Experimental and Theoretical Study of the Shrink Fit Assembly

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Abstract— Now a days there are several joining or assembly process to join the components or mating parts. In this report deals with the study of different types of materials which are making to shrink assembly used in different engineering application like shrink fit tool holder, cam fit to cam shaft, piston and gudgeon pin assembly, dual block rail wheel manufacturing, hub and shaft assembly, triple layer metal pipe manufacturing etc,. In the design of shrink fit application, the designer or engineer must know the knowledge about the simple term of shrink fit but which posses' bigger technical observation behind that. This project gives the clear report of shrink fit assembly which make by different metals like aluminium, brass, copper, mild steel because of these are the most useful material for engineering manufacturing and fabrication processes. This report is very much useful for future reference wherever the shrink fit thought will appear in future application.

Key words: Shrink Fit assembly, copper fit assembly, brass, Mild steel

I. INTRODUCTION

This invention relates to a process for assembling piece parts utilizing the shrink fit technique. Present methods for assembling piece parts incorporating shrink. This techniques include machining or other-wise forming the parts to be assembled such that the parts have corresponding dimensions which mate in the assembled condition, that is, one part or a portion thereof, is internally fitted within the other or a portion thereof at the corresponding assembly dimension.

When both piece parts are at the same temperature, whether ambient or otherwise, the mating assembly dimensions are a size such that the assembly dimension of the piece part to be internally fitted is greater than the size of the corresponding assembly dimension of the external piece part into which the internal part is to be inserted. To permit assembly, the larger, internal piece part is cooled to a temperature at which its assembly dimension is reduced to a size that is less than the size of the mating dimension of the external piece part, at which time the piece parts may be assembled.

When the two assembled pieces reach an equilibrium temperature where they again are both at the same temperature, the internally assembled piece part expands and the expansion pressures exerted thereby on the external piece part assembled thereto cause large compression forces at the assembly dimensions of 'both piece parts, securing the piece parts together. When the internally assembled piece part is cooled to a temperature sufficiently low to cause its corresponding assembly dimension to shrink to a size smaller than the mating dimension of the external piece part.

A. Definition

Shrink-fitting is a practice in which an interference fit is getting done by a relative size change following assembly. This is typically done by heating or cooling one component previous to assembly and allowing it to come again to the ambient temperature past assembly, employing the fact of thermal expansion to make a joint.

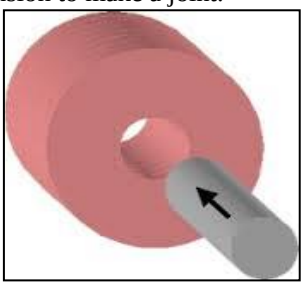

Fig. 1: Shrink Fit Assembly

For example, the thermal expansion of a piece of a metallic drainpipe allows a builder to fit the cooler piece to it. As the adjoined pieces reach the same temperature, the joint becomes strained and stronger.

B. Heating Temperature

Shrink-fits are assembled using heating to temperature where the increase beyond the interference. Mandatory temperature heating can be calculated like

$dt = \delta / \alpha\, d_i$ (1)

where

dt = temperature heating (^oC, ^oF)
δ = diametric interference (mm, in)
α = coefficient of linear expansion (m/m^oK, in/in^oF)
d_i = initial diameter of hole before expansion (mm, in)

Diametric interference can be calculated as

$\delta = dt\, \alpha\, d_i$

II. ESTIMATION OF PARAMETERS

An interference fit is a frictional shaft-hub connection. Friction surface Joint pressure is required for the torque transmission and this pressure is generating by the warp of shaft and hub. Appropriate assembly method shall be chosen between shrink fit and press fit. In the press fit case, assembly operation is achieved with the help of large amount of forces and forcing the shaft into the hub. In the shrink fit case, assembly operation is done via relative size change of parts from heat treatment. Representative examples are fitting shafts into bearing and bearings to the housings. The Interference fit calculator has been developed to calculate interference parameters such as

a) Press fit force
b) Required temperature for shrink fit
c) Von Misses stresses occurred on shaft and hub
d) Factor of safety values

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III. HEATING

Flame heating is done by using gas or fuels. In the way, the metal part is heated in the presence of hot flame. Examples heating contain flame straightening, hot forming, and flame hardening, and heating together with welding. The flame is used for melting purposes in flame brazing and for fusing purposes with flame sprayed coatings. With oxy fuel cutting and gauging, the flame heats to ignition temperature in order to start and maintain the cutting process.

Hydrocarbons such as methane, ethylene, acetylene, propane, and propylene or hydrogen are used as fuel gases for flame heating. The flame temperature and intensity rely on used fuel gases and mixing ratio of oxygen. Acetylene and hydrogen flames can be set to a normal or reducing atmosphere whereas all other common fuel gases have an oxidizing flame.

Fig. 2: Flame Heating

A. Thermal conductivity of metal

Thermal conduction of any material depends on 2 things:

1) Motionoffreeelectrons
2) Molecularvibrations

for metals, the thermal conduction is especially perform of the motion of free electrons. Because the temperature will increase, the molecular vibrations increase (in flip decreasing the mean free path of molecules). So, they hinder the flow of free electrons, so reducing the conduction. Just in case of nonmetals, there aren't any free electrons. So, solely the molecular vibrations are chargeable for conductivity of warmth and therefore for nonmetals the conduction will increase with increase in temperature.

Materials	Thermal coefficient per degree celsius × 10^{-6}
Cast iron	10.8
Mild steel	11.7
Aluminium	22.2
Stainless steel	17.3
Copper	16.6
Nickel	13.0
Brass	18.7
Bronze	18.0

Table 1: Thermal Coefficient of Different Materials

IV. DESIGN CONSIDERATION

Principle of this process are, When the metal is heating, the crystals or atoms to be expand to make the varying in dimension to be occur from original dimension. When the metal is under sudden cooling, the atoms are in shrink into the original dimension.

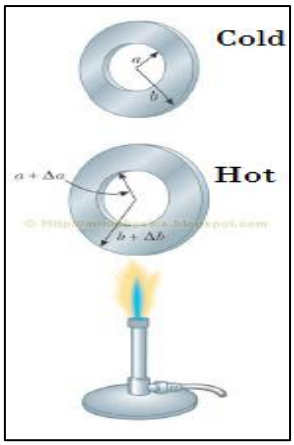

Fig. 3: Ring bore expands while heating

A. Design for bore assembly

Select two component for assembly with dimension given below,

Inner part- Rod Diameter - 15 mm
Length of the rod - 80 mm
Outer part- Ring
Inner diameter - 15 mm
Outer diameter - 35 mm
Width of the ring - 10 mm

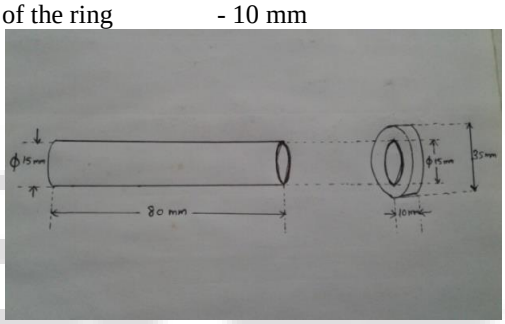

Fig. 4: Dimensions of assembly of parts

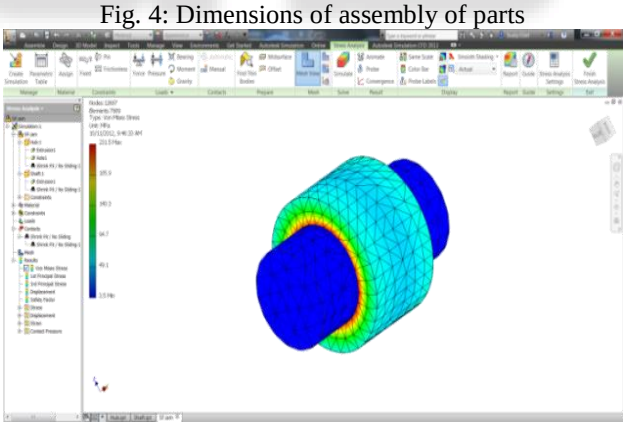

Fig. 5: Thermal distribution between the assemblies

V. ANALYSIS OF ALUMINIUM ASSEMBLY

A. Properties of aluminum for making shrink fit assembly

Co efficient of thermal expansion
of Aluminium - 22.2 * 10^{-6}/º C
Melting temperature - 660 º C
Modulus of elasticity (E) - 69* 10^3 N/mm^2
Size of the ring for assembly
Inner diameter - 15 mm
Outer diameter - 35 mm
Thickness - 10 mm

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Fig. 6: Aluminium specimen Shrink Fit assembly

B. Heating source

Source - Oxy-acetylene gas flame
Flame temperature - 2250 º C

C. Analysis of expansion

Heating time on aluminium ring - 14 sec
Initial bore diameter of the ring - 15 mm
Final bore after heating the ring - 16.5 mm (14 seconds)

D. Analysis of shrink fit force on rod

The amount of holding stress developed once contraction of the outer hole has occurred can be calculated:
$S_t = E * \Delta D / 4 * a (1+ a^2/ b^2)$
$S_r = E * \Delta D / 4 * a (1- a^2/ b^2)$
S_t and S_r - Tangential and radial stresses developed between the collar and the shaft.
'*a*' and '*b*' - Internal and external radii of the collar
E = Elastic modulus
ΔD = Change of inner diameter of hole.
Here,
ΔD = 16.5 -15 = 1.5 mm
$E = 69 * 10^3$ N/mm^2 or 69 GPa
a = 15 mm
b = 35 mm
Therefore,
Tangential force on shaft while contraction of ring $S_t = 4.08*10^3$ N/mm^2
Radial force on shaft while contraction of ring $S_r = 2.81 *10^3$ N/mm^2

E. Analysis of shrink fit assembly withstand tensile stress

Source for tensile load - By bearing puller arrangement
Tensile load given to the assembly while breaking =196.2N

F. Analysis of shrink fit assembly withstand torque

Source for torsional load - By vice and wrench arrangement
Torsional load given to the assembly while breaking – (25 * 9.81) * 0.30 = 73.57 Nm

VI. Analysis of Brass Assembly

A. Properties of brass for making shrink fit assembly

Co efficient of thermal expansion of Brass - $18.7 * 10^{-6}$/º C
Melting temperature - 940 º C
Modulus of elasticity (E) - $45 * 10^3$ N/mm^2
Size of the ring for assembly Inner diameter - 15 mm
Outer diameter - 35 mm
Thickness - 10 mm

Fig. 7: Brass specimen Shrink Fit assembly

B. Heating source

Source - Oxy-acetylene gas flame
Flame temperature - 2250 º C
Analysis of expansion
Heating time on brass ring - 20 sec
Initial bore diameter of the ring - 15 mm
Final bore after heating the ring upto - 20 second -16.3 mm

C. Analysis of shrink fit force on rod

The amount of holding stress developed once contraction of the outer hole has occurred can be calculated:
ΔD = Change of inner diameter of hole.
Here,
ΔD = 16.3 -15 = 1.3 mm
$E = 45 * 10^3$ N/mm^2 or 45 GPa
a = 15 mm
b = 35 mm
Therefore,
Tangential force on shaft while contraction of ring $S_t = 2.301 * 10^3$ N/mm^2
Radial force on shaft while contraction of ring $S_r = 1.591 *10^3$ N/mm^2

D. Analysis of shrink fit assembly withstand tensile stress

Source for tensile load - By bearing puller arrangement
Tensile load given to the assembly while breaking – 245.2 N

E. Analysis of shrink fit assembly withstand torque

Source for torsional load - By vice and wrench arrangement
Torsional load given to the assembly while breaking – (35 * 9.81) * 0.30 = 103 Nm
ANALYSIS OF COPPER ASSEMBLY

F. Properties of copper for making shrink fit assembly

Co efficient of thermal expansion of copper - $16.6 * 10^{-6}$/º C
Melting temperature - 1085 º C
Modulus of elasticity (E) - $120 * 10^3$ N/mm^2
Size of the ring for assembly
Inner diameter - 15 mm
Outer diameter - 35 mm
Thickness - 10 mm

Fig. 8: Copper specimen Shrink Fit assembly

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G. Heating source

Source - Oxy-acetylene gas flame
Flame temperature - 2250 º C

H. Analysis of expansion

Heating time on copper ring
noted by using timer - 27 sec
Initial bore diameter of the ring - 15 mm
Final bore after heating the ring upto 27 seconds-16.3 mm

I. Analysis of shrink fit force on rod

The amount of holding stress developed once contraction of the outer hole has occurred can be calculated:
ΔD = Change of inner diameter of hole.
Here,
ΔD = 16.3 -15 = 1.3 mm
E = 120 * 10^3 N/mm^2 or 12 GPa
a = 15 mm
b = 35 mm
Therefore,
Tangential force on shaft while contraction of ring S_t = 6.136 * 10^3 N/mm^2
Radial force on shaft while contraction of ring
S_r = 4.243 * 10^3 N/mm^2

J. Analysis of shrink fit assembly withstand tensile stress

Source for tensile load - By bearing puller arrangement
Tensile load given to the assembly while breaking – 343.3 N

K. Analysis of shrink fit assembly withstand torque

Source for torsional load - By vice and wrench arrangement
Torsional load given to the assembly – (35 * 9.81) * 0.30 = 103 Nm

VII. Analysis of Mild Steel Assembly

A. Properties of mild steel for making shrink fit assembly

Co efficient of thermal expansion of mild steel -11.7*10 $^{-6}$/º C
Melting temperature - 1500 º C
Modulus of elasticity (E) -210 * 10^3 N/mm^2
Size of the ring for assembly
Inner diameter - 15 mm
Outer diameter - 35 mm
Thickness - 10 mm

Fig. 9: MS specimen Shrink Fit assembly

B. Heating source

Source - Oxy-acetylene gas flame
Flame temperature- 2250 º C
Analysis of expansion
Heating time on mild steel ring
noted by using timer -40 sec
Initial bore diameter of the ring -15 mm
Final bore after heating the ring upto 40 seconds- 15.9 mm

C. Analysis of shrink fit force on rod

The amount of holding stress developed once contraction of the outer hole has occurred can be calculated:
ΔD = Change of inner diameter of hole.
Here,
ΔD = 15.9 -15 = 0.9 mm
E = 210 * 10^3 N/mm^2 or 210 GPa
a = 15 mm
b = 35 mm
Therefore,
Tangential force on shaft while contraction of ring S_t = 7.434 * 10^3 N/mm^2
Radial force on shaft while contraction of ring S_r = 5.140 * 10^3 N/mm^2

D. Analysis of shrink fit assembly withstand tensile stress

Source for tensile load - By bearing puller arrangement
Tensile load given to the assembly while breaking – 510.12 N

E. Analysis of shrink fit assembly withstands shear stress

Source for torsional load - By vice and wrench arrangement
Torsional load given to the assembly while breaking - (35 * 9.81) * 0.30 = 147.15 Nm

VIII. Observation

Assembly	Time in sec
Aluminium	14
Brass	20
Copper	27
Mild steel	40

Table 2: Time Elapsed For Expansion

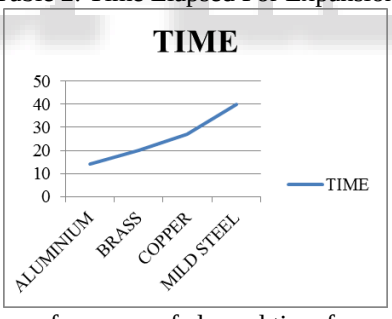

Fig. 10: performance of elapsed time for expansion

Assembly	(D_o - D_i) in mm
Aluminium	1.5
Brass	1.3
Copper	1.3
Mild steel	0.9

Table 3: Bore Expansion

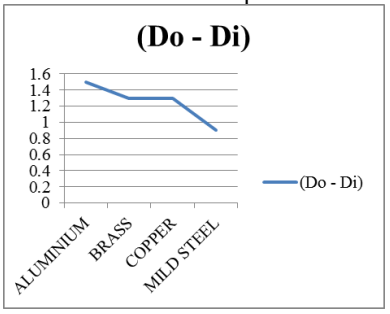

Fig. 11: performance chart of dia expansion

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Assembly	Tangential Stress $\times 10^3$ N/MM^2	Radial Stress $\times 10^3$ N/MM^2
Aluminium	4.08	2.81
Brass	2.301	1.59
Copper	6.136	4.243
Mild steel	7.434	5.140

Table 4: Holding Stress On Shaft

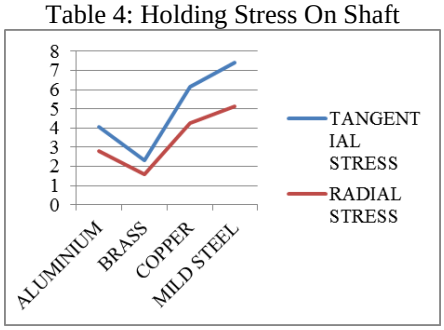

Fig. 12: performance chart of holding stress

Assembly	Tensile Load in N	Torsional Load in NM
Aluminium	196.2	73.57
Brass	245.2	103
Copper	343.3	103
Mild steel	510.12	147.15

Table 5: Load Withstand Capacity

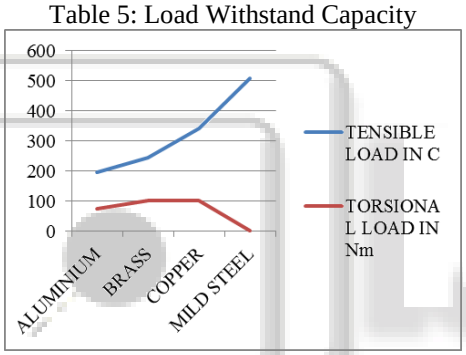

Fig. 13: performance chart of load withstand capacity

IX. Conclusion

This research involves the analysis of different metals by making shrink fit assembly which gives different performance level under thermal expansion, load withstand. Cast iron, mild steel, stainless steel, brass, copper, nickel, aluminium are the most available material used for engineering application.

In our research, we have analyzed different materials with shrink fit assembly. It gives the result of

- Dimension of ring and rod before heating.
- Thermal expansion and temperature level of the material.
- Thermal distribution over the surface.
- Change in dimension, shrinkage level of the parts after cooling.
- Strength of joining of the parts.

Here mild steel assembly gives the better performance over the other so that it withstand max load capacity. At the same time aluminum having an instant expansion at low temperature which is suitable for thermal sensitive shrink fit assembly.

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