A COMPARATIVE STUDY OF THE EFFECT OF STATIC AND DYNAMIC FORMING ON THE BIAXIAL NOTCHED FATIGUE STRENGTH OF 1100 SH 14 ALUMINUM

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by
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Abstract

To determine the relative effects of explosive and static forming on the fatigue life of 1100 SH 14 Aluminum, commonly known as commercially pure Aluminum, biaxial fatigue tests were performed on statically and dynamically formed domes. It was found that the life of the statically formed material was significantly more than the explosively formed material. It is proposed that the reduction in fatigue life may be due to the higher hardness of the statically formed material, and/or the formation of microcracks due to the explosive shock wave.

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CHAPTER 1

Introduction

1.1 Background

The advent of a new generation of "high-velocity metal working processes" including electromagnetic, electrohydraulic, pneumatic-mechanical and explosive metal working, was a major breakthrough in sheet metal forming technology in recent years. In general these most recent high-velocity metal working techniques differ from conventional processes in that the forming velocity is at least one order of magnitude higher as compared in Figure 1.1. The characteristics of various high-velocity metal working processes are given in Table 1.1.

As process techniques became more refined and the limitations of the process became clearer, the role of high-velocity metal forming became increasingly important. The technical requirements of the United States space program gave an impetus to the developement and refining of high-energy forming techniques. The demands of the aerospace industry included the following: the forming of metal parts and components beyond the then present capabilities of conventional equipment, parts made of exotic alloys which were difficult to form, parts requiring very close tolerances, and parts required in such small numbers that the cost of conventional equipment was not justified.

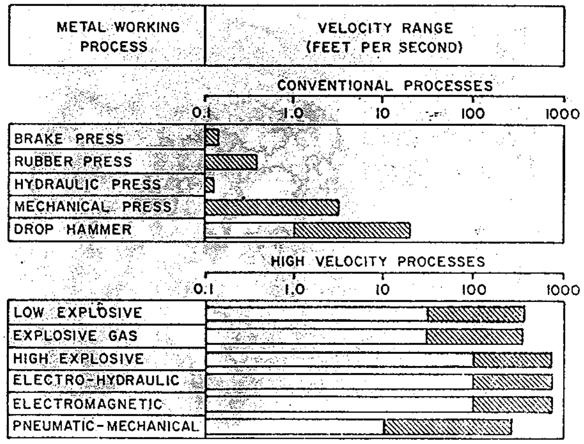

Figure 1.1 Deformation Velocities in High-Velocity and Conventional Metalworking Processes (Ref. 1)

	High explosive—standoff	High explosive—direct contact	Propellant closed die	Gas mixtures		Electromagnetic	Electrohydraulic		Pneumatic-mechanical
				Combustion	Detonation		Exploding bridgewire	Spark discharge	
Metalworking operations.	Draw forming, expanding, flanging, stretch forming, coining, blanking, sizing, beading.	Hardening, welding, cutting, perforating, cladding, powder compacting.	Tube bulging, powder compacting, sizing, perforating, flanging.	Tube bulging, flanging, sizing, stretch forming, draw forming.	Draw forming, stretch forming.	Swaging, tube bulging, sizing, flanging, shallow drawing, coining, blanking.	Tube bulging, drawing, flanging, coining, blanking, sizing.	Tube bulging, drawing, flanging, coining, blanking, sizing.	Forging, powder compacting, extruding.
Size limitations	Limited only by available blank size, presently ~ 12 ft.	Part size not limiting.	1-in. to 5-ft. diameter. Limited by equipment.	Up to 5-ft. diameter.	Present: 1 ft. diameter. Future: 9 ft. diameter.	1-in. to 1-ft. diameter; 4-ft. diameter and larger in sizing operations.	¼-in. to 4-ft. diameter or larger.	¼-in. to 4-ft. diameter or larger.	Up to ~ 2-ft. diameter; larger on future machines.
Shape complexity	Small and intricate, large and simple.	Simple shapes	Compound surfaces, nonsymmetrical shapes.	Compound surfaces, nonsymmetrical shapes.	Simple dishes, domes, surfaces of revolution.	Compound surfaces, corrective forming on large complex shapes.	Complex surfaces and shapes, especially tubular.	Complex surfaces and shapes, especially tubular.	Complex shapes, thin forged sections.
Principal advantage	Neither pressure nor energy limited; i.e., large parts.	Extremely high pressures (1.5 to 7 million psi).	Reduces number of operations to produce complex parts.	Uniform pressures permitting accurate forming of thin parts.	Adaptability to production forming.	Controllability and repeatability, swaging operations.	Controllability and repeatability.	Controllability and repeatability.	Controllability and repeatability, close tolerances on forgings.
Capital investment	Low	Low	Low	Moderate	Moderate to high	Moderate to high	Moderate	Moderate	Moderate.
Tooling costs	Low	None to low	Moderate	Moderate to high	Low	High if work coil is regarded as part of tooling.	Low	Low	Moderate. (See ch. 6.)
Labor costs	High	Moderate	Low to moderate	Moderate to high	Moderate	Moderate	Moderate	Moderate	Moderate.
Production rate	0.5 to 4 parts per hour or less depending on part and facility.	0.5 to 4 parts per hour depending on part and facility.	2 to 12 parts per hour depending on part and facility.	2 parts per hour or less.	6 to 12 parts per hour.	Up to 1,000 parts per minute for simple parts and automated transfer equipment.	4 to 12 parts per hour or more depending on part complexity and equipment.	Up to ~ 50 parts per hour depending on part complexity and equipment.	Up to ~ 200–300 parts per hour with automatic equipment; depends on part complexity.
Energy costs	Low	Low	Low	Low	Very low	Moderate	Moderate	Moderate	Low.
Leadtime required to place facility in operation.	Short	Short	Short	Moderate	Moderate to long	Moderate to long	Moderate to long	Moderate	Moderate.
Safety considerations.	Operation with trained personnel, safety equipment, and shielding.	Trained personnel	Trained personnel.	Trained or experienced personnel.	Trained or experienced personnel.	Equipment interlocks, high voltage safety practices, trained personnel.	Equipment interlocks, high voltage safety practices, trained personnel.	Equipment interlocks, high voltage safety practices, trained personnel.	Guards and shields, trained personnel.
Facility location	Usually requires remote or special facility.	Field or plant	In-plant or separate facility.	Separate facility	In-plant	In-plant	In-plant	In-plant	In-plant.
Energy range	Detonator to ~ 100 lb. high explosive at 1–2 × 10⁶ ft-lb per lb.	0.5 to 8 lb. per ft² high explosive.	Low to moderate (squib, smokeless cartridge).	Low (burning gas mixtures).	Low to moderate (detonation wave in gas).	4 500 to 175 000 ft-lb.	20 000 to 175 000 ft-lb.	10 000 to 100 000 ft-lb.	Up to 500 000 ft-lb.
Workpiece deformation velocity.	60–400 ft/sec	Not applicable	50–200 ft/sec	60–100 ft/sec	60–200 ft/sec	50–200 ft/sec	50–200 ft/sec	50–200 ft/sec	50–200 ft/sec.
Energy transfer medium.	Water, elastomers, sand, molten salts.	Direct contact or buffer material.	Air or water; high-velocity projectile or ram.	Gas pressure	Gas pressure	Air (could be operated in vacuum).	Water or other suitable liquid.	Water or other suitable liquid.	High-velocity ram.

Table 1.1 Charactaristics of High-Velocity Metalwork Processes (Ref. 1)

Because explosives were found to be the most compact and the cheapest energy source available (one pound of dynamite will release approximately two million joules of energy, yet costs less than $0.40) explosive forming has been utilized more in industry than most other high-energy forming processes.

Not only was explosive forming being used in the aerospace field but also in such diverse applications as the formation of stainless steel dentures, missile nose cones, propeller hubs, helicopter crew leg armour, railway tank car bulk heads, pressure vessel heads, and prototypes in the automotive industry.

The changes in mechanical and metallurgical properties of materials formed by high strain rates are not fully understood. Moreover, the relative effect of explosive forming on material properties as compared to the effect of static forming requires further investigation. Most results published have given qualitative rather than quantitative figures. There has also been considerable lack of agreement in published research.

In recent years one of the more important fields of endeavour involved the comparative fatigue life of explosively and statically formed materials. Findings have ranged from negligible differences between static and dynamic forming to significantly reduced fatigue life due to explosive forming. This decreased fatigue life has been attributed to microcrack formation and nonuniformity in straining. Due to the uncertainty of the cause of the decreased fatigue strength more research is required to clarify the effect of explosive forming on fatigue strength.

1.2 Statement of Problem

This thesis is principally an experimental study of the comparative effect of dynamic and static forming on the fatigue life of 1100 SH 14 Aluminum.

1.3 Scope of Thesis

The thesis is divided into five chapters. Chapter One is an introduction to the field of explosive forming.

A review of literature associated with the comparison of the effects of dynamic and static forming on materials is given in Chapter Two.

Chapter Three describes all experimental studies carried out relating to and including the relative effect of explosive and static forming on the fatigue life of 1100 SH 14 Aluminum.

Test results and discussion of results are presented in Chapter Four.

The thesis is summarized and the author's conclusions are