GEOMETRICAL CONSIDERATIONS EFFECT ON COMBUSTION CHAMBER PERFORMANCE

M. E. KASSAB *

ABSTRACT

The performance of a combustion chamber and flame stability depend mainly on its geometrical design. It is important to create an anchored flame in a determined position which could be achieved by the creation of a recirculation zone. The recirculated flow is obtained utilizing the combustor geometry.

A simplified mathematical model is developed to correlate the relation between the geometry and the recirculated flow in addition to the effect of other parameters such as injection methods and temperature inside the combustion zone.

Using the cold flow simulation and visualization methods the flow structure at different positions could be traced. Quantitative visualization measurements are used to estimate the flow in the recirculated zone.

A comparison between the theoretical results and experimental measurements shows an acceptable coincidence.

* Dr. Eng., Research Specialist (Research & Development Dept., Engine Factory, Arab Org. for Indust., Helwan, Cairo, Egypt). Member AIAA (U.S.A). Member AAAF (France).
I. INTRODUCTION

In a combustion chamber, especially in a turbojet combustor, the designer's task is to achieve an anchored flame in a determined position under all the severe operating conditions. This zone into which the fuel would be sent.

Flame stabilization at the severe conditions is realized by the creation of a recirculation zone which is the center of the intensive change between fresh mixture (or air) and the burned hot gas.

The recirculated flow required for flame stability is created using geometrical methods, i.e., utilizing the chamber construction, the create the prementioned zone, which means that the designer is restricted by some considerations related to the combustion process, one of them is the flow distribution between the three zones of the combustion chamber (combustion, dilution, and cooling). The second is the flame stability directly related to the flow in the primary (combustion) zone.

2. STABILITY BY GEOMETRICAL METHODS

2.1. STABILITY BY CONFINED JETS

This stability mode is related to the jet theory and flow propagation and diffusion between the jet and surroundings depending on the relative velocity (fig.1).
2.2. BLUFF BODY STABILITY

A "bluff body" is a solid object of such a shape that, when it is suspended in a fluid stream, a re-circulatory flow is formed in its immediate wake. This recirculation carries up-stream and mixes with fresh, unburned gas, the products of combustion of fuel and oxidant which were injected earlier.

![Diagram of recirculating flow behind sphere, gutter and strut.]

FIG. 2. RECIRCULATING FLOW BEHIND SPHERE, GUTTER AND STRUT.

2.3. STABILITY BY OPPOSITE INJECTION

Which creates a zone of recirculation similar to that created in the wake of a bluff body. The characteristics of that zone depend mainly on the relative velocity between the jet and the opposite.

![Diagram of stability by opposite injection.]

Fig 3
2.4. STABILIZATION BY LATERAL ORIFICES

Which create a set of inclined jets, when meet, form a zone of recirculation will be the center of fuel injection, and consequently, center of combustion. That form of flow and the effect of geometrical considerations on it, is the interest of the present paper.

![Diagram of flow](image)

Fig(4)

3. THEORETICAL STUDY

A simplified mathematical model is developed to correlate the relation between the geometry of both the chamber and orifices and the flow distribution inside the combustor. Simplification of the model appears in the following assumptions:

- Similarity of cold and hot flows.
- Incompressible flow.
- Steady flow.
- Similarity of the combustor geometry allow to treat only a sector as two dimensional flow.

3.1. GEOMETRICAL EFFECT ON THE FLOW DISTRIBUTION:

The results show the direct relation between the flow passing to the primary flow through the orifices and the relative area of the orifices.
3.2. RECIRCULATED FLOW CALCULATION;

3.2.1. With no premixed flow:

The model understands different fuel injection modes, and the first case with no premixed flow, shows how changes the recirculated flow with the combustor geometry (blockage) at different jet angles.
3.3.2. Permixed flow injected through swirlers;

One of the injection modes in the combustion chamber is the swirler which has an interference effect on the flow inside the combustion zone.

![Fig. 6](image)

3.3.3. Permixed flow injected through prevaporization can:

Another injection mode where a fuel / air mixture is injected in the opposite direction of the main flow inside the recirculation zone and interfering with. The prevaporization flow has an effect on both quantitative and qualitative feature of the recirculation zone. 

![Fig. 7](image)
3.4. GEOMETRICAL EFFECT ON THE ENTRAINED FLOW:

This flow is the vortex formed inside the recirculation zone and represents an important factor of flame stability. The figure shows the effect of orifices geometry on that flow.

![Graph](image1)

3.5. INTERFERENCE OF TEMPERATURE EFFECT:

The temperature effect interferes with the geometrical effect on both recirculated and entrained flow. Some results are shown in figures (9, 10) which show that the blockage has a rapid effect on the recirculated flow at high temperature of combustion.

![Graph](image2)
4. EXPERIMENTAL STUDY:

Using a hydromechanical model, the flow inside one sector of the combustion chamber is studied after the adjusting of the similarity with the actual flow. Examples of the results and their comparison with the theoretical results are shown in figures.
REFERENCES


Nomenclature

- $m_t$: Total flow (Compressor exit).
- $m_1$: Primary flow.
- $m_R$: Recirculated flow = R. $m_1$
- $m_c$: Can flow = C. $m_1$
- $m_{sw}$: Swirl flow = Sw. $m_1$
- $m_e$: Entrained flow
- $\alpha_j$: Jet angle
- B: blockage