Testing Epoxy Resins with the Tensile and Tor- 
sional Split Hopkinson Bar Techniques

A. GILAT, The Ohio State University; R.K. GOLDBERG, G.D. 
ROBERTS, NASA Glenn Research Center. 
E-mail: gilat.1@osu.edu

Epoxy types E-862 and PR-520 have been tested in tension and shear 
with the split Hopkinson bar technique at strain rates ranging from 400 
s⁻¹ to 800 s⁻¹, and with a hydraulic machine at lower strain rates. The 
results show that the resins are very sensitive to the rate of deformation. 
The maximum stress increases with increasing strain rate. The resins 
which are typically brittle in tension, exhibit a relative ductile behavior in 
shear. Comparison of the material response in tension and shear shows 
that the hydrostatic component of the stress has a significant effect on 
the response. The stresses that are required to deform the material in 
tension (when a hydrostatic tensile stress is present) are lower then the 
stresses that are estimated from shear tests by assuming no hydrostatic 
tensile stress effect.

The Current Status of Superplastic Forming 
Manufacturing in the United States

D.G. SANDERS, The Boeing Company 
E-mail: daniel.g.sanders@boeing.com

In recent years, we have seen the emergence of Superplastic Forming 
(SPF) from its origins as a niche technology associated with low volume 
production quantities. SPF has now taken a large leap forward to enter 
into the medium volume market for automobile parts and has penetrated 
into the high volume aerospace sheet metal fabrication arena. 
Boeing and several other aircraft companies invested heavily in the de- 
velopment of the SPF process parameters for titanium and aluminum 
materials, the design of hot presses, finite element analysis, character- 
ization of design limitations and the establishment of allowable material 
properties for integral monolithic designs to replace built-up assemblies. 
During the 1970’s through the 1990’s, SPF in the United States (U.S.) 
making sector was directed primarily at aerospace structure, high-
end luxury sports cars, specialty architectural work, rail car interiors 
and even artwork. We now witnessing a most remarkable transition for 
the superplastic materials and the fundamental forming process itself as it 
evolves again into a more mainstream and prolific production technology. 
Aerospace applications for SPF have been heavily influenced by military 
aircraft requirements for bomber and fighter projects such as the B-1, B- 
2, F-15E, F/A-18 and Joint Strike Fighter prototypes. Parts for these 
USAF airframes were hand-built in small lot sizes of one to three parts. 
At Boeing, the natural progression of SPF and hot forming methodology 
turned towards commercial aviation during the design of the B-777, B-
737-NG and most recently the 7E7 Dreamliner. SPF production rates 
have increased from one or two parts per month on the military side of 
the business to several hundred per month required for passenger jetliner 
manufacturing applications. 
During 2002-2004, we started to see evidence that the primary auto-
mobile producers in the U.S. had begun full-scale development of several 
pseudo-SPF processes, which utilize the fast forming ability of the 5083- 
SP aluminum alloy at elevated temperatures using high pressure air 
combined with the multi-action form die techniques traditionally associated 
with drawing and other conventional steel sheet metal stamping 
methods. Traditional aerospace SPF parts require about 30 minutes per 
forming cycle, while the new hybrid SPF process forming rates can be 
less than 15 seconds. 
SPF advances have been made possible by concurrent advances in many 
other enabling technologies. Through the application of new alloys and 
clever engineering design, SPF implementations at Boeing have resulted 
part consolidation, weight reduction, faster through-put, inventory reduc- 
tion, elimination of tooling families, simplified assembly and substantial 
earnings. Rapid prototyping with ceramic dies has speeded the time 
to market.
The teaming and partnering of government institutions, industry part- 
tners, international consortiums and the key universities studying the SPF 
phenomenon is of vital importance. The recent efforts of these organi-
izations have already resulted in substantial reductions in cost for large 
volume superplastic formed aluminum car parts. Collaboration will 
continue to be an essential element as SPF manufacturing enters into the 
mainstream automotive and perhaps even the domestic goods markets.

Past, Present and Future of Semi-Solid Form-
ing of High Temperature Alloys

P. KAPRANOS, The University of Sheffield, 
E-mail: p.kapranos@sheffield.ac.uk

Since the discovery of Semi-Solid Metal Processing or Thixoforming 
some 30 years ago at MIT, and especially during the past decade or so, 
there have been significant developments in this technology. Thixo-
forming is now a commercial process, with millions of components being 
produced each year for the automotive industry (fuel rails, suspension and 
engine parts) using aluminium alloys with conventional or slightly modi-
died die casting alloy compositions, e.g. Al-7Si-0.3-0.6Mg (356/7 type 
alloys) and for the consumer products/electronics markets mainly using 
magnesium alloys (computer, VCR, mobile phones accessories, sports 
goods).

Because of the fine microstructures and the high integrity associated 
with thixoformed products, thixoformed aluminium products have re-
placed steels and some forged, machined or cast aluminium parts, with 
the consequent savings in manufacturing time and weight. Thixoform-
ing produces complex near-net-shaped components of high integrity, with 
mechanical properties better than cast components. As a relatively new 
process, before proving its value as a commercial success, thixoforming 
had to exploit alloys that were already available. However this phase of 
development is now over and millions of thixoformed automotive parts 
are now in every day use in the cars we drive (e.g. USA, 2.4 million 
break cylinder parts per year and 2,000 front suspension parts per day in 
Italy). However, the true potential of this process will only be utilized 
through an expanding portfolio of alloys that will redress the needs in the 
aerospace industry for near net shape, high strength and consistent high 
integrity products.

Looking closer into the area of alloy development we can discern two 
main strands: that of high strength aluminium alloys KAPRANOS & 
Atkinson [2002] and another concerned with high melting point alloys 
KIRKWOOD [1996].

Current research in the later field is concentrating on the development 
of high melting point alloys such as steels, iron-alloys, copper-alloys, su-
peralloys and other exotic materials, to further exploit the potential ben-
efits of this under-utilised metal forming technique.

However, although thixoforming of high melting point alloys offers ex-
citing possibilities and tremendous potential, and has already been part 
of the original work of over thirty years ago, it is currently still in the 
research stage of development.