The Study of Erosive Property of EN-8 and AISI 1020 Material using Gas Jet Erosion Tester

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Abstract - *A Gas Jet Erosion Tester is generally used to study the relative erosion behaviour of coated and uncoated materials at varying erodent velocity, erodent discharge, erodent size and attack angle. In many applications like propeller blades of turbo machinery, wear resistant coatings in helicopter blades and turbine blades and other sectors like coal plants and material handling industries, erosion problem is a major concern where erosion rate affects the operation of entire structure. In such cases, erosion rate plays a vital role in design, selection of efficient material and material coatings. Automobile sector is one such where the erosion rate of EN-8 material affects the working of general-purpose axles and shafts, gears, stressed pins and keys. In the present study using Gas Jet Erosion Tester, the wear volume characteristic of EN-8 material and AISI 1020 with varying attack angle and erodent velocity is respectively determined.*

Key Words*: *Erodent velocity; Erodent discharge; Attack angle; EN8; AISI 1020; Gas Jet Erosion Tester

1. INTRODUCTION

In early 1800's, machines were designed to operate at slow speeds having larger clearances between the machine elements so that excessive friction could be avoided and the dimensional variation could often be tolerated without affecting the performance of the machine. However, development of high speed engines in the early 20th century gave rise to a concept of wear which has an impact on performance of the modern machines till date. In recent years, with the efficient use of electron microscope and the microanalysis method to characterise the wear phenomenon, rapid development in understanding the complex phenomenon like slip and twinning has been possible. Historically, major progress in understanding wear mechanisms and development of wear were which were used to quantify wear were seen during 1950-1965. During this period, prominent laws such as Linear Wear Law (also called the Archard equation) and Khrushov Abrasive Wear law were developed where the common types of wear namely, adhesive and abrasive were taken into account.

Wear is a complex event, consisting of several simultaneous and interacting processes, involving mechanical, chemical and material parameters in addition to few complex mechanisms like slip and twinning (Ref 1). Erosion wear is the function of erodent discharge, erodent velocity, erodent size and shape, carrier fluid, environment conditions, attack angle and hardness of both particle and target material. This type of wear is amongst the principal forms of wear, caused by the impingement of solid erodent particles, streams of fluids on a target surface leading to material abstraction. Wear is characterised by change in appearance and surface profile of a body as shown in Fig- 1. In broad-spectrum, it is the contour aspects of these changes, such as a dimensional variation, a change in profile, or residual thickness of a coating, that results in failure. Optical scanner windows, lens, and decorative finishes are some common examples for dimensional variation.

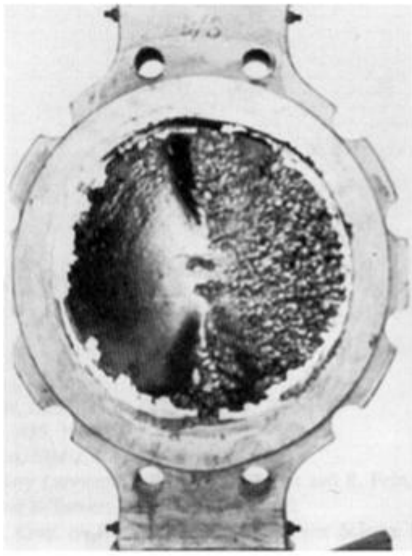

Fig- 1: Examples of wear showing erosion damage on a butterfly valve component.

Different models having made use of various materials in different environment conditions explain the erosion phenomenon. Among those illustrations, Naresh Kumar and Rupinder Kanwar (Ref 2) considered uncoated and coated sample with Chromium Oxide for evaluating the erosion studies with varying attack angle. They observed that the uncoated samples (SS-304) gave higher erosion rate at 60^0 than the 90^0 impact angles and the coated sample of SS-304 (coated with Cr_2O_3) gave better results in terms of erosion when compared to uncoated sample, having higher material erosion at 60^0 impact angle in both cases.

Abhishek Jivrag and Shashikant Pople (Ref 3) used Inconel625 as the target material for the evaluation of erosion behaviour. The wear rate from Inconel625 was at the peak at 30^0 attack angle and had similar values when carried out at ambient and elevated temperatures (200^0C). J. Malik et. al (Ref. 4) experimentally investigated the erosion behaviour of stainless steels (AISI 310S and AISI 316), carbon steel (AISI 1020) and Aluminium 6060 and used bulk hardness of the target material to evaluate the erosion behaviour. They concluded that, for all the test specimens the erosion rates increased with increase in impact velocity and the maximum erosion rate in the specimen was found to occur between 15^0 and 30^0 impact angles.

Among various models presented for velocity calculation, a model presented by A. Ruff and L. Ives (Ref 5) refers to the velocity measurement of solid erodent, where the velocity measurement is calculated by manually measuring the distance travelled by the erodent particles using Double-Disc method.

Cullen M. Moleejane et. al (Ref 6) considered the effect of microstructural features of EN8 material and recorded the mechanical response of the system caused due to the grain size present within the solid state mixtures using heat treated specimen. After performing hardness test and tensile tests, they concluded that with decrease in grain size, the mechanical strength and toughness of the EN8 material increased.

2. OBJECTIVES

The main objectives of the current work are:

1. To carry out Gas Jet Erosion studies on unalloyed medium carbon steel (EN8) with varying erodent attack angles.
2. To carry out G76 test using AISI 1020 steel.
3. To establish a quantitative relationship between the variables from the results obtained from erosive test on AISI 1020 steel at 30 m/s and 70 m/s independently.
4. To establish a quantitative relationship between the variables from the results obtained from erosion test of EN8 material subjected to different attack angles.

3. METHODOLOGY

1. Material selection
2. Obtaining EN8 material from the supplier.
3. Preparing the EN8 specimen.
4. Carry out tests to obtain the mechanical properties.
5. Subjecting the specimen to Hardness Test (Brinell).
6. Preheat the erodent (at 150^0C) to ensure that it is free from moisture content.
7. Carry out velocity and discharge calibration of the erodent.
8. Perform required tests.

4. EXPERIMENTAL SETUP AND TESTING

In this study, an Air Jet Erosion Tester manufactured by DUCOM Instruments Private Limited (Model:TP-471-1000) was used to study the solid particle erosion behaviour of EN-8 and AISI 1020 material (Fig- 2).

Fig- 2: Ducom Gas Jet Erosion Test Rig

4.1 EXPERIMENTAL SETUP

The block diagram of the experimental setup is as shown in Fig-3. The nozzle dimensions and other specifications of the equipment comply with ASTM-G76-95 (Ref 7) standard and all tests were performed at ambient temperature. Erodent discharge was calculated by collecting the erodent mass flow through the nozzle in 10 min at a specified wheel frequency. Erodent velocity was measured using double disc rotating method as explained by A. Ruff and L. Ives (Fig- 4) with an accuracy of ±2 m/s.

Both erodent discharge and velocity calibrations were periodically checked.

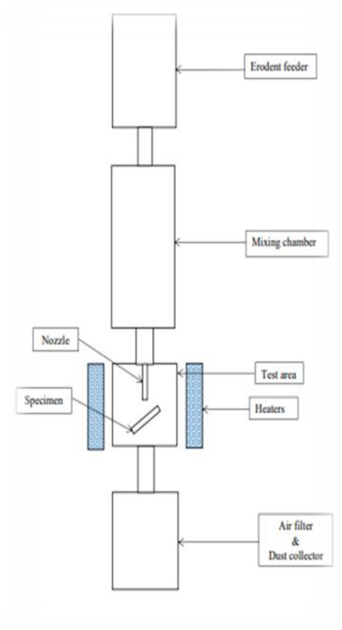

Fig- 3: Block diagram of experimental setup

Fig- 4: Double-Disc unit (left) and angle measurement for velocity (right)

4.2 TEST SPECIMENS

Solid particle erosion tests were performed for EN-8 and AISI 1020 material. The chemical composition and mechanical properties of each material is given in Table-1 and Table-2 respectively. All specimens were machined into required size and ground up to 400 grit size paper to ensure uniform surface finish.

Table -1: Chemical composition of test materials (Wt. %)

Grade	C	Mn	P	S	Si
EN8/080M40	0.36-0.44	0.60-1.00	0.05	0.005	0.10-0.40
AISI 1020	0.17-0.23	0.3-0.6	≤ 0.04	≤ 0.05	-

Table – 2: Mechanical properties of test materials

Material	Max. Stress (N/mm²)	Yield Stress (N/mm²)	0.2% Proof Stress (N/mm²)	Elongation	BHN
EN8/080M40	700-850	465 (Min.)	450 (Min.)	16% Min.	201-255
AISI 1020	420	350	325	15% Min.	121

4.3 EXPERIMENTAL CONDITIONS

Erosion tests were performed in accordance with ASTM G-76-95 test standard (Ref 6). Angular alumina with particle size of 50 microns was used as an erodent in the experiments. To make sure that the alumina is free from moisture content, the erodent was baked in the oven at 150^0 C before pouring the erodent into the hopper. The compressed air stream was used to accelerate alumina particles passes first through a moisture trap and then through an air filter to ensure clean and dry air. Tests were carried out at the velocities of 30 and 70 m/s. At each velocity, the erosion characteristics were investigated at six attack angles starting from 15^0 to 90^0 measured from vertical (Fig-5) in steps of 15^0 while keeping the particle flow rate unchanged (2 g/min) in all experiments. All the tests were conducted for 10 minutes. The samples were then cleaned and weighed to determine mass loss and volume loss of the specimen.

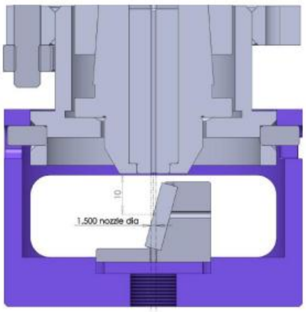

Fig- 5: Attack angle setup

The erosion test from EN-8 specimen was conducted in the conditions as mentioned in Table-3.

Table-3: Test conditions

Erodent Used	50 micron Alumina
Erodent discharge rate	2 g.min^{-1}
Erodent velocity	30 m.s^{-1}

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Attack angle	$15^0, 30^0, 45^0, 60^0, 75^0$ and 90^0
Test temperature	Ambient
Nozzle	Alumina (ϕ15 x ϕ1.5 x 50 mm long)

5. RESULTS AND DISCUSSIONS

Photographs of EN-8 Samples (Fig-6) shows the scars caused due to erosion from the surface of the specimens subjected to various attack angles. Among them, larger scar is seen when the specimen is subjected to minimum attack angle. This is because of the maximum contact surface area exposure for the erodent particles.

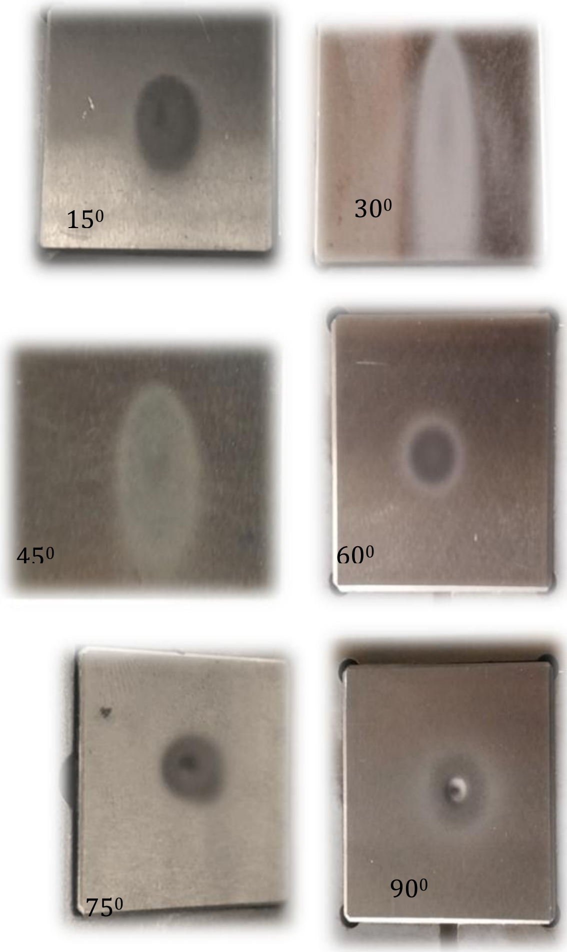

Fig- 6: Wear scars produced when EN8 specimen is subjected to different attack angles

The variation in volume loss (%) with the change in attack angle is shown in Table-4.

Table-4: Comparison of volume loss (%) from EN-8 specimen with various attack angles.

Attack angle	15^0	30^0	45^0	60^0	75^0	90^0
Volume loss (%)	0.0301	0.0203	0.0201	0.0156	0.0124	0.0114

The Chart-1 shows the 2nd order variation of volume loss (%) with attack angle whose polynomial function is given by $y = 2.54E\text{-}06x^2 - 4.98E\text{-}04x + 3.58E\text{-}02$ with $R^2=0.947$.

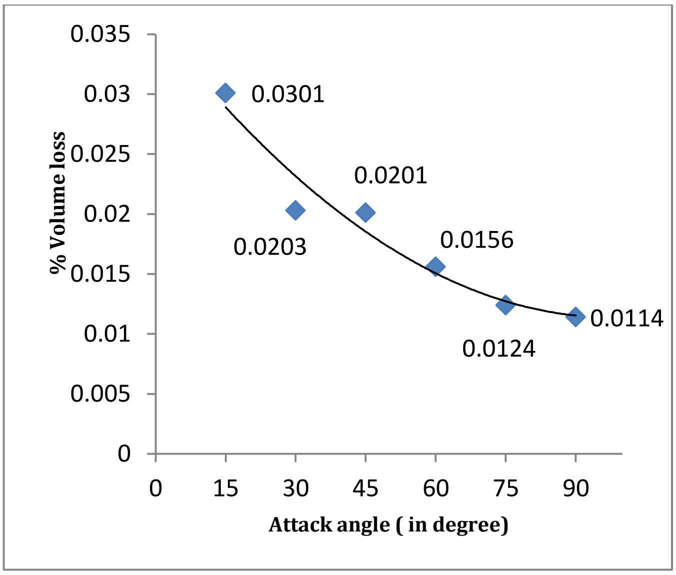

Chart- 1: 2nd order variation

The Chart-2 shows the 5th order variation of volume loss (%) with attack angle whose polynomial function is given by $y = -2.66E\text{-}10x^5 + 7.58E\text{-}08x^4 - 8.17E\text{-}06x^3 + 4.11E\text{-}04x^2 - 9.70E\text{-}03x + 0.107$ with $R^2=1$.

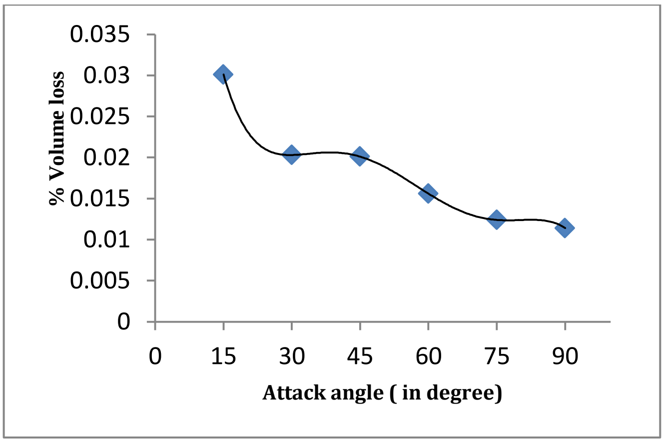

Chart- 2: 5th order variation

The progressive wear volume from the AISI 1020 steel at erodent velocity 30 m/s and 70 m/s incurred during the G76 test are as shown in Table-5.

Table- 5: Comparison of Erosion value of AISI 1020 specimen with various erodent velocities.

Erodent velocity (m/s)	30			70		
Erosion Value (mm^3/g)	0.0368	0.0394	0.0432	0.3507	0.3634	0.3647

The Chart-3 shows the 2nd order variation of cumulative Erosion Value for AISI 1020 material, erodent velocity being at 30 m/s whose polynomial function is given by y = 6.35E-04x² + 6.35E-04x + 3.56E-02 with R^2=1.

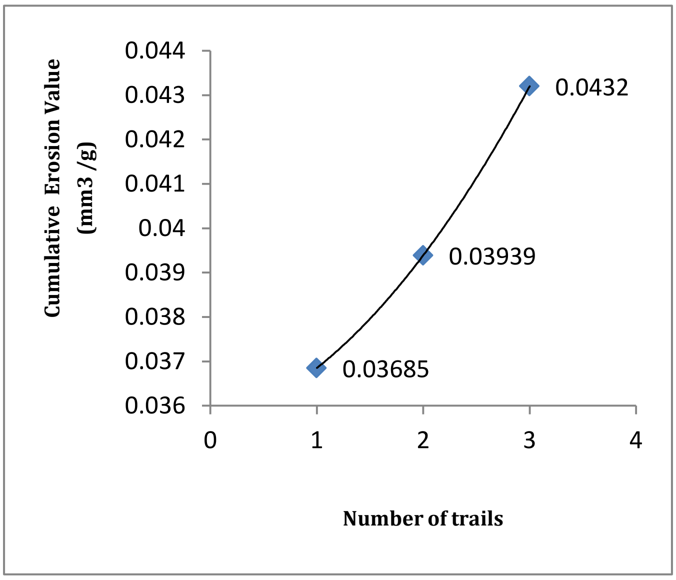

Chart- 3: Cumulative Erosion Value at 30 m/s

The Chart-4 shows the 2nd order variation of cumulative Erosion Value for AISI 1020 material, erodent velocity being at 70 m/s whose polynomial function is given by y = -5.71E-03x² + 2.98E-02x + .327 with R^2=1.

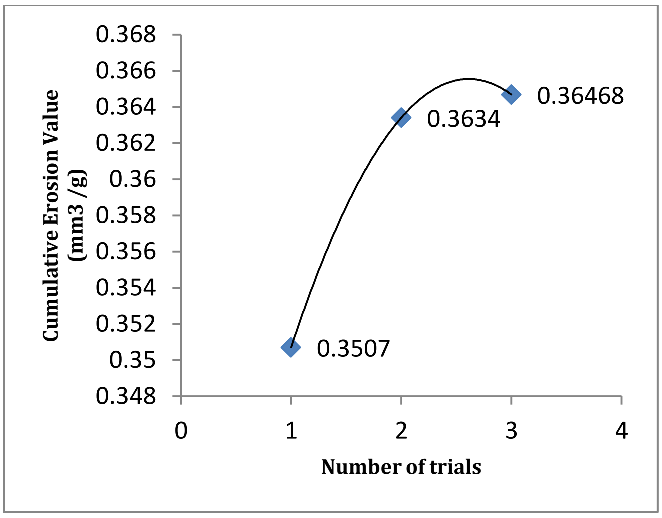

Chart- 4: Cumulative Erosion Value at 70 m/s

6. CONCLUSIONS

1. The wear in uncoated samples of EN-8 material shows the ductile type behaviour due to their maximum wear rate being at lower attack angles (15^0, 30^0 and 45^0). The wear rate considerably decreased at higher attack angles (60^0, 75^0 and 90^0), highest volumetric loss being at 15^0 attack angle.

2. The wear scars were characterised by an ovoid shape at attack angles 15^0, 30^0 and 45^0, whereas a nearly circular was seen at 60^0, 75^0 and 90^0.

3. The erosion value of the standard AISI 1020 material describes the wear rate being less at lower erodent velocity and the material wear increases considerably with increase in erodent velocity.

4. The volume loss (%) and attack angle for the given environmental conditions can be related by 2nd order polynomial function which is given by:
y = 2.54E-06x² - 4.98E-04x + 3.58E-02 with R^2=0.947.

5. The volume loss (%) and attack angle for the given environmental conditions can be related by 5th order polynomial function which is given by:
y = -2.66E-10x⁵ + 7.58E-08x⁴ - 8.17E-06x³ + 4.11E-04x² - 9.70E-03x + 0.107 with R^2=1.

6. The 2nd order polynomial function for cumulative Erosion Value of AISI 1020 material, erodent velocity being at 30 m/s for given test conditions is given by:
y = 6.35E-04x² + 6.35E-04x + 3.56E-02 with R^2=1.

7. The 2nd order polynomial function for cumulative Erosion Value of AISI 1020 material, erodent velocity being at 70 m/s for given test conditions is given by:
y = -5.71E-03x² + 2.98E-02x + .327 with R^2=1.

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BIOGRAPHIES

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