AN ANALYSIS OF THE GenFixx™ MECHANICAL ASSEMBLY TECHNIQUE COMPARED TO A BRAZED ASSEMBLY TECHNIQUE USED IN SEVERE SERVICE VALVE COMPONENT APPLICATIONS

General Carbide|UK, Daventry, England **August 2011**

Functionally, the ability of a tungsten carbide/steel assembly to succeed mechanically in severe service valve component applications is dependent upon the strength and reliability of the method of attachment. In common use today is a brazed assembly, employing standard braze procedures to achieve a good bond between two dissimilar materials, tungsten carbide and stainless steel.

A recently-developed mechanical fastening technique, GenFixx™, compares favourably with braze in terms of joint strength and is more predictable in its reliability. The functionality of any particular braze joint cannot be validated or verified without destroying the assembly. Put another way, the assembly cannot be tested non-destructively to give the manufacturer/designer a higher level of confidence in success of the braze process. Thus, the designer must rely on the reputation of the brazing operator, rather than on a verifiable and visibly assured assembly technique.

Severe service valve assemblies are subjected to extensive wear and corrosion from the working environment. The method of attachment should not add to the risk factor in determining the success and long life of a severe service valve assembly.

The recently-developed GenFixx assembly technique reduces that risk factor and demonstrates improved tensile strength in the joining of carbide and steel. It also provides a higher degree of reliability, which is extremely desirable in this application.

Introduction

The ability of a carbide/steel trim assembly to withstand various mechanical forces plays a crucial role in the success of the overall valve assembly. Standard brazing practices were usually considered sufficient to ensure that a good braze joint was achieved. Because the braze joint can not be tested by non-destructive means to verify the integrity of the assembly, an unreliable situation may exist in what should be a very reliable trim device.

If a mechanical fastener technique could be employed to provide equal joint strength, and be predictable and reliable in its anti-vibration, anti-rotation characteristics, then that assembly technique would provide a higher degree of reliability. It is suggested that a 10% failure rate for brazed assemblies occurs just from the braze operations in manufacturing. Brazing involves the joining of two materials with very different coefficients of thermal expansion (CTE), meaning that steel will expand 2 to 3 times more than cemented carbide. Upon cooling, a high degree of stress is created in the carbide, which can cause cracking and failure during production. Moreover, experience has shown that another 10% may fail in use which means as much as 20% of all brazed assemblies will fail due to the braze technique alone. In addition, if the method of brazing chosen is torch brazing, highly localized heating will result in the steel, which could affect the chemical/physical properties of the parent material due to the concentrated high temperature.

The GenFixx technique (patent pending) employs the use of an internally- or externally-threaded tungsten carbide component mated to a threaded steel body with high temperature epoxy added to resist vibration. The component is also reinforced by a tungsten carbide pin inserted laterally for anti-rotation protection (See Figure 1.)

(Figure 1 – GenFixx)

Recently a test was conducted to compare the GenFixx mechanical assembly technique to a typical brazed assembly of the same design, and the results were dramatic.

First-Phase Testing

General Characterisation and Testing Methods

General Carbide|UK recently engaged the services of an independent laboratory to test the joint strength of GenFixx and braze. The independent laboratory that conducted the tests is:

Westmoreland Mechanical Testing & Research, Ltd.
5 Beaumont Road
Beaumont Industrial Estate
Banbury, Oxfordshire OX16 1RH, UK
Telephone: +44 (0) 1295 261211

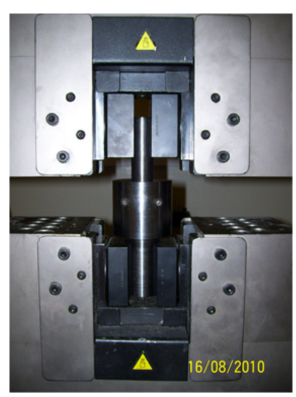
The laboratory conducted static tensile tests on three specimens each of brazed and GenFixx assemblies, as shown in Figure 1.

The tungsten carbide grade used for all six specimens was grade GC-010, and the steel used was 17-4PH stainless steel. The thread employed for the test was identical to that used in field applications for severe service valve assemblies. (i.e., ¾" x 20 UNJ thread) The brazed assembly was identical in size to the GenFixx assembly but had neither internal threads nor pins. It was brazed using MX18N braze foil at 0.006" thick at normal temperatures with standard flux and good brazing practices employed.

(Figure 2)

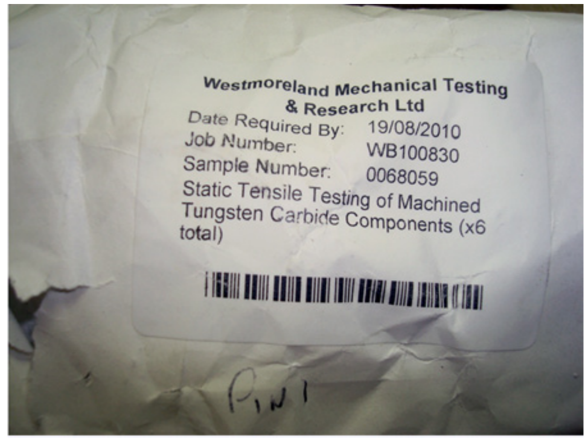
The tests were conducted under strict laboratory conditions using an Instron 250 kilo Newton tensile test apparatus (Figure 2). The technician set the Instron machine to operate at a speed of 1 mm/minute to pull apart the brazed assembly specimen in tension with the intent to sever the braze joint and measure and record the load needed to accomplish shearing of the three specimens. It was likewise intended to pull the GenFixx specimen apart in tension by stripping the threaded, pinned and epoxied joint, and measure the load needed to accomplish that on the three specimens.

The carbide end of the specimen was modified by grinding two 4.5mm radius grooves in it, allowing two steel pins to nest in the grooves, which would create the gripping points for the machine on the carbide end. The steel end was gripped by inserting the threaded shaft into a mating thread on the gripping fixture. (See a similar fixture method shown in Figures 3 and 4.)



(Figures 3 and 4)

The photos of the failed test specimens of each type are shown in the Figures below.



(Figures 5(a) through 5(g))

Results and Discussion

By examining the failed carbide/steel assemblies, it was revealed that the static tensile test did not actually determine the strength of either joint because the carbide material failed in tension at a location above or around the joints in all six specimens. In the GenFixx assemblies, the cross pin was intact in all cases and can be readily seen in Figures 5(e) through 5(g). In addition, most of the carbide threads are still engaged, but the surrounding material is fractured. In the brazed specimens, the joint is intact, but the surrounding material failed. Thus, neither the brazed assembly joint nor the GenFixx assembly joint failed in any of the tests.

Because cemented carbide is known as a ”brittle” material, it does not demonstrate a high degree of tensile strength, and the measured values are not surprising. As a brittle material, cemented carbide also adheres to Weibull’s Statistical Strength Theory, which explains the influence of micro-porosity as stress concentrations on the strength of all brittle materials. A brittle material will not exhibit plastic deformation preceding the initiation of a crack. A crack, however, could be initiated by a micro-void in the material, or by a stress riser such as a sharp corner or radius ground into it. Thus, the gripping technique for the tensile test for the carbide must not be allowed to be, in and of itself, a site of crack origination due to a stress concentration created by the gripping grooves. It was thus proven that the gripping technique was not a factor in the test results.

The data shows that GenFixx has at least equal strength to a standard brazed assembly. The results of the tensile tests are shown in SI units in Table 1 for the three assemblies employing the braze technique (without pin), and three GenFixx assemblies (with pin).

WMTR Test log Number	Specimen Details	Maximum Load (kN)	Extension @ Max Load (mm)
68059	Specimen with pin 1	124.79	6.02
68060	Specimen with pin 2	155.23	7.56
68061	Specimen with pin 3	164.33	6.80
68062	Specimen without pin 1	185.06	7.87
68063	Specimen without pin 2	138.42	6.48
68064	Specimen without pin 3	131.33	5.26

(Table 1)

Table 1 data, converted to English units, is shown in Tables 2 and 3.

Brazed Assembly test data

WMTR Test log Number	Specimen Details	Maximum Load (lbf)	Stress at Max Load (psi)	Exten-sion @ Max Load (Inch)
68062	Specimen without pin 1	40929	28742	0.310
68063	Specimen without pin 2	31118	21853	0.255
68064	Specimen without pin 3	29524	20733	0.207

(Table 2)

GenFixx™ Assembly test data

WMTR Test log Number	Specimen Details	Maximum Load (lbf)	Stress at Max Load (psi)	Extension @ Max Load (Inch)
68059	Specimen with pin 1	28054	19701	0.237
68060	Specimen with pin 2	34897	24506	0.298
68061	Specimen with pin 3	36943	25943	0.268

(Table 3)

The amount of load needed to fracture the GenFixx joint ranged from 28K lbf to almost 37K lbf. Hence, by calculation, the amount of stress imposed on the joint at failure ranged from a low value of 19.7ksi to a high of 25.9ksi.

These test results mean that the GenFixx technique was at least as good as braze in these tests, but a second test would be needed to measure the load at failure of the joint. That test would need to be designed to have failure occur at the joints, and the values measured should be below the value of the strength of material for tungsten carbide.

Second-Phase Testing

A second test was devised to measure the joint strength of each method without failing the carbide material. The thread size selected was ¼" x 20 UNC, a size not normally used in field applications but a size sure to fail at the joint. The brazed assembly was identical in size to the GenFixx assembly but had neither internal threads nor pins. It was brazed using MX18N braze foil at 0.006" thick at normal temperatures with standard flux and good brazing practices employed. The same Instron testing apparatus was used with the same gripping fixtures employed in First-Phase Testing, and one specimen of each technique was manufactured and tested.

Figure 6 shows the failed specimens, one GenFixx and another brazed .

(Figure 6)

It is interesting to note that the failed brazed specimen exhibited total ”wetting” of the braze material on all joined surfaces, including the pin area. Although it was a “good” braze joint by all standards, it is a determination that one is unable to make unless the joint is destroyed.

Results and Discussion

The results of the tensile tests for each assembly are shown in SI units in Table 4. #78079 is the brazed assembly, and #78080 is the GenFixx assembly.

WMTR Test log Number	Maximum Load (kN)	Extension @ Max Load (mm)
78079	22.57	2.67
78080	22.82	3.29

(Table 4)

Table 5 shows the above data converted to English units.

WMTR Test log Number	Maximum Load (lbf)	Stress at Max Load (psi)	Extension @ Max Load (psi)
78079	5074	2429	0.105
78080	5131	2456	0.127

(Table 5)

The GenFixx specimen displayed 1% greater break strength than the equivalent-size braze joint, a small but significant difference. A portion of the carbide threads were, in fact, pulled apart exposing the cross pin which did not shear but the strength of the threads in tension surpassed the shear strength of the braze material on the pin surfaces, as well as the pure tensile strength of the braze material on the mating carbide plug surface. Thus, the results show that GenFixx is stronger than an equivalent braze joint.

The practical application for such an improved fastening technique such as GenFixx may be seen in Figure 7 below.

(Figure 7)

Summary

The initial test conducted by Westmoreland Mechanical Testing & Research was inconclusive regarding the tensile strength of the GenFixx assembly technique compared to the tensile strength of an identically-brazed assembly. What the test revealed, however, was that both fastening techniques exceeded the strength of the carbide material, and the GenFixx technique has sufficient strength to match a standard brazed assembly.

The second test was successful in proving the joint strength of both techniques with GenFixx, matching and slightly exceeding the break strength of an equivalent brazed joint. An added benefit of GenFixx is visual verification of a successful joint. In contrast, a braze joint must be destroyed to determine if it has been fully brazed. Because the success of a brazed assembly cannot be verified by non-destructive means, the GenFixx method is superior in its predictability and reliability by simple visual examination.

Severe service valve trim parts, such as plugs and seats, are dependent upon the strength and reliability of the attachment method . The GenFixx assembly technique can perform equal to, or better than, a brazed assembly when joining two dissimilar materials such as cemented carbide and stainless steel. Most importantly, GenFixx provides the designer with a higher degree of confidence in the reliability of the joint.

Reference

The Designer's Guide to Tungsten Carbide, General Carbide Corporation, Greensburg, PA USA.

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