The Use of Serrated Core Metallic Gaskets on Air Coolers

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ABSTRACT

The use of solid metal gaskets to seal air cooler inspection tubes has resulted in problems with relation to sealability and damage to header faces. This paper discusses the use of a different style of gasket and details the advantages and benefits resulting from such a change. The discussion includes an analysis, supported by laboratory testing and successful field experiences, using three-dimensional mathematical techniques

INTRODUCTION

Air Coolers or Fin Fans are used extensively within refining as a method of cooling fluids in a vapour form. The exchangers traditionally have fluid travelling through horizontal tubes with a draught forced by the action of a belt driven fan below. The tubes are finned to provide a greater surface area and at either end the tubes are attached to headers. One header is fixed and one header floats. Visual inspection of the horizontal tube is carried out by the removal of a metallic plug at either end of the tube. The metallic plug uses a sealing washer to deform and make a seal.

Mild steel washers have been traditionally used to effect a seal for fin-fan studs on heat exchangers. Several problems are experienced with these washers resulting in leaks. The majority of problems are related to the fact that high bolt loads and smooth surface finishes are required to create a seal. High loads damage and stretch the threads of both the stud and housing, thereby making it more difficult to achieve the required loads on re-use. This results in a labour intensive process of bolt re-tensioning during operation, bolt-hole face re-machining and stud replacement.

To overcome these problems the use of a serrated core gasket, often called a kammprofile, specially machined to suit studs on fin-fan applications was proposed. The particular gasket proposed was a variant of the type known as a “ PN ” kammprofile consisting of a serrated metal core faced with a conformable material, usually graphite**,** on either side. The kammprofile gasket has been used on sealing faces for many years. The initial German DIN Standard, DIN 2697, detailed a profile for the serration. The dimensions and form of the serration have been modified over time and now include shallow and convex profiles.

A graphite faced kammprofile seals at much lower gasket stresses (5000psi / 34.5MPa for fin-fan kammprofiles) than the previously used mild steel washers (18,000psi /

124MPa). This means that lower bolt-loads can be applied to a kammprofile arrangement to effect a seal. It has been found that about 25% of the load required by mild steel washers is sufficient with the modified kammprofile gasket. This reduced bolt-stress means that the studs and housings are less likely to undergo damage.

The solid metal gasket requires a high stress to cause plastic deformation to make a seal. The high surface stress generated on the metal core gasket, cause the tendency of the metal core to warp and buckle, see fig1a. The deformation of the metal makes removal of the sealing element from the plug difficult. The kammprofile metal core doesn't deform, the majority shape change is due to the soft facing . This coupled with the low seating stress required to effect a seal eases removal of the gasket.

Metallic gaskets require a surface finish of a maximum value 1.6 μmetre Ra, a smooth surface finish, and do not tolerate any nicks or scratches. A gasket consisting of just mild steel damages and scours the sealing faces of both the stud and the housing requiring face preparation before replacement. A metal washer examined under magnification clearly shows the rotation scratch of the metallic plug, Figure 1. The gasket face in contact with the header will deform under the high stress levels. Figures 2 & 3 show the typically poor preparation of the sealing face on manufacture of the air cooler header plate.

In addition to the benefit of the lower bolt load requirement, the graphite facing on the kammprofiles can accommodate minor nicks and scratches on the sealing faces. The graphite also acts to protect the facings from scouring, scratching and rust damage. Also the surface finish requirement of up to 6.3μm Ra is not as smooth as for a mild steel washer (up to 1.6μm Ra) and is therefore easier to maintain.

Overall, the utilization of kammprofiles means less joint preparation and maintenance is required (in terms of re-tightening, re-machining and stud replacement) for an all round tighter seal.

The compression characteristics of the two styles of gasket have been analyzed using computer controlled compression test equipment. The characteristic plot of stress versus strain indicates the lower load to deform the Kammprofile than the solid metal gasket and the higher value of recovery. These two properties can give improved sealing. The curves are shown in Figures 4 & 5.

FINITE ELEMENT ANALYSIS (FEA) BOLT LOAD DETERMINATION

The bolt load requirement for the kammprofile and mild steel washer has been verified by the finite element analysis technique. FEA is an accepted technique for the prediction of performance of structures. Through years of experience and development in this area, FEA is capable of modeling seals realistically and accurately.

A three-dimensional FEA model for each gasket type (kammprofile and mild steel washer) for a 1-inch fin-fan stud assembly was generated. The model included a half section though part of the housing, stud and gasket (refer to Figure 6). The models and FEA method were used to determine the bolt stress required to load the gaskets to the recommended minimum stresses (5,000psi / 34.5MPa for the kammprofile and 18,000psi / 124Mpa for the mild steel washer). This was accomplished by imposing displacements on the bolt until the desired gasket stress was achieved. The model included the uneven loading applied to the gasket due to the angle of the thread.

The seating stress to generate a seal was verified by a sealing test on a compression test machine. The data used to develop the FEA model was based on actual compression testing with the loading applied in an even manner.

Kammprofile

Figure 7 shows the stress distribution through the stud and housing arrangement. From this Figure it can be seen that a surface stress of 5,000psi / 34.5Mpa on the kammprofile gasket is achieved by a bolt stress of 2,900psi / 20MPa. This value is somewhat less than that determined by empirical calculations (around 3,500psi / 24MPa). The reason for this difference is related to the relative stiffness of the assembly. However the determined value is suitably close to the empirical value. A factor of two is recommended to allow for normal bolt relaxation and the surface stress loss resulting from the temperature and pressure of operation.

Mild-Steel Washer

For the mild steel washer, Figure 8, shows that a surface stress of 18,000psi / 124MPa for the gasket is achieved by a bolt stress of 11,600psi / 80MPa. This value is also suitably close to the empirical value. Again, a factor of two is recommended to allow for normal bolt relaxation and the surface stress loss resulting from the temperature and pressure of operation.

FIELD EXPERIENCE

Several sites within the UK have carried out successful comparison trials of the kammprofile against the solid metal. Applications with a variety of temperature, pressure and media have all shown improved performance over the solid metal style. The successful use of the kammprofile on several leaking exchangers has resulted in the removal of drip trays and that a seal was obtained without the expense of machining flange faces.

A large user of metal washers recently replaced over 10,000 units on a turnaround. The maintenance department reported a single leak on the header plugs. The failure analysis revealed that the stud was incorrectly tensioned. The previous turnaround on the unit suffered major delays due to leakage on the units with reports from the maintenance team indicating over 100 leaks. The change to Kammprofile style was deemed a total success.

Extrudation of the graphite sealing material is prevented by the serrations machined in to the core. The angle of thread pitch applies an uneven loading to the metallic core. The graphite compaction into the grooves is unaffected by the uneven loading.

The kammprofile gasket does not exhibit the deformation of the solid ring even under the similar stress applied to the solid ring. The solid metal ring will twist and warp under high loading. The kammprofile core and the soft facing maintain contact.

The benefit of changing to the kammprofile style gasket is equivalent in cost increase to machining five plugs out and fitting over size plugs and is therefore very cost effective.

RECOMMENDED TORQUE VALUES

The following are recommended torque values derived from actual field trials that created satisfactory seals with kammprofiles and mild steel washers:

Nominal Stud Diameter	Torque applied to seal Mild-Steel Washers	Torque applied to seal “PN” Kammprofiles
1 $^{1}/_{8}$ "	250 Ft.lbs	50 Ft.lbs
1 $^{1}/_{4}$ "	300 Ft.lbs	75 Ft.lbs

CONCLUSIONS

Because the minimum seating stress for the kammprofile is low, much lower bolt loads are required to achieve a given level of tightness than with the mild steel washer. A greater amount of loading is therefore available to assure continued sealing during operation.

The lower stress requirement means that the sealing faces and stud/housing threads are stressed to a significantly lesser degree. The risk of mechanical damage is reduced thus eliminating expense of thread renovation.

The use of graphite facing removes the possibility of the metal washer sticking, reduces the marking of the sealing face and lowers the coefficient of friction between the components.

Unlike the solid metal gasket, a large range of surface finishes can be tolerated by the graphite faced kammprofile gasket.

Fig 2. View of solid metal washer, Header Face

Fig 3 , Magnified Image of metal washer, Header side, showing machine marks on header flange.

Fig 1, Solid metal washer, showing scratch marks from metal plug.

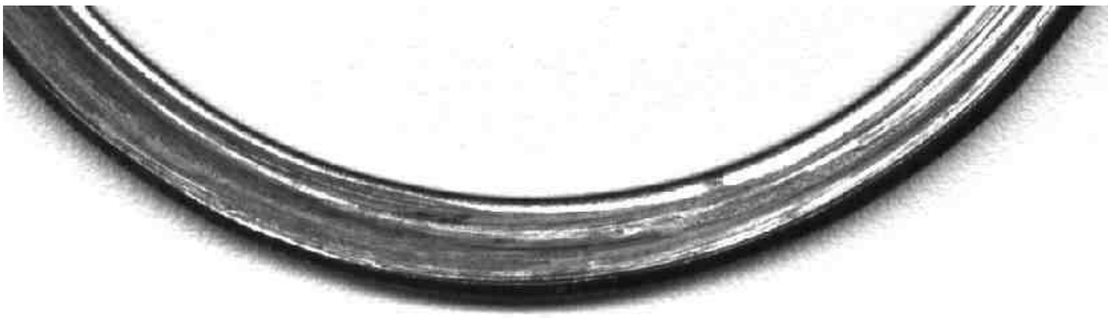
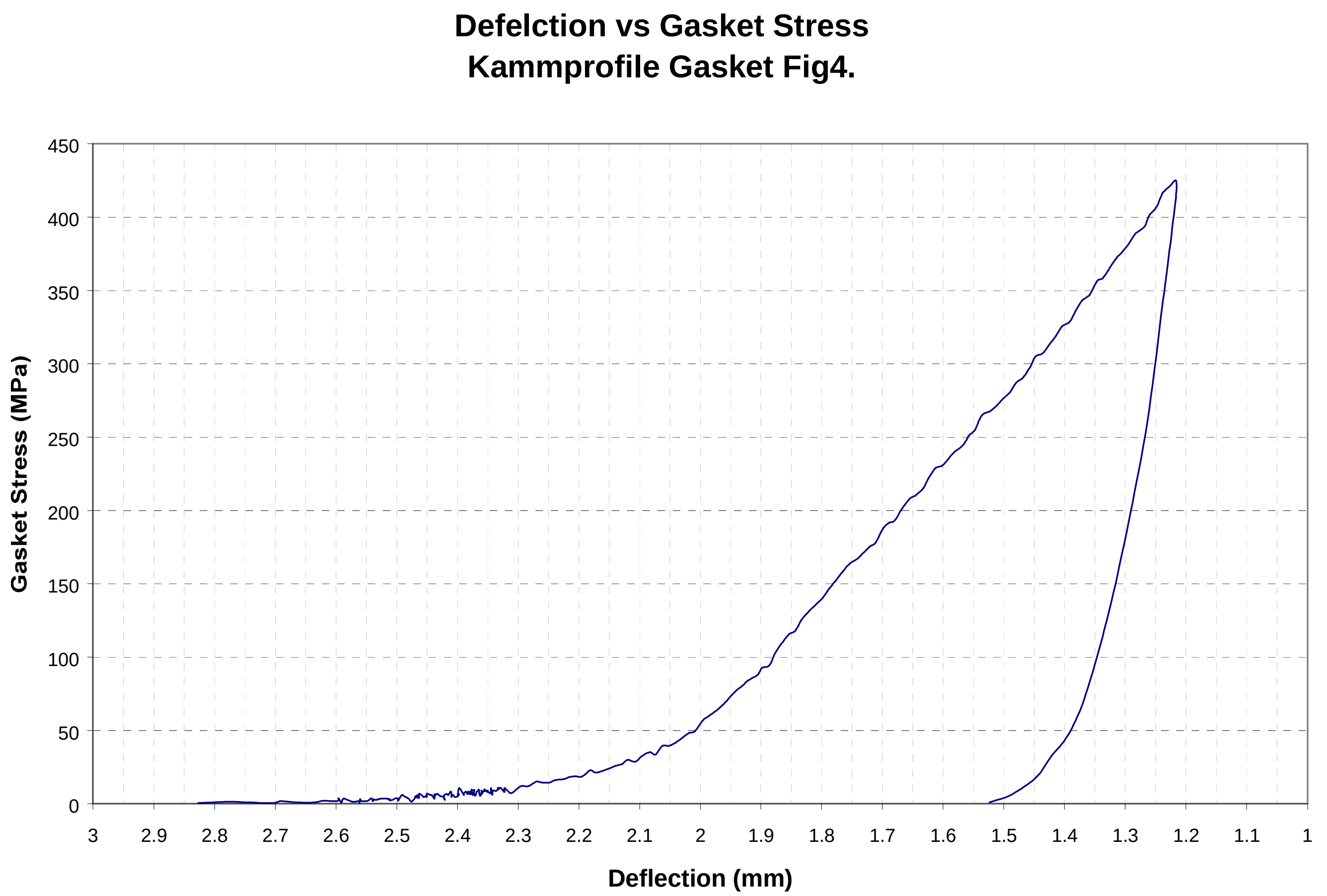


Fig1a, Solid metal washer Magnified, Showing dishing and Scratch from metal plug.


Defelction vs Gasket Stress
Kammprofile Gasket Fig4.
Gasket Stress (MPa)
450
400
350
300
250
200
150
100
50
0
3
2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
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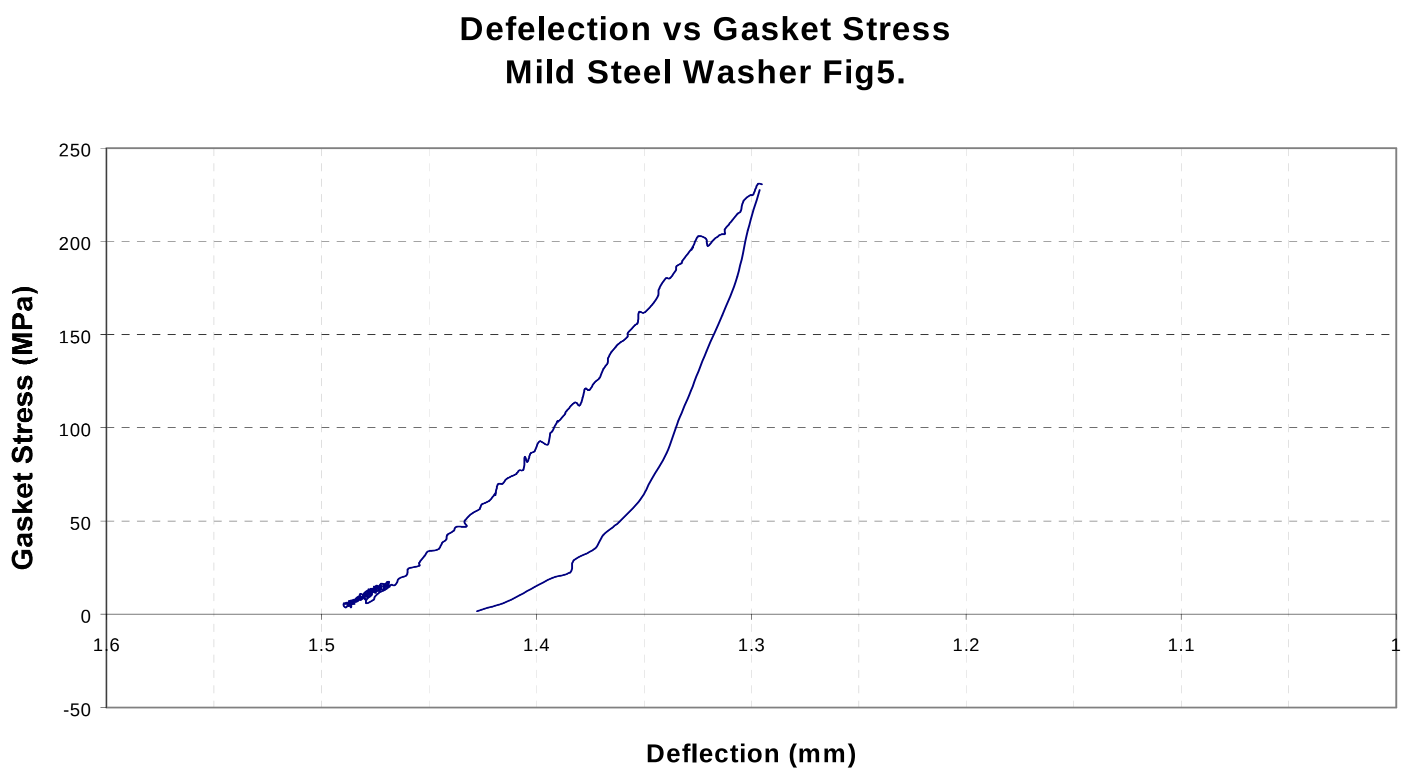
1.4
1.3
1.2
1.1
1
Deflection (mm)


Defelection vs Gasket Stress
Mild Steel Washer Fig5.
Gasket Stress (MPa)
250
200
150
100
50
0
-50
1.6
1.5
1.4
1.3
1.2
1.1
1
Deflection (mm)

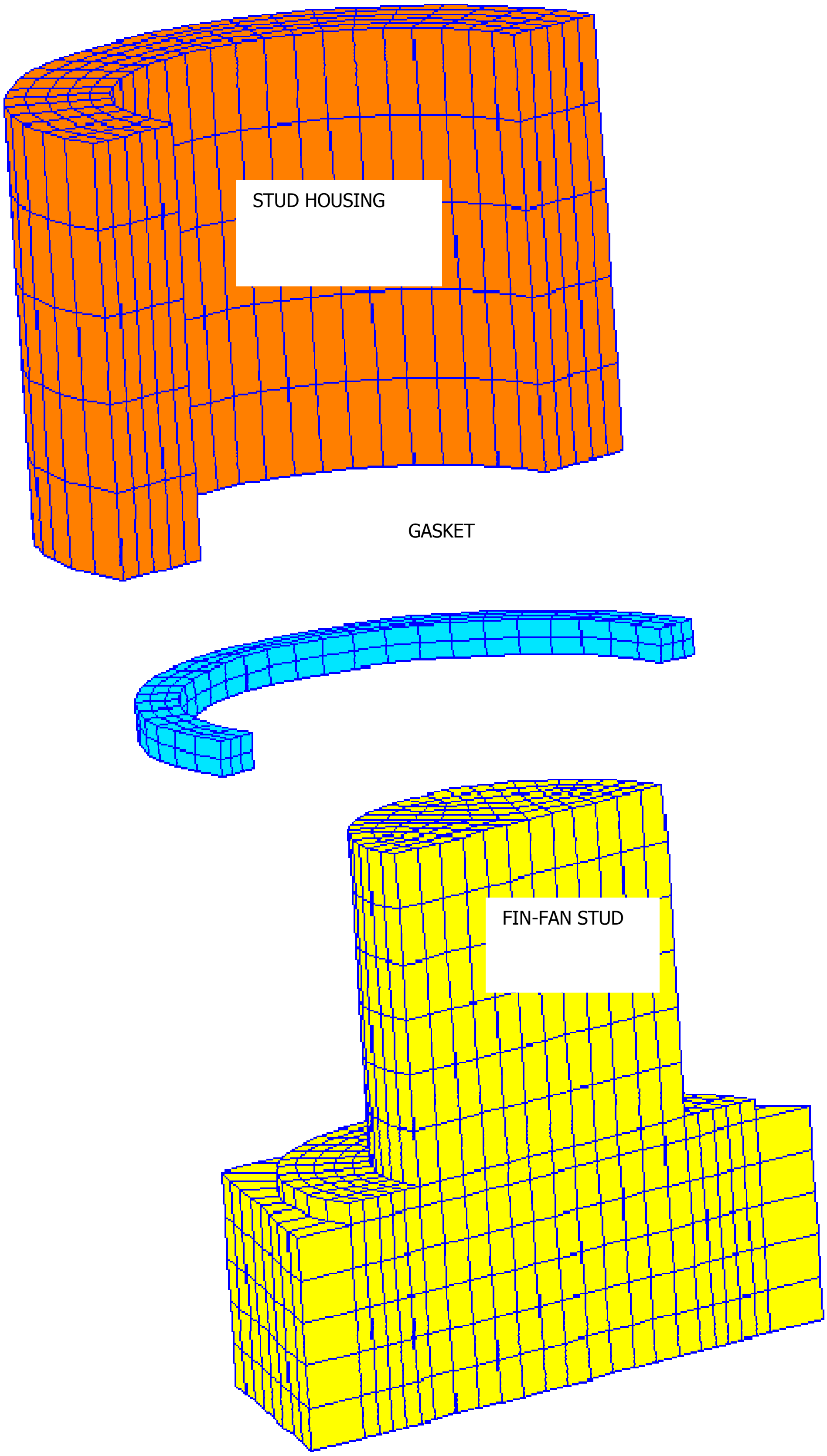
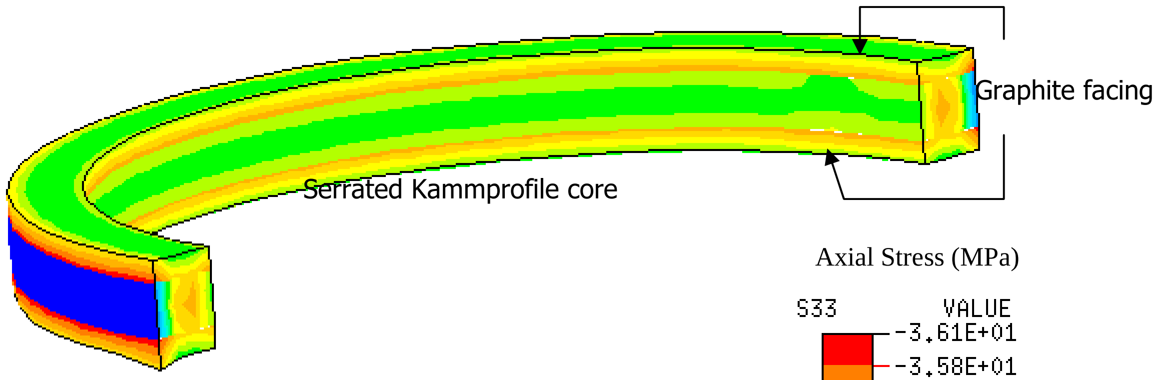
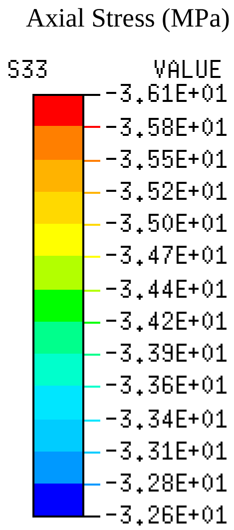


Figure 6. 3D meshed FE model components





A gasket stress of 35MPa (5,000psi) is generated by the application of 20MPa (2,900Ppsi) bolt stress. The bolt stress is somewhat less than expected due to the relative stiffness of the assembly, but is still within the range anticipated.

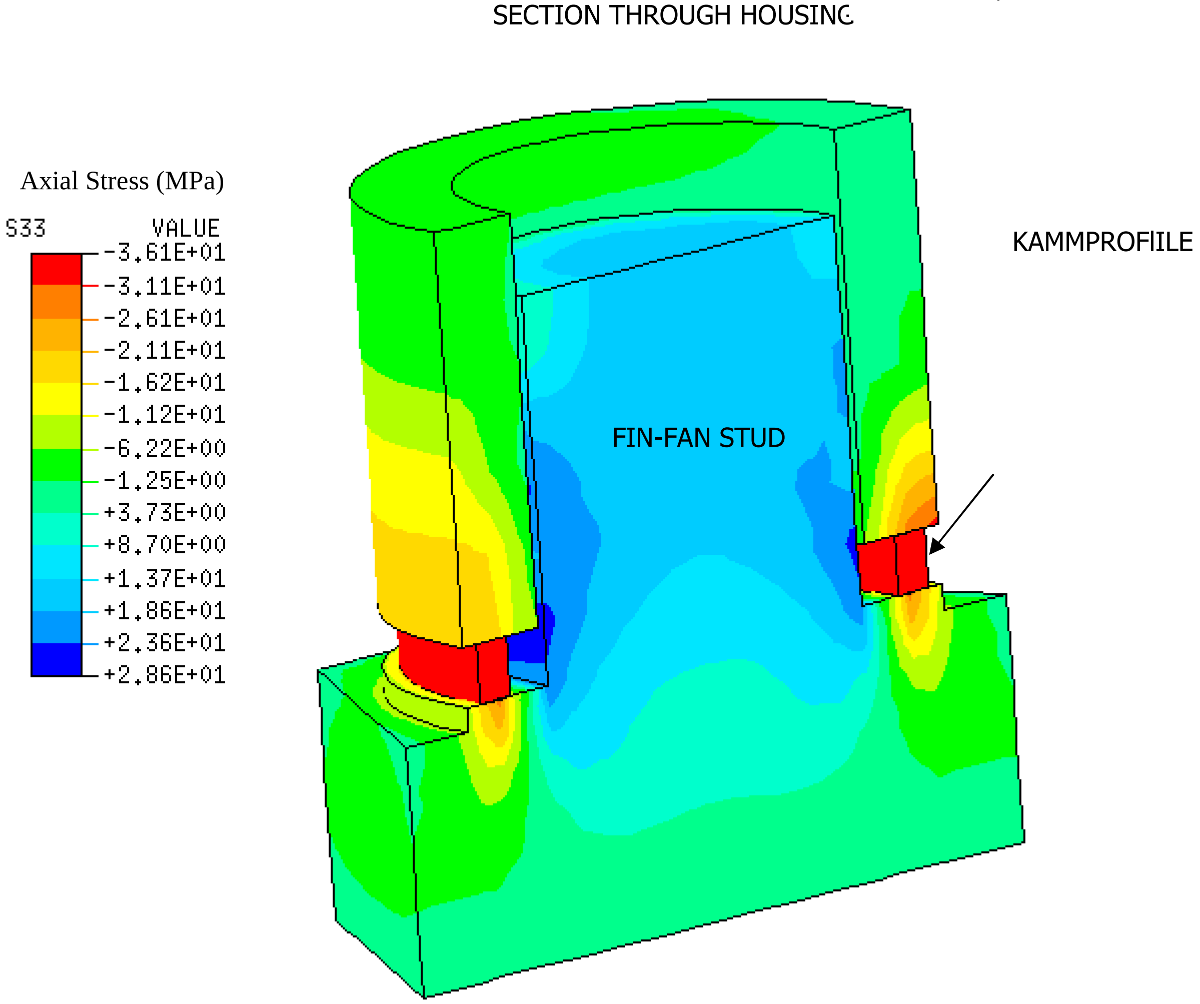
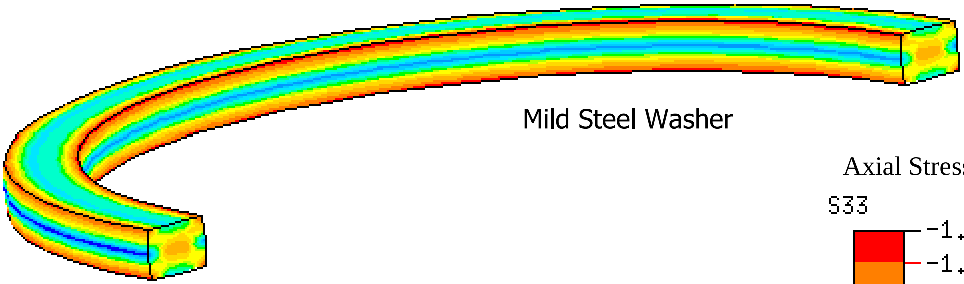
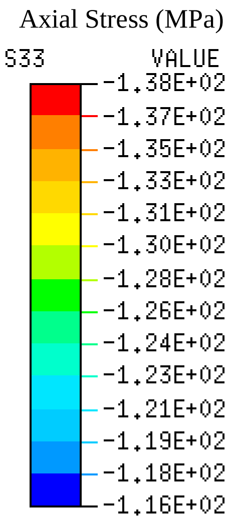


Figure 7. Stress distribution through kammprofile and fin-fan stud as determined by FEA





A gasket stress of 125MPa (18,000psi) is generated by the application of 80MPa (11,600psi) bolt stress. The bolt stress is somewhat less than expected due to the relative stiffness of the assembly, but is still within the range anticipated.

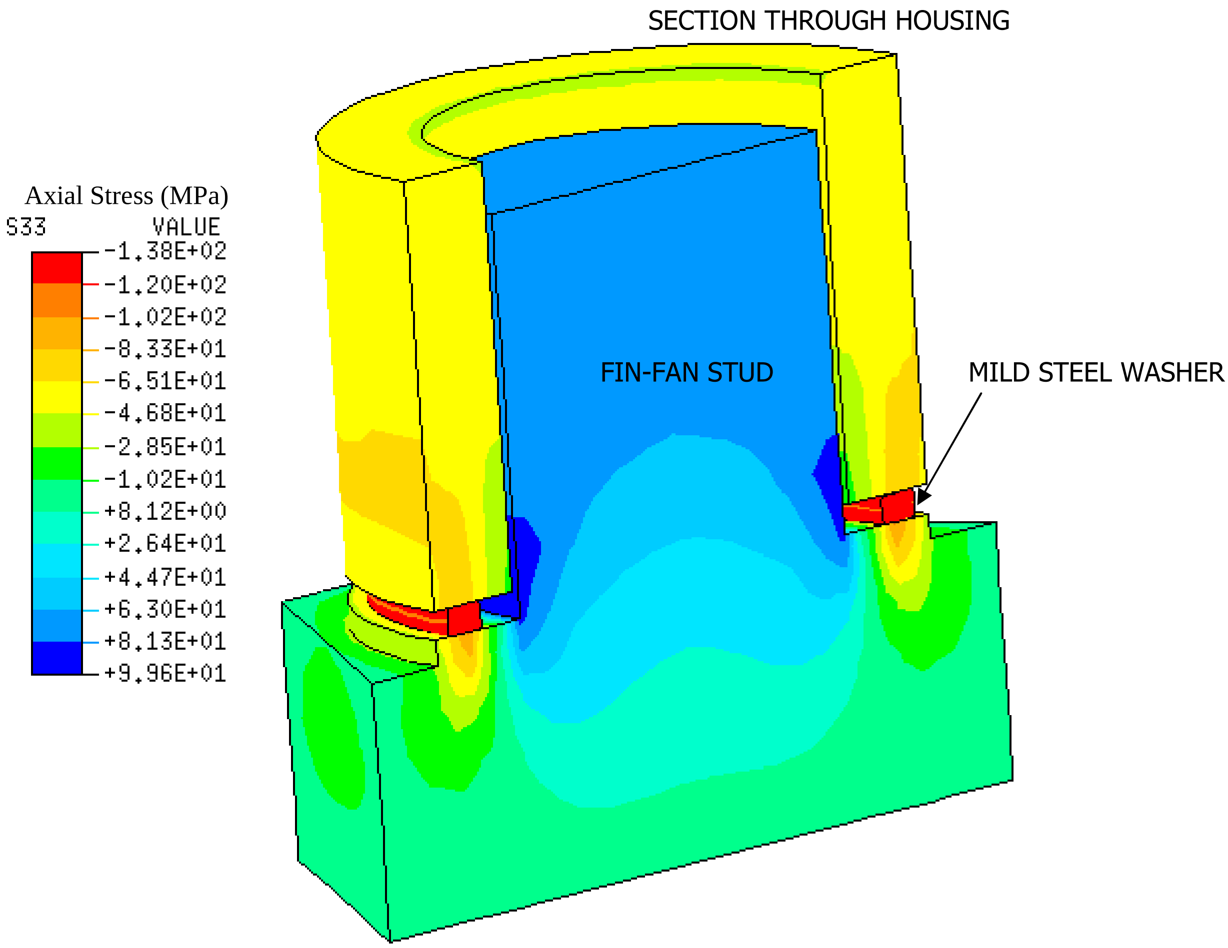


Figure 8. Stress distribution through mild steel washer and fin-fan stud as determined by FEA