Analysis over the Creep Fatigue and Impact Failures and Techniques to Avoid Them till a Limit

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Abstract— The creep, fatigue and impact failures are the common failures occurred in the metals and alloys. These failures mainly depend on the strength of material, structure of material, material properties, working temperature, physical environment, variable stresses etc. If any component is subjected to the variable stresses continuously then it should be made such type material or alloy that is more flexible, more stable against tensile, compressive and shear stresses. Besides it the required changes and developments in the design of the product also may help sufficiently to avoid these defects. Generally to avoid these defects the product design should be better at weakest point.

Keywords: Creep Strength, Fatigue Strength, Impact Strength

I. Introduction

The quality and performance of the product depends on the strength and rigidity of the material if it is subjected to the variable loads. In other words we can say that the product is accepted better if it is subjected to less defects and failures and gives the long stable life. To produce these type products a perfect combination is required of the material, material structure, production technique, heat treatment and design.

II. Methodology or Literature Survey

Methodology related to the proper requirement of strength and other mechanical properties in the material used for the product –

Here the strength of product may be divided according the type of failure. Means if the product is subjected to the fatigue action only then its fatigue strength should be better as far as possible. Generally the fatigue strength of the product will be excellent if the product material have the important properties as springiness, flexibility, toughness and good bending strength etc. Besides it the product subjected to the fatigue should be made by the press forging method as far as possible because by forging a homogenous internal strength is obtained. Here the material particles are added together and make many lines or planes over one another according the profile or shape of the product as fig.(A). Hence the whole product will be subjected to the resistance if any type load is applied on it as tensile load, compressive load, shear load or variable load.

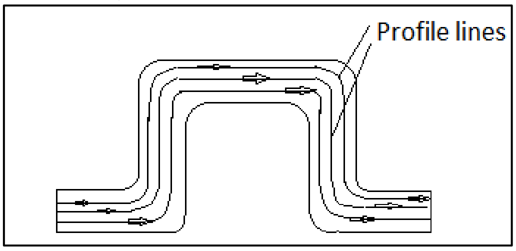

Fig. A: profile or shape of product

Means the every small point or area of the product is connected strengthfully with the profile lines rigidly. If the product is subjected to the creep action then at such condition the material used in the product should be stable at high temperature also. Means its compact or bonding strength of particles should be rigid and stable at some high temperature than normal. Generally if the product is made by press forging (for metals and alloys) then at such condition the bonding strength between particles becomes high automatically. Besides it if the product is made by many number of material layers of same size, the overall bonding strength of the product becomes more than the single product.

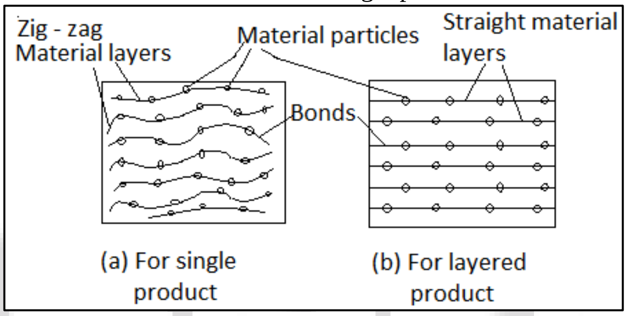

Fig. B: bonding between particles of the material

Here according the fig.(B) it is clear that in single product the bonding between particles may be more zig - zag while in layered product the bonding between particles is straight and uniform. If the product is subjected to the impact action again and again then here it is necessary that the toughness of the material of the product should be maximum as far as possible. Besides it if the material of the product has the other properties as springiness, flexibility etc. the effect of impacts and vibrations on the material is also reduced sufficiently. The product should be made by press forging method so that the good bending strength is obtained. Besides it a proper gap should be provided to deflect the product easily.

III. Analysis

A. Analysis Related to the Effect of Other Factors on the Fatigue Failure:

Let the maximum deflection developed one sided (y) in fatigue depends on the variable stress (σ_v) of material, bonding strength of material (σ_b), density of material (ρ) and crossectional area of the product (A).

Then by Buckingham's π theorem $\rightarrow f(\sigma_v, \sigma_b, \rho, A, y) = 0$ $\rightarrow$ Equ.(A)

So the number of variables

(n) = 5

Now on putting the dimensions of all variables $\rightarrow$

$A = (L^2)$, $y = (L)$, $\rho = (ML^{-3})$, $\sigma_v = (ML^{-1}T^{-2})$, $\sigma_b = (ML^{-1}T^{-2})$

So it is clear that the number of dimensions (m) = 3

So the number of π terms = 5-3 = 2

So we can write as $f_1(\pi_1, \pi_2) = 0 \rightarrow$ Equ.(B), where

$\pi_1 = (y^{a1}.\ \sigma_v{}^{b1}.\rho^{c1}.A) \rightarrow$ Equ.(C)

$\pi_2 = (y^{a2}.\ \sigma_v{}^{b2}.\rho^{c2}.\sigma_b) \rightarrow$ Equ.(D)

Now on putting the all dimensions at both sides of the equation (C) $\rightarrow$

$(M^0L^0T^0) = \{(L)^{a1}.\ (ML^{-1}T^{-2})^{b1}\ (ML^{-3})^{c1}.(L^2)\}$

On comparison of dimensions at both sides $\rightarrow$

$a_1-b_1-3c_1+2 = 0$ Equ.(E)

$b_1+c_1 = 0$ and $-2b_1 = 0$

So $b_1 = 0$ then $c_1 = 0$

Then from equation (E)$\rightarrow$ $a_1 = -2$

Then again from equation(C) –

$\pi_1 = \{ A/y^2\} \rightarrow$ Equ.(F)

Now on putting the all dimensions at both sides of the equation (D) $\rightarrow$

$(M^0L^0T^0) = \{(L)^{a2}.\ (ML^{-1}T^{-2})^{b2}\ (ML^{-3})^{c2}.(ML^{-1}T^{-2})\}$

On comparison of dimensions at both sides $\rightarrow$

$a_2- b_2 -3c_2-1 = 0$ Equ.(G)

$b_2+c_2+1=0$ and $-2b_2-2=0$ So $b_2 = -1$ and $c_2 = 0$

Then from equation(G)$\rightarrow$ $a_2 = 0$

Then again from equation(D) –

$\pi_2 = \{ \sigma_b / \sigma_v \} \rightarrow$ Equ.(H)

Then from equation (B) $\rightarrow$

$f_1 (A/y^2, \sigma_b / \sigma_v) = 0$

Then $A/y^2 = \phi(\sigma_b / \sigma_v)$

Or $y^2/A = \phi(\sigma_V / \sigma_b)$

Or $y^2 = A\phi(\sigma_V / \sigma_b)$

Hence the one sided deflection in fatigue does not depend on the density of material (ρ).

B. Analysis Related to the Effect of Other Factors on the Creep Failure:

Let the creep per hour (y) in creep failure depends on the bonding strength of material (σ_b), density of material (ρ), crossectional area of the product (A) and time (t).

Then by Buckingham's π theorem $\rightarrow f(\sigma_v, t, \rho, A, y) = 0$ $\rightarrow$ Equ.(A)

So the number of variables

(n) = 5

Now on putting the dimensions of all variables $\rightarrow$

$A = (L^2)$, $y = (L)$, $\rho = (ML^{-3})$, $\sigma_v = (ML^{-1}T^{-2})$, $t = (T)$

So it is clear that the number of dimensions (m) = 3

So the number of π terms = 5-3 = 2

So we can write as $f_1(\pi_1, \pi_2) = 0 \rightarrow$ Equ.(B), where

$\pi_1 = (A^{a1}.\ c^{b1}.\rho^{c1}.\ \sigma_b) \rightarrow$ Equ.(C)

$\pi_2 = (A^{a2}.c^{b2}.\rho^{c2}.t) \rightarrow$ Equ.(D)

Now on putting the all dimensions at both sides of the equation (C) $\rightarrow$

$(M^0L^0T^0) = \{(L^2)^{a1}.\ (LT^{-1})^{b1}\ (ML^{-3})^{c1}.(ML^{-1}T^{-2})\}$

On comparison of dimensions at both sides $\rightarrow$

$2a_1+b_1-3c_1-1 = 0$ Equ.(E)

$c_1 +1= 0$ and $-b_1-2= 0$

So $b_1 = -2$ and $c_1 = -1$

Then from equation (E)$\rightarrow$ $a_1= 0$

Then again from equation(C) –

$\pi_1 = \{ \sigma_b/\rho c^2\} \rightarrow$ Equ.(F)

Now on putting the all dimensions at both sides of the equation (D) $\rightarrow$

$(M^0L^0T^0) = \{(L^2)^{a2}.\ (LT^{-1})^{b2}\ (ML^{-3})^{c2}.(T)\}$

On comparison of dimensions at both sides $\rightarrow$

$2a_2+ b_2 -3c_2 = 0$ Equ.(G)

$c_2 = 0$ and $- b_2+1 = 0$

Then $b_2 = 1$

Then from equation(G)$\rightarrow$

$a_2 = -1/2$

Then again from equation(D) –

$\pi_2 = \{ ct / A^{1/2} \} \rightarrow$ Equ.(H)

Then from equation (B) $\rightarrow$

$f_1 (\sigma_b/\rho c^2, ct / A^{1/2}) = 0$

Then $ct/A^{1/2} = \phi(\sigma_b / \rho c^2)$

Or $t = (A^{1/2}/c)\phi(\sigma_b / \rho c^2)$

Hence the creep per hour in creep failure depends on the given all factors.

C. Analysis Related to the Effect of Various Factors on Impact Failure –

Let the impact failure depends on the various factors as maximum energy stored in the material during impact (U), density of material (ρ), bonding strength of material (σ_b), maximum deflection of product at impact point (y) and bulk modulus of material (K).

Then by Buckingham's π theorem $\rightarrow f(\sigma_b, U, \rho, K, y) = 0$ $\rightarrow$ Equ.(A)

So the number of variables

(n) = 5

Now on putting the dimensions of all variables $\rightarrow$

$U = (ML^2T^{-2})$, $y = (L)$, $\rho = (ML^{-3})$, $\sigma_b = (ML^{-1}T^{-2})$, $K = (ML^{-1}T^{-2})$.

So it is clear that the number of dimensions (m) = 3

So the number of π terms = 5-3 = 2

So we can write as $f_1(\pi_1, \pi_2) = 0 \rightarrow$ Equ.(B), where

$\pi_1 = (y^{a1}.\ U^{b1}.\rho^{c1}.\sigma_b) \rightarrow$ Equ.(C)

$\pi_2 = (y^{a2}.U^{b2}.\rho^{c2}.K) \rightarrow$ Equ.(D)

Now on putting the all dimensions at both sides of the equation (C) $\rightarrow$

$(M^0L^0T^0) = \{(L)^{a1}.\ (ML^2T^{-2})^{b1}\ (ML^{-3})^{c1}.(ML^{-1}T^{-2})\}$

On comparison of dimensions at both sides $\rightarrow$

$a_1+2b_1-3c_1-1 = 0$ Equ.(E)

$b_1+c_1+1= 0$ and $-2b_1-2= 0$

So $b_1 = -1$ and $c_1 = 0$

Then from equation (E)$\rightarrow$ $a_1= 3$

Then again from equation(C) –

$\pi_1 = \{y^3\sigma_b / U\} \rightarrow$ Equ.(F)

Now on putting the all dimensions at both sides of the equation (D) $\rightarrow$

$(M^0L^0T^0) = \{(L)^{a2}.(ML^2T^{-2})^{b2}\ (ML^{-3})^{c2}.(ML^{-1}T^{-2})\}$

On comparison of dimensions at both sides $\rightarrow$

$a_2+2b_2 -3c_2 -1= 0$ Equ.(G)

$b_2+c_2+1= 0$ and $-2b_2-2 = 0$

Then $b_2 = -1$ and $c_2 = 0$

Then from equation (G) $\rightarrow$

$a_2 = -1$

Then again from equation (D) –

$\pi_2 = \{K / Uy\} \rightarrow$ Equ.(H)

Then from equation (B) $\rightarrow$

$f_1(y^3\sigma_b/U, K /Uy) = 0$

or $K/Uy = \phi(y^3\sigma_b/U)$
or $K = Uy\phi(y^3\sigma_b/U)$
Hence it is clear that the impact failure does not depend on the density of the material (ρ).

IV. Final Result

Various type mechanical and metallurgical properties are improved if the product is made by forging method.

By improving some required mechanical and metallurgical properties the resistivity of the product against the fatigue failure, creep failure and impact failure may be improved sufficiently.

V. Conclusion

Hence we can say that if we provide the proper strong support at the weak point or on the cause of failure then the failure may be avoided till a long time period.

References of the Books

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