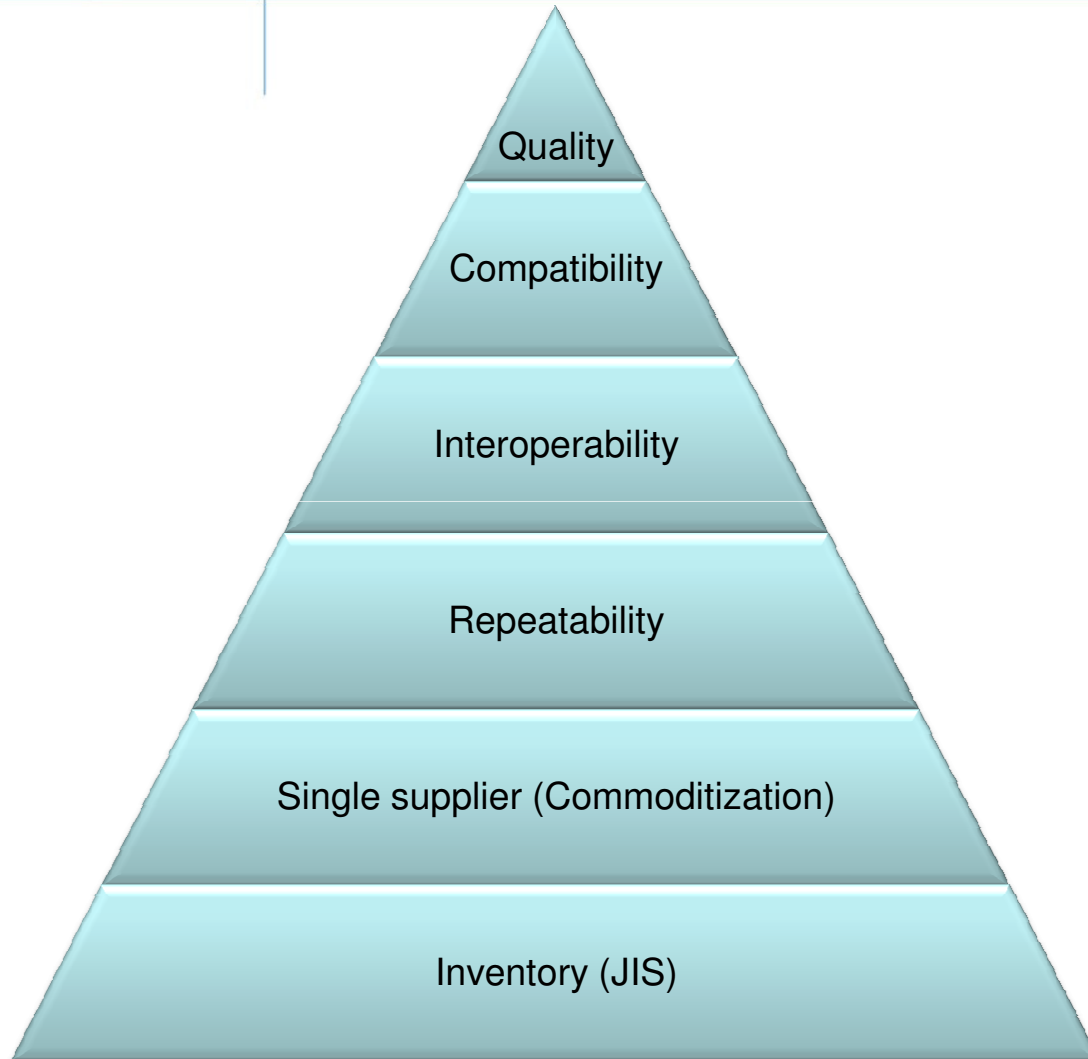
Stress - Corrosion Cracking

- Inter-granular fracture mechanism - highly stressed fasteners after a period of time
- caused by corrosive environment with a sustained tensile stress above threshold value
- Adverse grain orientation increases susceptibility to stress corrosion

Hydrogen Embrittlement

- This occurs whenever there is free hydrogen in close association with metal
- This free hydrogen will form due to the electrolytic bath plating process
- This type of challenge is exclusive for high strength materials
- There are 3 types hydrogen – metal problems
 - Hydrogen chemical reaction
 - Internal hydrogen embrittlement
 - Hydrogen environment embrittlement

OBJECTIVES OF FASTENERS STUDY



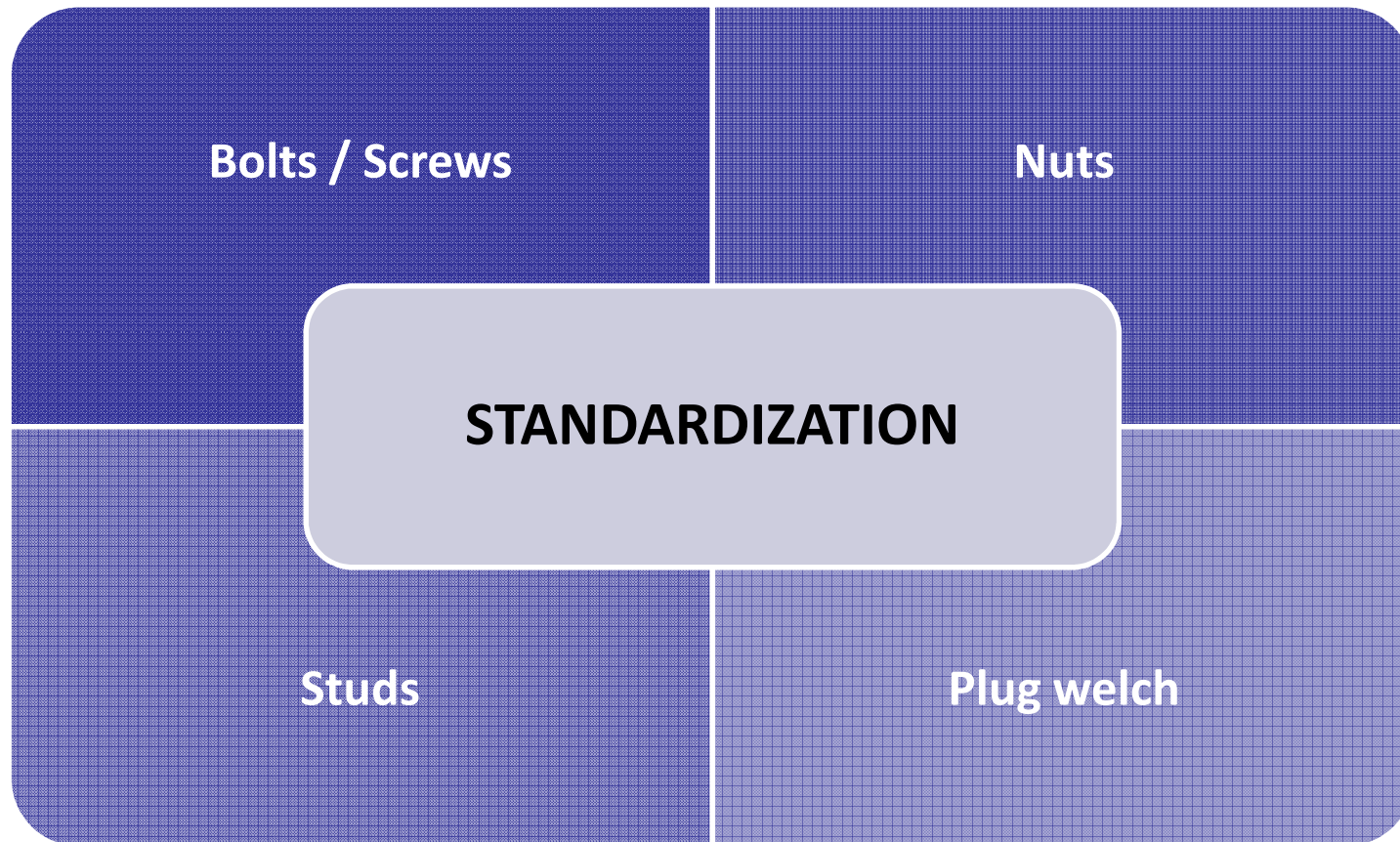
CASE STUDY GOALS

BENEFITS

1. No need to develop new part.
2. Uniqueness in description.
3. Eliminates delay in New projects.
4. Duplication of new part no can be eliminated
5. Eliminates wastage of man power.
6. Repetition of Strategic Sourcing process is not required.
7. Less storage space.
8. Volume consolidation.
9. Low inventory
10. New tool development not required at supplier end.

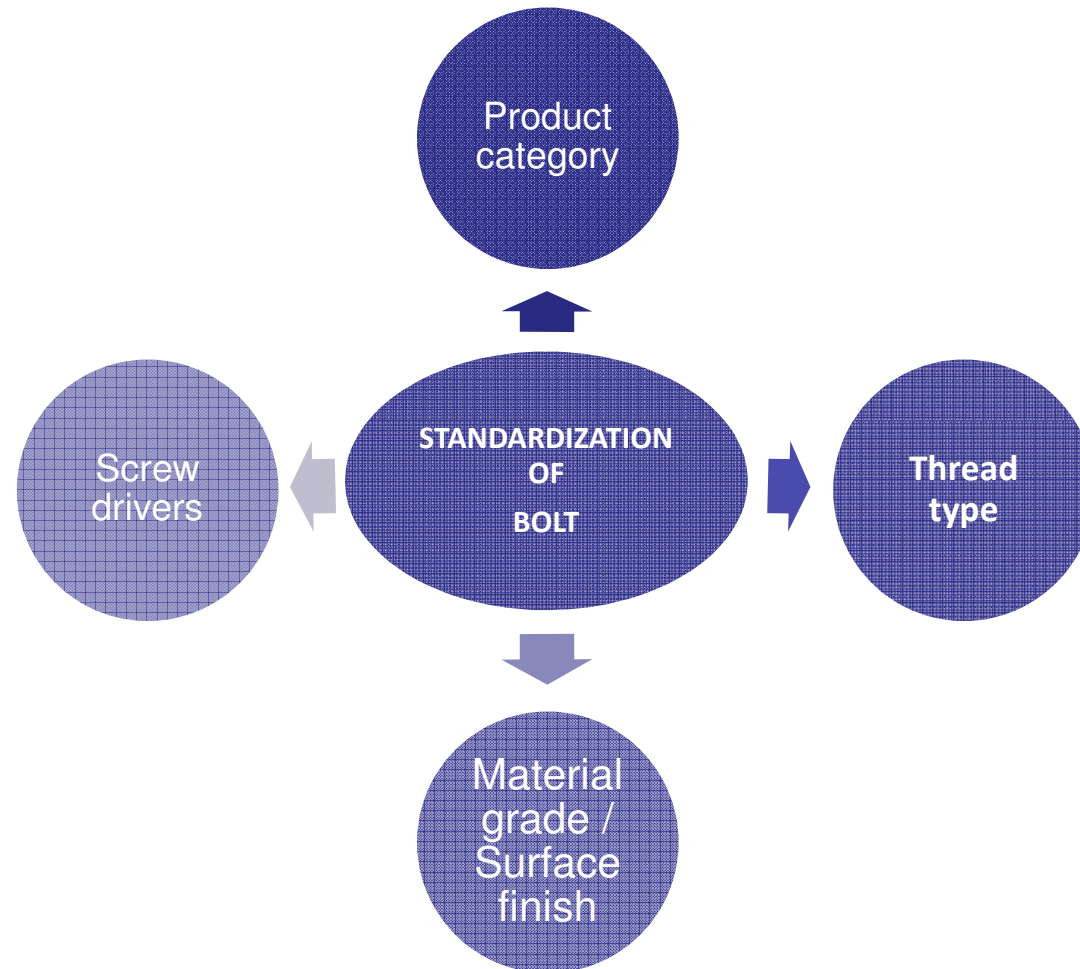
CASE STUDY – OVER VIEW

STANDARDIZING & DOWNSIZING OF FASTENERS SYSTEM



CASE STUDY – OVER VIEW

(Contd.)



CASE STUDY – OVER VIEW

(Contd.)

Product category

- Product segregated based on Engine models (Possibility of commonization between 2.5 L & 3.0 L engine)

Thread type

- Bolts are preferred only based on ISO thread profile, BSW, UNS, UNC thread types calls for additional investment

Material grade / Surface finish

- Check the technical compatibility between the tensile strength nomenclatures like grades like 7T, 9T, 8.8, 9.8 etc (Refer Slide : 13)
- Check the possibility of commonizing the Surface passivation

Screw drivers

- Number of socket change ideally should be less in any assy.
- More variety of screw drive requires frequent socket change (Refer slide no:23)

CASE STUDY – OVER VIEW

(Contd.)

STANDARDISATION-OPTIMIZATION-COST REDUCTION

- Diversity
 - 3 basic types ~ Bolt, Nut and Screw
 - 5 Types of thread standards in use presently
 - Type ~ Flanged and Non-flanged
 - 6 Types bolt head
 - 2 Pitches ~ Coarse and Fine
 - 19 *Inch* sizes
 - 17 *Metric* sizes
 - Length from 2mm to 150mm
- Total $3 \times 5 \times 2 \times 6 \times 2 \times 2 \times 18 \times 33 = 2,47,680$ combinations possible!!

CASE STUDY – OVER VIEW

(Contd.)

STANDARDISATION

- In order to standardize the M12 bolts instead M14 bolts the following are the factor to be considered

❖ Bolt clamping force

❖ Hydrogen embrittlement

SPECIFICATION	M12	M14
STRENGTH CLASS	**	10.9
	12.9	**

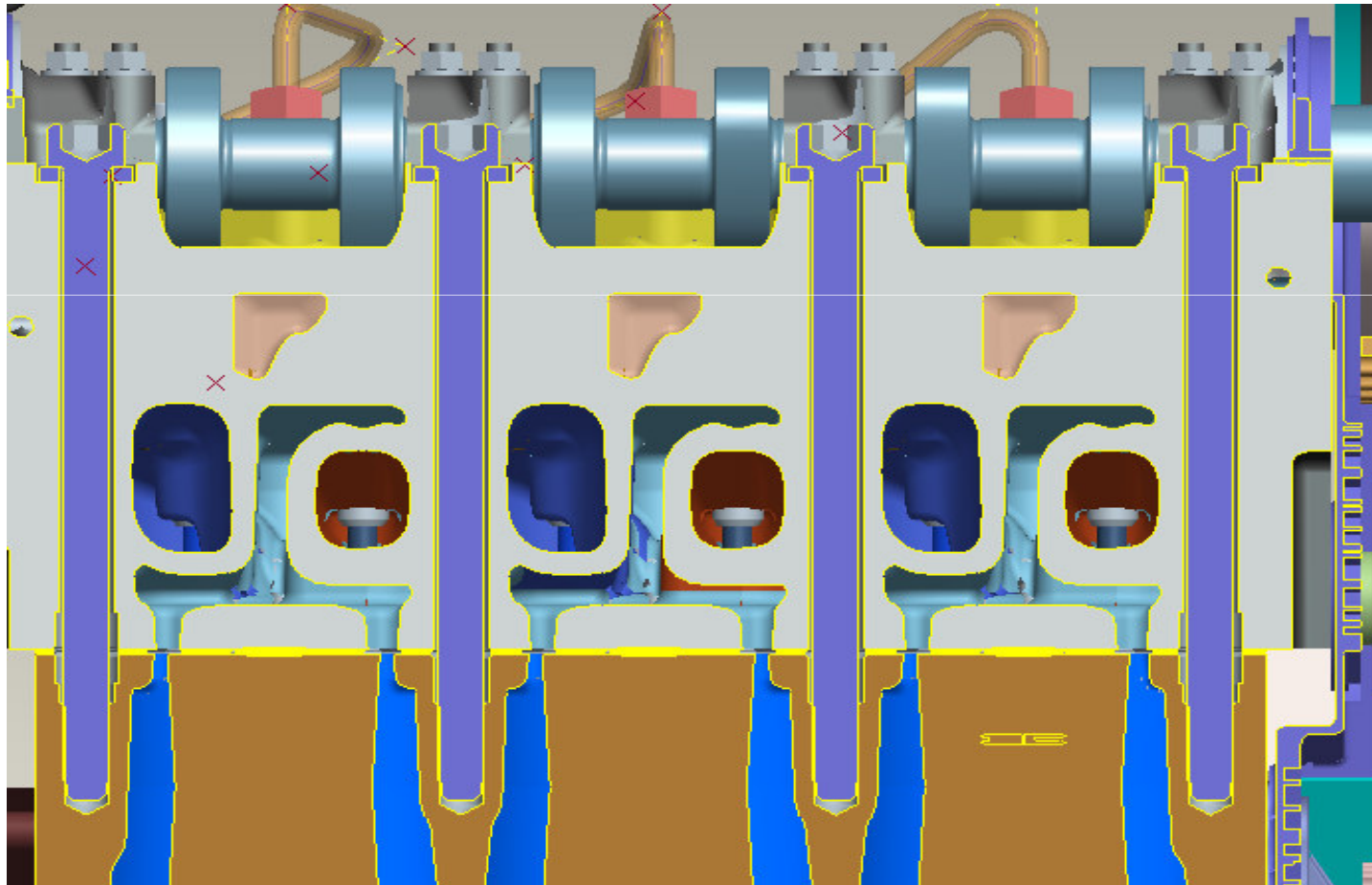
The chances of Hydrogen embrittlement is high on 12.9 strength class than 10.9. In order to avoid that failure mode special surface passivations (Phosphated or chrompassivated) are incorporated and the bolts are standardized to M12 type

CASE STUDY – OVER VIEW

(Contd.)

STANDARDISATION

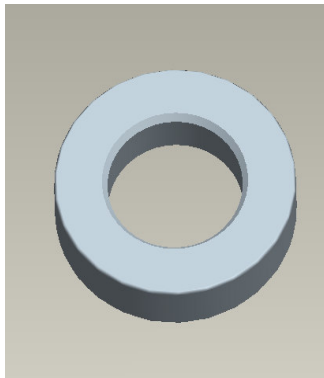
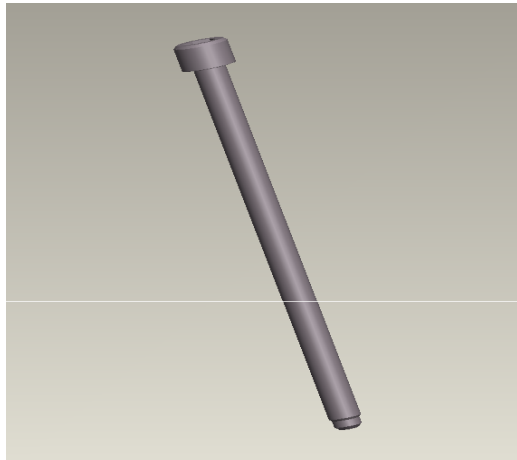
ORIGINAL DESIGN
CYL HEAD BOLT - SOCKET HEAD BOLT
WITH WASHER



CASE STUDY – OVER VIEW

(Contd.)

**ORIGINAL DESIGN
CYL HEAD BOLT & WAHSER**



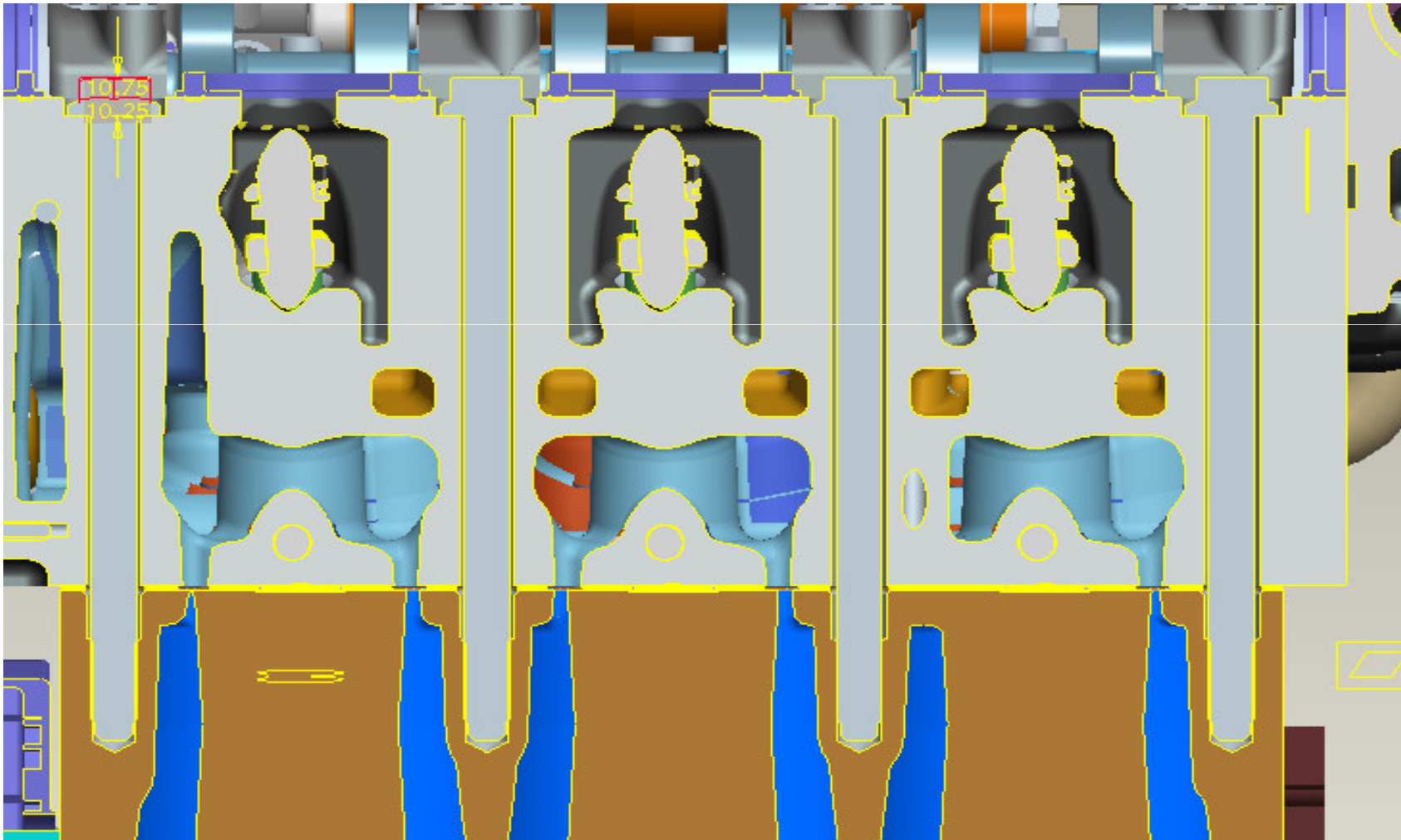
**NEW DESIGN
CYL HEAD BOLT**



CASE STUDY – OVER VIEW

(Contd.)

NEW DESIGN PROPOSAL CYL HEAD BOLT – HEXAGON FLANGE BOLT



CASE STUDY – OVER VIEW

(Contd.)

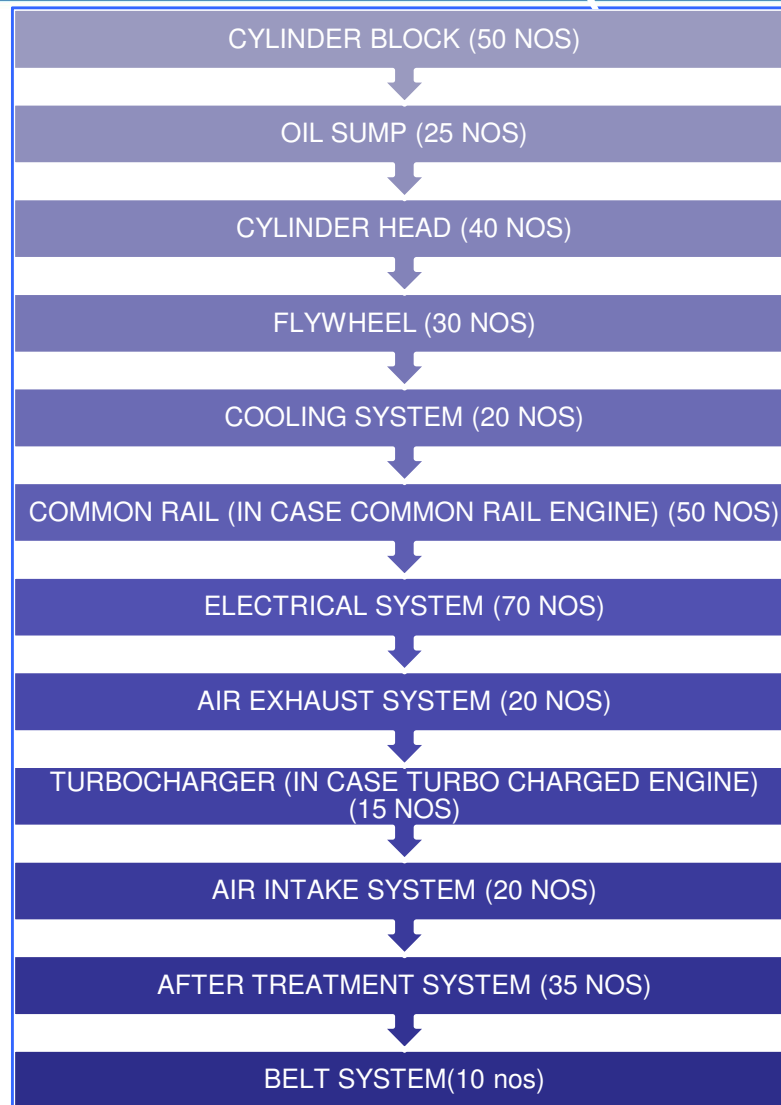
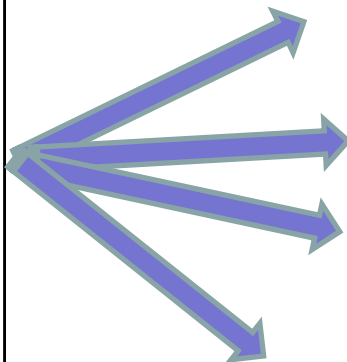
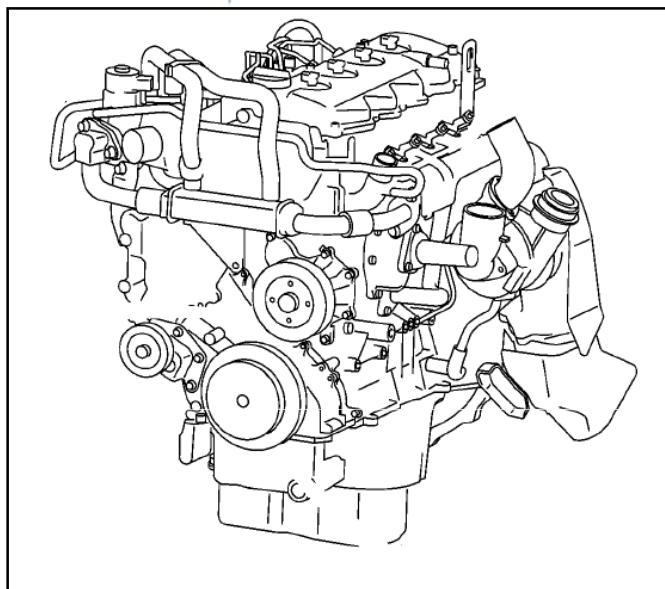
RESULTS ACHIEVED BY USING HEX FLANGE BOLT OVER SOCKET HEAD BOLT

- These type of head configuration is followed in all Indian automobile OEMs and also others.
(i.e. Ashok Leyland, TATA, CUMMINS, MARUTI, MAN, GM – USA, MACK TRUCK – USA)
- Reliability is more in Hex flange bolt compared to socket head bolt, and hence the field failure is less comparatively.
- Washer is not required in Hex flange bolt design.
- Manufacturing process is simpler for Hex flange bolt.
- Process cost is cheaper than socket bolt.

CASE STUDY – OVER VIEW

(Contd.)

Tool optimization



- If the sequence of engine assy, will be done thru' M6, M8 , M10 and M12 Fasteners, the tool handling time during assembling & disassembling the engine will be optimized.

CASE STUDY – OVER VIEW

(Contd.)

Tool optimization

Location on engine	Thread size	Type	Internal soc	External soc	A/F
Engine block/head /sump	1/8"	Plug		Yes	5 mm
	1/16"	Plug		Yes	4 mm
	M24	Plug		Yes	13.5 mm
Engine block	M8	Bi Hex	Yes		10 mm
Block to sump	M10	Hex Flange	Yes		16 mm
Cyl. head/sump/ Flywheel	M16	Hex Flange	Yes		21 mm
	M12	Hex Flange	Yes		15 mm
	M12	Hex Flange	Yes		16 mm
	M12	Hex Flange	Yes		16 mm
	M8	Bi Hex	Yes		10 mm
	M12	Hex Flange	Yes		16 mm
	M10	Hex Flange	Yes		15 mm
Flywheel	M6	Soc Head		Yes	5 mm
Flywheel\Block	M6	Stud	Yes		10 mm
Flywheel \ clutch	M8	Stud	Yes		13 mm
Cooling system\Exhaust system	M8	Stud	yes		13 mm
	M8	Stud	Yes		13 mm
	M8	Stud	Yes		13 mm
	M8	Stud	Yes		13 mm
	M8	Soc Head		Yes	6 mm

CASE STUDY – OVER VIEW

(Contd.)

Tool optimization

Location on engine	Thread size	Type	Internal soc	External soc	A/F	
Common rail\Electrical\ Exhaust \ Turbocharger	M8	Hex head	Yes		13 mm	
	M8	Hex head	Yes		13 mm	
	M8	Hex head	Yes		13 mm	
	M8	Hex head	Yes		13 mm	
	M8	Hex head	Yes		13 mm	
	M8	Hex head	Yes		13 mm	
	M10	Hex head	Yes		16 mm	
	M8	Soc Head			Yes	6 mm
	M10	Soc Head			Yes	8 mm
	M14	Soc Head			Yes	12 mm
	M4	Hex head	Yes			7 mm
	M6	Hex head	Yes			10 mm
	M6	Hex head	Yes			10 mm
	M6	Hex head	Yes			10 mm
	M6	Hex head	Yes			10 mm
	M6	Hex head	Yes			10 mm
	M8	Hex head	Yes			13 mm
	M8	Hex head	Yes			13 mm
	M8	Hex head	Yes			13 mm
	M8	Hex head	Yes			13 mm

CASE STUDY – OVER VIEW

(Contd.)

Tool optimization

Location on engine	Thread size	Type	Internal soc	External soc	A/F
Air Intake/After treatment devices	M10	Hex head	Yes		16 mm
	M10	Hex head	Yes		16 mm
	M6	Soc Head		Yes	5 mm
	M6	Soc Head		Yes	5 mm
	M8	Soc Head		Yes	6 mm
	M8	Soc Head		Yes	6 mm
	M8	Soc Head		Yes	6 mm
	M8	Soc Head		Yes	6 mm
	M8	Hex head	Yes		13 mm
	M8	Hex head	Yes		13 mm
	M10	Hex head	Yes		16 mm
	M10	Hex head	Yes		16 mm
	M6	Soc Head		Yes	5 mm
	M6	Soc Head		Yes	5 mm
	M8	Soc Head		Yes	6 mm
	M8	Soc Head		Yes	6 mm
	M8	Soc Head		Yes	6 mm
	M8	Hex head	Yes		13 mm
	M8	Hex head	Yes		13 mm

CASE STUDY – OVER VIEW

(Contd.)

COST REDUCTION

- BSF nuts being replaced by UNF/Metric nuts
 - Feasibility Analysis

Inch			Metric Equivalent		
Size	Dia. (mm)	Tensile Stress Area (mm ²)	Size	Dia. (mm)	Tensile Stress Area (mm ²)
1/4	6.35	23.03	M6	6.00	20.12
5/16	7.94	36.65	M8	8.00	36.61
3/8	9.53	54.19	M10	10.00	57.99
7/16	11.11	74.77	M12	12.00	84.27
1/2	12.70	98.06	M14	14.00	115.44

- Report from [*Aeronautical research council, UK*](#) confirms the technical feasibility of change

CASE STUDY – OVER VIEW

(Contd.)

Report Test Results

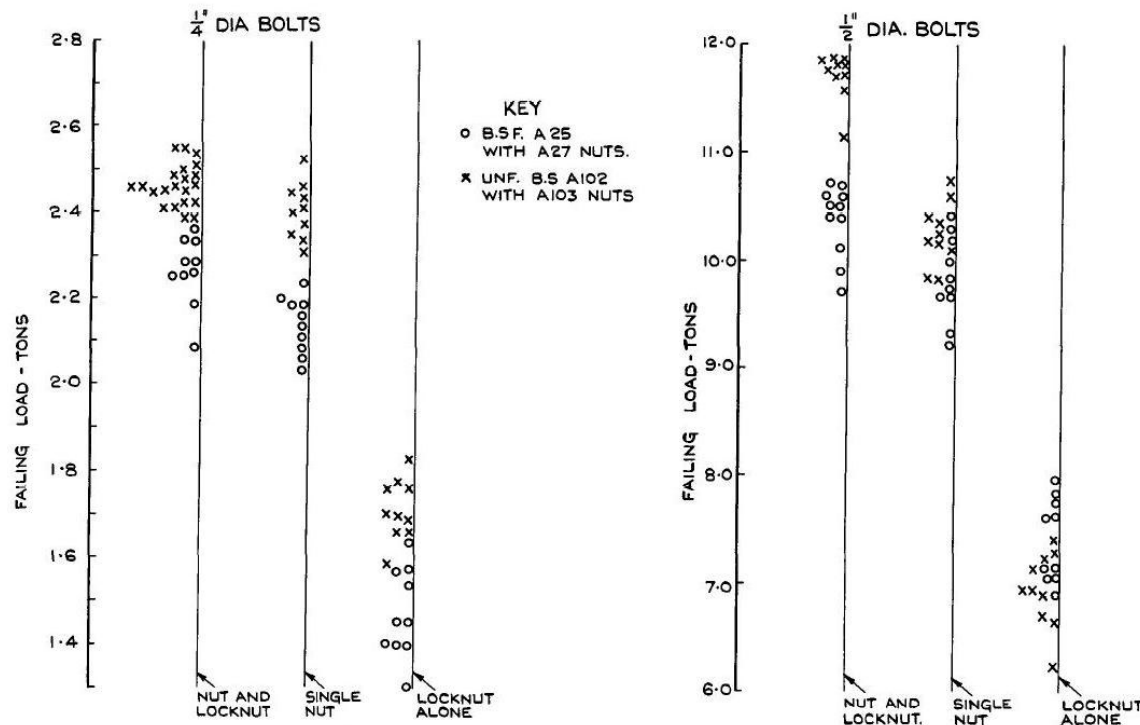


FIG. I. TENSION TEST RESULTS.

4 CONCLUSIONS

The bolt/nut combinations with Unified threads to the aircraft Specification A.102 are on the average not less strong in tension than the corresponding BSF bolts to aircraft Specification A.25, except for the $\frac{1}{2}$ " diameter bolt with single locknut, where the UNF bolts are slightly weaker than the BSF. It is to be noted that in general, with a single nut, failure occurred in the thread of the UNF bolts, but in the core of the BSF bolts.

CASE STUDY – OVER VIEW

(Contd.)

Milestones

Old Description	New Description	Units	Size	Savings
PL.NUT-1/4BSF	NUT-1/4BSF	inch	1/4	
PL.NUT-1/4UNF	NUT-1/4UNF	inch	1/4	
PL.NUT-M6X1	NUT-M6x1	mm	M6	11%
PL.NUT-5/16BSF	NUT-5/16BSF-	inch	5/16	
PL.NUT-5/16UNF	NUT-5/16UNF-	inch	5/16	
PL.NUT-M8X1.25	NUT-M8x1.25-	mm	M8	9%
PL.NUT-3/8BSF	NUT-3/8BSF-	inch	3/8	
PL.NUT-3/8UNF	NUT-3/8UNF-	inch	3/8	
PL.NUT-M10X1.5	NUT-M10x1.5-	mm	M10	19%

Proposed Replacement Part

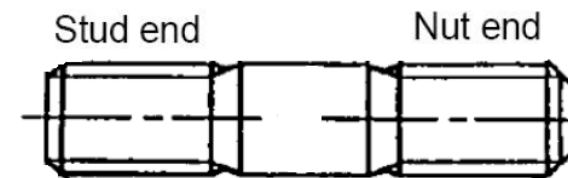
CASE STUDY – OVER VIEW

(Contd.)
STUDS

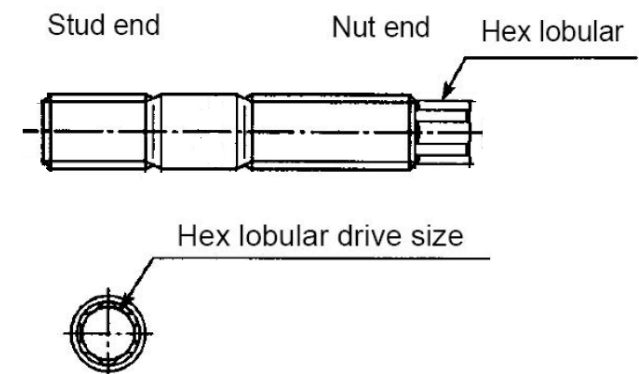
COST REDUCTION

- ❖ Standardization of ordinary studs with hexa lobular studs
- ❖ Since the manufacturing cost for hexa lobular studs are 5% costlier than ordinary type, the assembling and disassembling time for hexa lobular type is 12% lower.
- ✓ **Cost impact of the assembling and disassembling time & tools requirement will lead 7% cost reduction in hexa lobular type than ordinary stud type.**

Ordinary type



Hexa lobular type



CASE STUDY – OVER VIEW

(Contd.)

STANDARDISATION-COST REDUCTION

PLUG WELCH

- ❖ Plug welchs are one of the permanent type fasteners used in engine block, head and sump mostly.
- ❖ The interference between the holes on the mating parts with Plug Welch plays a critical role.
- ❖ The factors affecting the interference is as follows
 - Pressure of water /air used on leak test
 - Vibration of the engine
 - Pull out load for interference
- ✓ In order to standardize the Plug Welch across the model the following interference calculation is considered as the first step.

CASE STUDY – OVER VIEW

(Contd.)

STANDARDISATION-COST REDUCTION

PLUG WELCH

STANDARDISATION OF KD ENGINE WELCH PLUGS WITH ASHOKLEYLAND CURRENT ENGINE									
S.NO	INTERFERENCE AS PER KD ENGINE			INTERFERENCE AS PER ASHOKLEYLAND ENGINE			DIFFERENCE		
	MAX	MIN	NOM	MAX	MIN	NOM	MAX	MIN	NOM
1	0.21	0.06	0.13	0.15	0.04	0.10	0.06	0.02	0.04
2	0.27	0.10	0.18	0.20	0.07	0.14	0.07	0.03	0.05
3	0.27	0.10	0.18	0.24	0.07	0.16	0.03	0.03	0.03
4	0.29	0.12	0.20	0.22	0.09	0.15	0.07	0.03	0.05
5	0.35	0.13	0.24	0.31	0.09	0.15	0.04	0.04	0.04
6	0.35	0.13	0.24	0.30	0.10	0.20	0.05	0.03	0.04
7	0.38	0.16	0.27	0.32	0.09	0.15	0.06	0.07	0.07
8	0.38	0.16	0.27	0.35	0.15	0.25	0.03	0.01	0.02
9	0.47	0.22	0.34	0.40	0.20	0.30	0.07	0.02	0.04
10	0.47	0.30	0.39	0.37	0.26	0.32	0.10	0.04	0.07

Even though the variation on interference is 10 ~ 100 microns, considering other constraints like process change for manufacturing, components identification the factors affecting the interference Pressure of water /air used on leak test ,Vibration of the engine, Pull out load for interference are evaluated and standardize it across the engine model.

RESULTS ACHEIVED

The results achieved on this case study is given below

S.NO	DESCRIPTION	RESULTS ACHEIVED
1	STANDARDIZATION	96 VARITIES TO 26 VARIETES
2	TOOL OPTIMIZATION	20% TIME SAVED DUE TO TOOL HANDLING 4 SPANNERS CAN ABLE TO ASSEMBLE & DISASSEMBLE ENTIRE ENGINE
3	COST REDUCTION	7% TOTAL ENGINE COST SAVED

