SHEET FORMING BY PRODUCING THE COVERAGE WITH A SIMULTANEOUS WORKING SYSTEM OF BALLS

FPF - Flexible Partial Forming

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ABSTRACT

FPF, a flexible partial forming method in comparison to peen forming represents a slow motion peen forming with a working system of balls. System of tools, forming strategy and application in aircraft industry will be shown. Especially for the very difficult formable material titanium (TiAl6V4) it will be demonstrated how parts for the pressure bulkhead of the Airbus A 330/340 are formed. This method can be regarded as a low cost alternative to hot forming methods of titanium sheets by special development and modification of peen forming.

KEYWORDS

FPF - Flexible Partial Forming (patented), forming of sheet metal, partial forming method, low tensile stresses, low cost, less space, flexible, alternatively or in addition to peen forming.

INTRODUCTION

In the aircraft industry qualified forming methods as stretch-forming, deep drawing and a lot of special methods like peen forming, super plastic forming, age forming and some since now less propagated methods like DPF (Dornier Panel Forming) and the here presented FPF are used (patented and patent applications in Europe and world-wide /1/). It is sure that the well known conventional methods will be mostly applicated, because less of special personal know-how is necessary and the production equipment is already available. But in some cases the parts cannot be formed with conventional technologies and agreeable costs.
Therefore for Airbus A 310 fuselage panel and Ariane 4 watertank panel, both with integrated stringers, shot peen forming convex /2/ is used, for emergency exit panel A 310 a shape punch forming method and for the Ariane 5 bulkhead segments the concave shot peen forming method /3/ is

used. These are all large parts. The pressure bulkhead of A 330/340 needs spherical formed sheets for crack stoppers made of titanium alloy TiAl6V4. Even with forming smaller parts of this material there are a lot of problems, too. Material and production costs, yield point ratio and the influence of temperature are the parameters to be considered for the properly forming method if forming these thin sheets to a spherical contour. There were only two cold forming methods left, peen forming (KSU) and flexible partial forming (FPF). Tried were both. Shot peen forming was not successful because the wanted spherical geometry was not reached in spite of the dominant influence of the direction of rolling. With FPF it was from the first try no problem to reach the intended geometry of all different crack stoppers for the pressure bulkhead.
In this case the sheet will be formed between a special system of embedded hard metal balls and a spherical hard metal punch. Similar to shot peen forming the geometry depends on the coverage, the indentation, prestressing and the forming strategy. In principle, FPF is a forming method, free of high kinetic energy and without the possible negative influence of high speed forming on the behaviour of the material /4/.
For this forming method a test programme has been carried out and the technique is qualified and in production.
In this report the process itself will be shown, examples are given and some results of the test programme will be presented.

TOOLS

The most significant characteristic of the the FPF-process is the layer mounting with forming-units inside a "tool cage". During a single work cycle a number of forming-units can therefore have a simultaneous effect on the workpiece with the same amount of force.
The forming units in the cage-layer can move laterally, thus enabling the forming-units in the workpiece-layer to move vertically and horizontally. The illustrations in Fig. 1 show how a continuous adaption of the workpiece-layer makes possible a transformation from an initially flat condition to a finally curved form. Rollers, barrels or balls of various dimension made of hardened steel or hard-metal can be utilized. The cage itself is preferably manufactured out of steel with a hard-metal surface. Table 1 shows the applications of balls, barrels or rolls dependent on the wanted geometry.

MACHINE

For the developement of the forming process, a special hydraulic Eckold-press was installed. The forming energy is applied to the workpiece in pulses by a press-head using forces and speeds which are preselected separately. The hydraulic system is programmable, special valves guarantee constant force and speed. The C-frame is very stiff, the bowing under maximum load is 0,2 mm. This is important for high puls frequency and less energy consumption.

After every work stroke the workpiece is manual moved slightly in order to maintain a smooth distribution of imprints (Fig. 2). For a greater number of equal parts a CNC-controlled handling unit will be necessary and more economical.

FORMING PROCESS

The zone of plastic deformation in the material under the imprint of a ball is by and by known. This zone depends on the energy, which is transformed into the part (Fig. 3). Therefore the energy of the tool (ball) must be suitable and the sheet must be able to catch the energy. When using free flying balls by peen forming the energy is dependent on the materials of both, the ball velocity, diameter and the stiffness of the sheet. When using FPF the force of the press together with the form and the hardness of the punch define the result of the forming process (Fig. 4).

If using e.g. soft material for the punch, rubber or other material with high elasticity, usually a concave form even will be the result when choosing small balls by FPF.

The following diagram (Fig. 5) shows the result of some tests to form a flat disk by FPF to a part of sphere under different pressure and number of strokes. The material was TiAl6V4 with a thickness of 1,2 mm. In this case it was impossible to get a real sphere geometry. We assume that the influence of the rolling direction (texture) prevented the intended exact shape. The best result in symmetry between rolling direction and transverse to rolling direction can be reached with low pressure. The behaviour of Ti15V3Cr3Al3Sn is similiar but less significant.

EXAMPLE OF APPLICATION

For the Airbus A330/340 a pressure bulkhead with special crack-stoppers of titanium alloy TiAl6V4 was designed. Fig. 6 shows the bulkhead with a diameter of about 3,5 m. Some of the parts, e.g. the boundary angle and the center part are made by super plastic forming. For the other parts we looked for another forming method than hot forming, because the manufacturing costs of hot forming technics are mostly much higher than cold forming technics (Fig. 7). We looked for cheaper methods and found some cold working technics. Two processes seam to work, shot peen forming and FPF, at that time under development. Tests have shown, that free shot peen forming was not succesfull in spite of the dominant influence of the direction of rolling. With FPF it was no problem to get all the intended geometries of the different parts. Fig. 8 shows some of these parts. The parts do not have a constant radius. In the middle of the bulkhead the radius is about r = 5000 mm. The radius decreases to about r = 500 mm at the boundary of the part. The different curvature of the crack stoppers will be attained by changing the coverage and the hydraulic pressure. The smallest part needs about N = 40 strokes, the largest part with a dimension of 660mm x 360mm needs about N = 1600 strokes.

Fig. 9 shows the hydraulic press and the worker, testing a part on the checking model. The main problem is to reach all the different curves of one part at the same time. Therefore the worker needs some experience to reach the correct curvature of the part in a short time.

The great advantage of this producing method is the possibility to cut and drill all parts to the final contour before forming process. And so we do. Cutting and drilling with a stack of sheets is done on a NC-controlled machine.

FPF also is used at Dorniers plant to straighten the super plastic formed parts and also to straighten the integral wing panels of aluminium alloy before carrying out Dornier Panel Forming process. Especially the flat curved center parts do not have the correct geometry after the hot forming process at any case.

PHYSICAL PROPERTIES

The mechanical properties after forming are the main question. In our case, especially the crack propagation should be low to get a long inspection intervall. But of course we also looked for the static and dynamic strength.

Fig. 10 shows the result of the crack propagation tests. With increasing coverage we got the best results. So we believe, that the imprints of the balls itself have the same effect like local crack stoppers.

POSSIBILITIES OF APPLICATION

The FPF process is particularly suitable for producing relatively small curvature in sheet-metal or milled integral components. In addition the process can also be used generally for straightening this type of workpieces.

The advantages compared with other processes are:

- less energy and less required floor space,
- universal tools which are relatively economical: only some few fixed balls for low cost with long life,

- cold working of high-strength component-materials, e.g. steel, titanium and aluminium alloys,
- decoupling "tool force" from "tool speed",
- no elastic-plastic "overforming" to reach intended geometry,
- low working noises,
- process is easy to master and
- a very low scrap risk.

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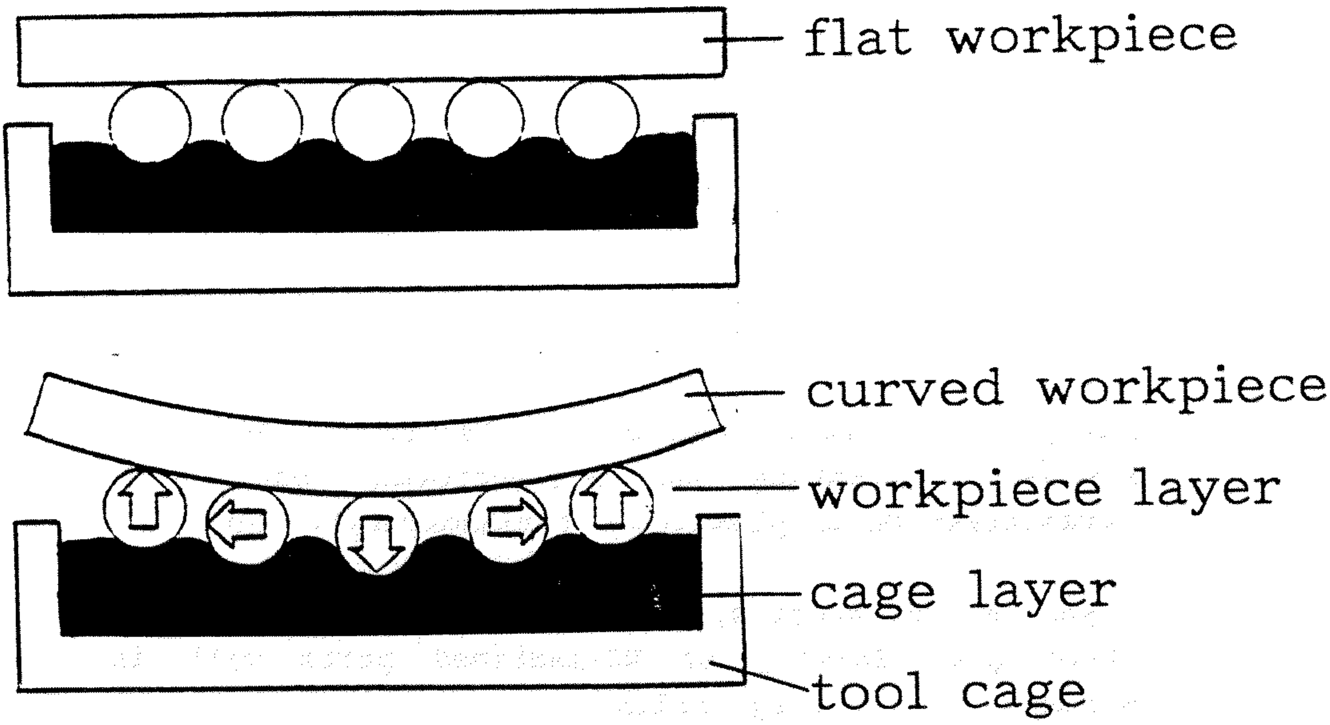

Fig. 1: System of FPF - tool

	uniaxial	spheroid	spherical
ball		●	●
barrel	●	●	●
roll	●		

Tab. 1: Shape of forming-units dependent on the wanted sheet shape.

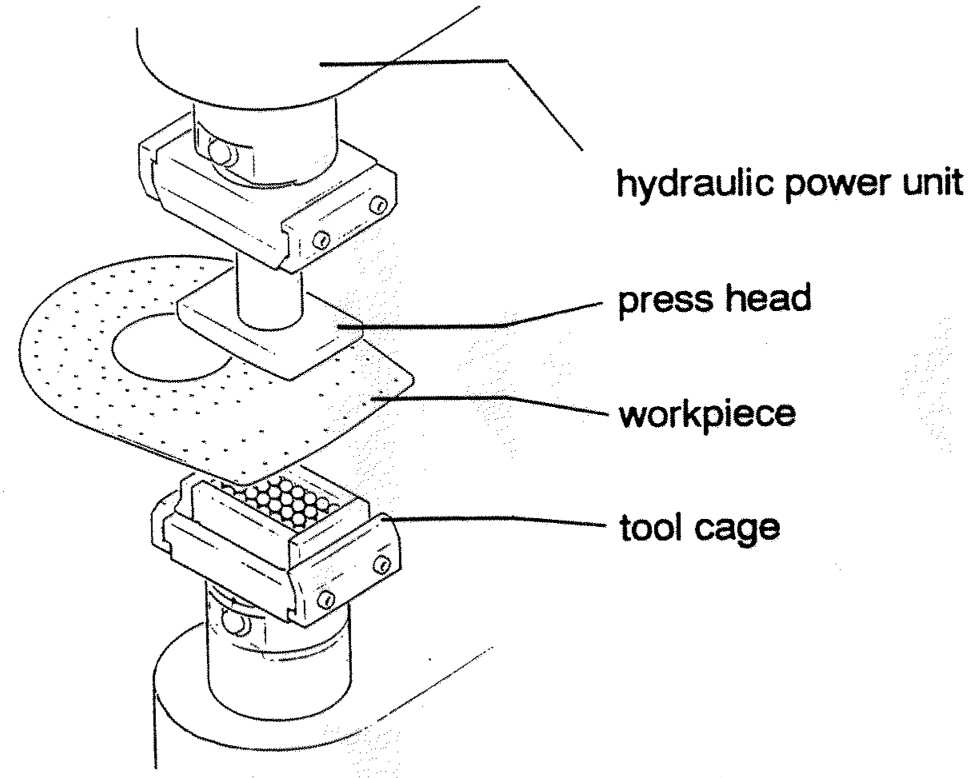

Fig. 2: Manual handled sheet between FPF-tools.

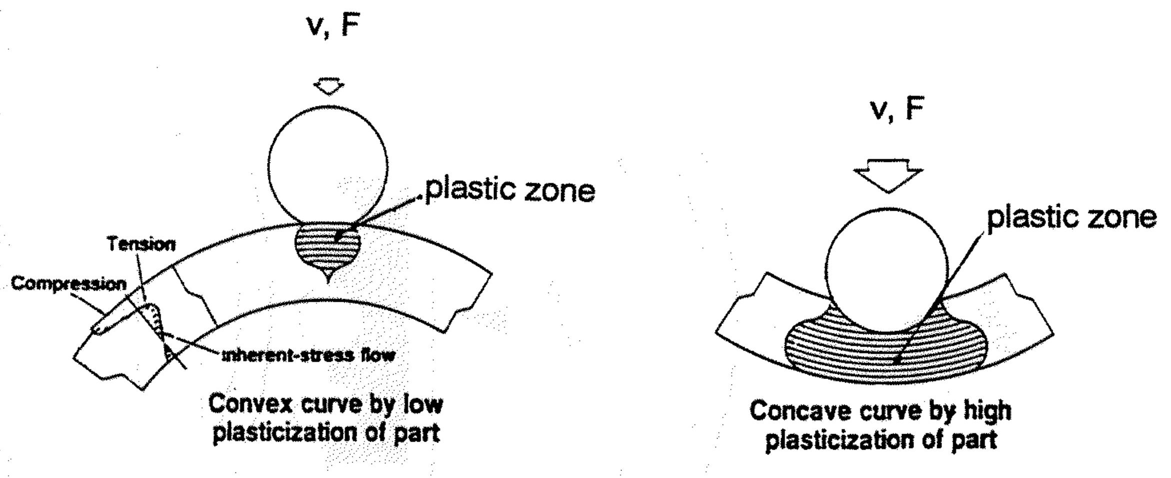

Fig. 3: Curvature of sheet dependent on transformed energy (velocity v or force F).

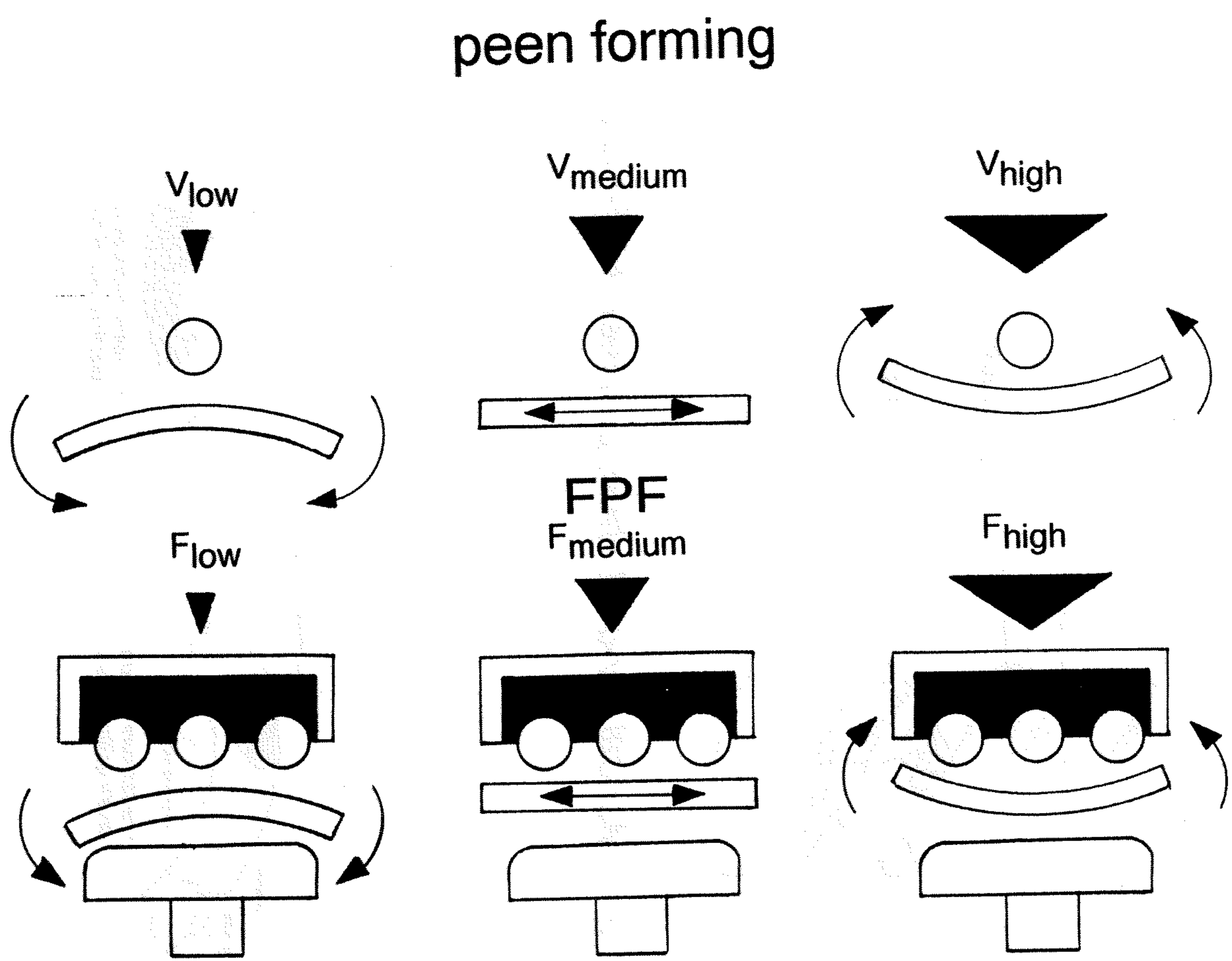

Fig. 4: Influence of energy (velocity or force) transformed into the sheet material by peen forming or FPF.

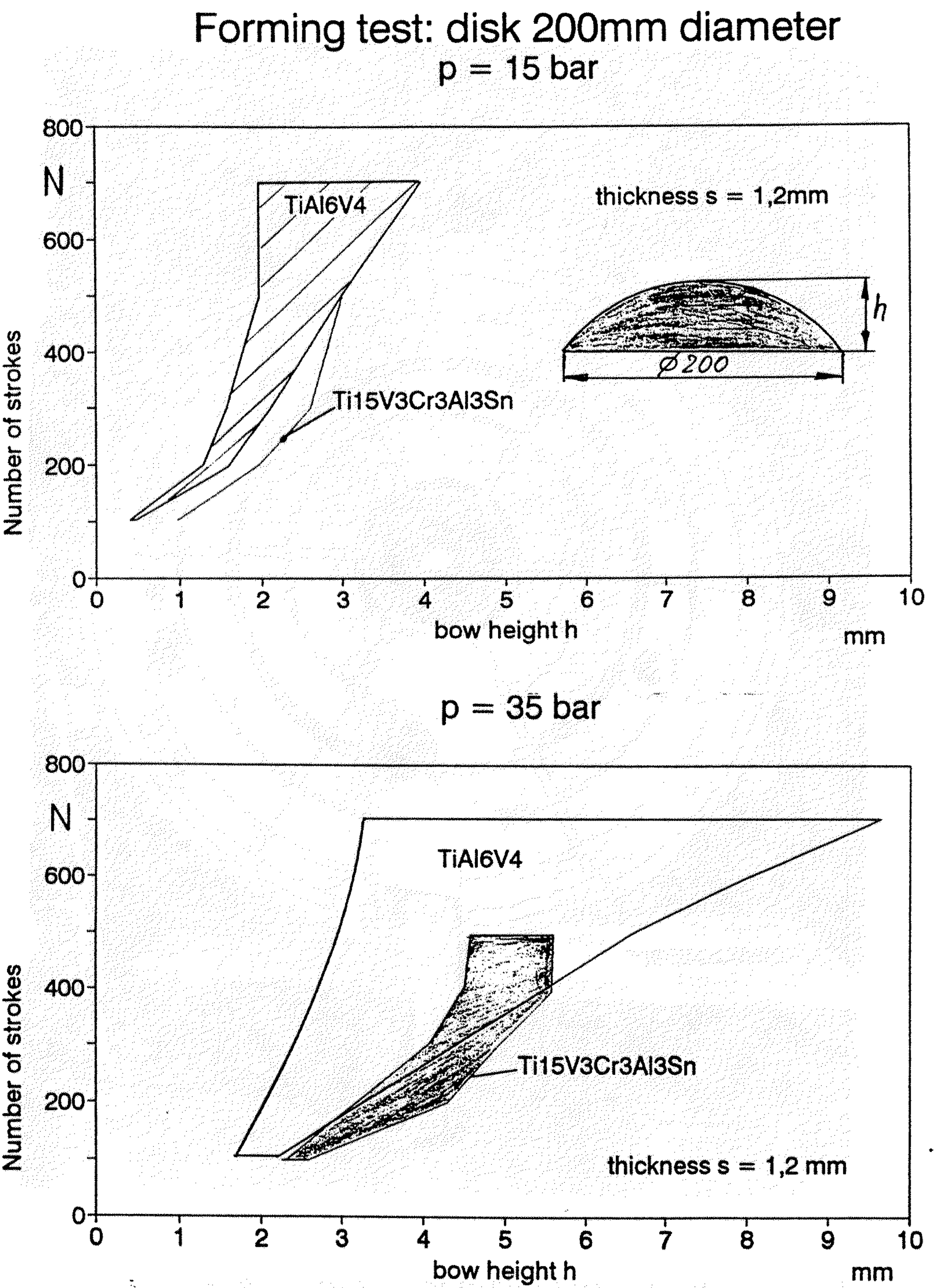

Fig. 5: Curvature ratio of sheet (rolling direction: L ; cross: LT) in dependence of stroke number N and pressure p.

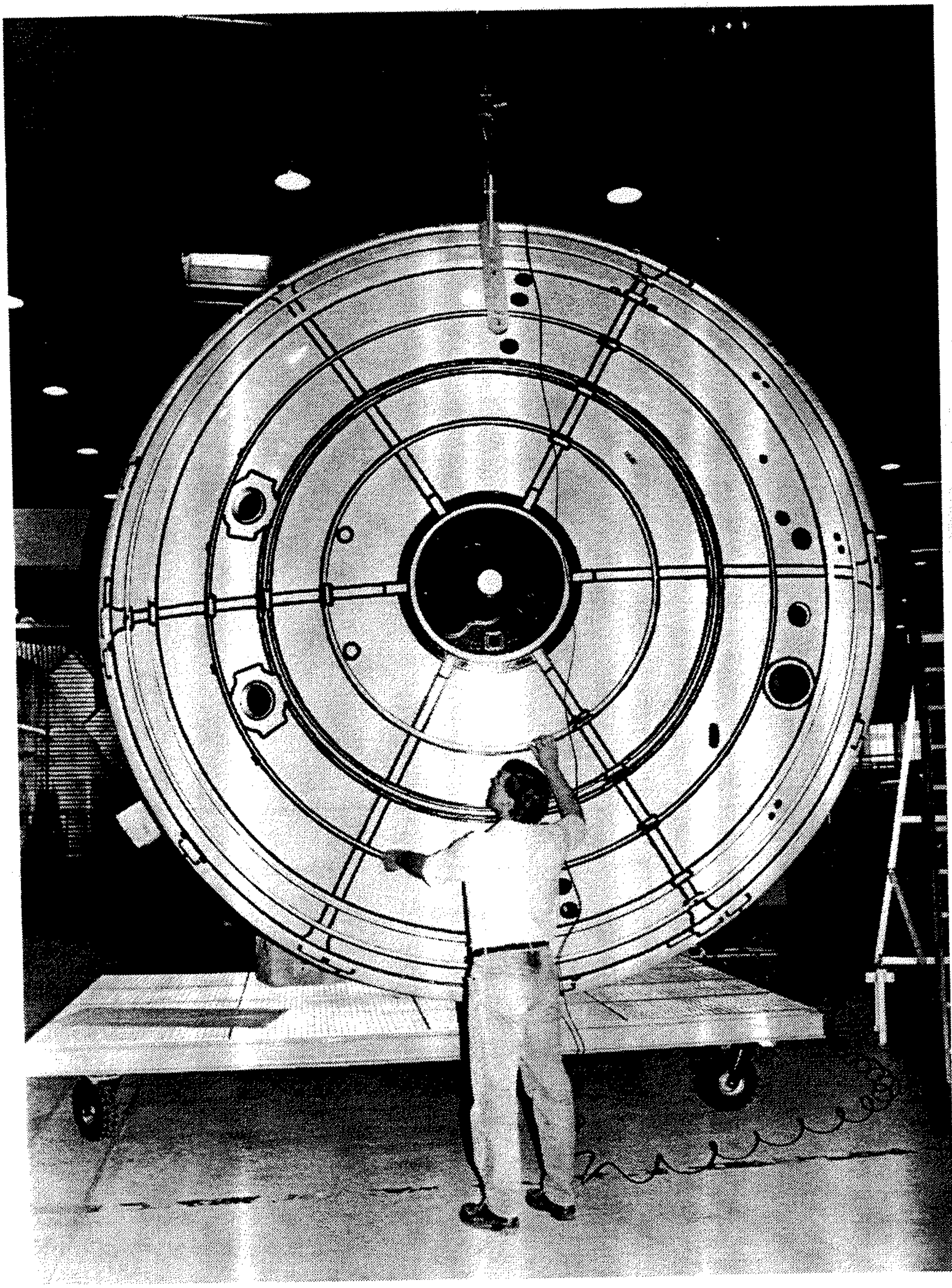

Fig. 6: *Pressure bulkhead of Airbus A 330 / 340.*

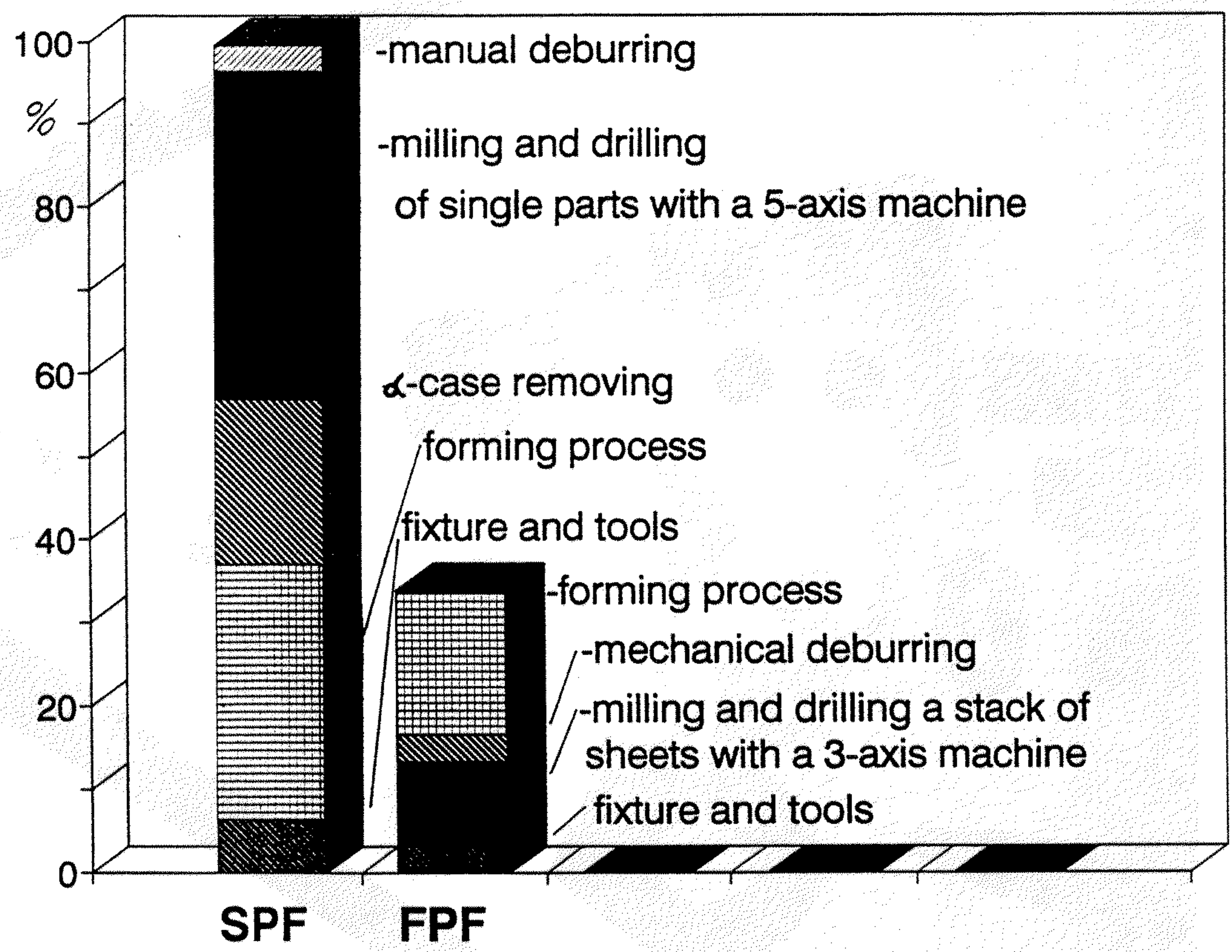

Fig. 7: Cost relationship between a hot (SPF) and a cold (FPF) forming process.

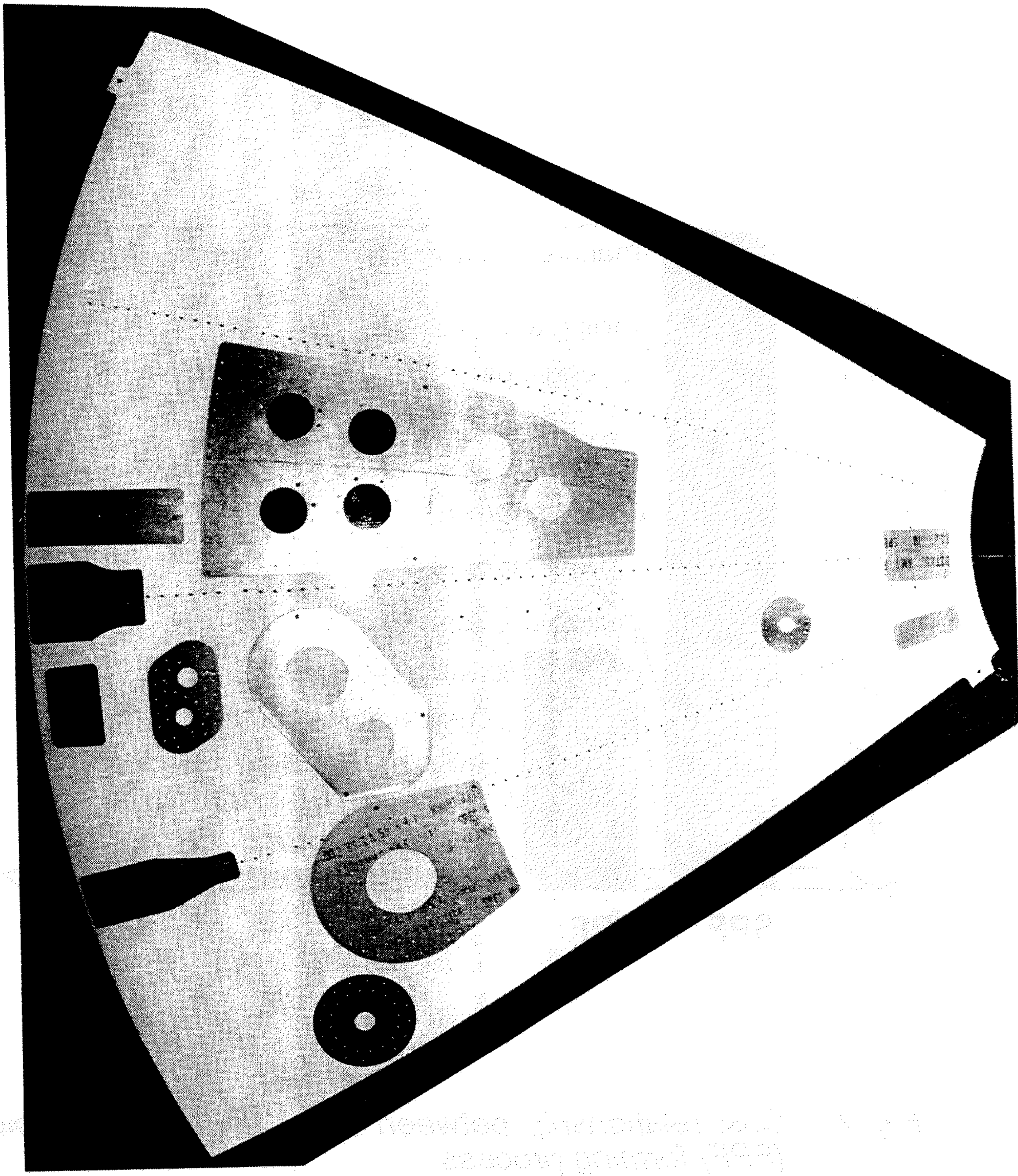

Fig. 8: Some different crack stoppers of A 330/340 pressure bulkhead formed with FPF.

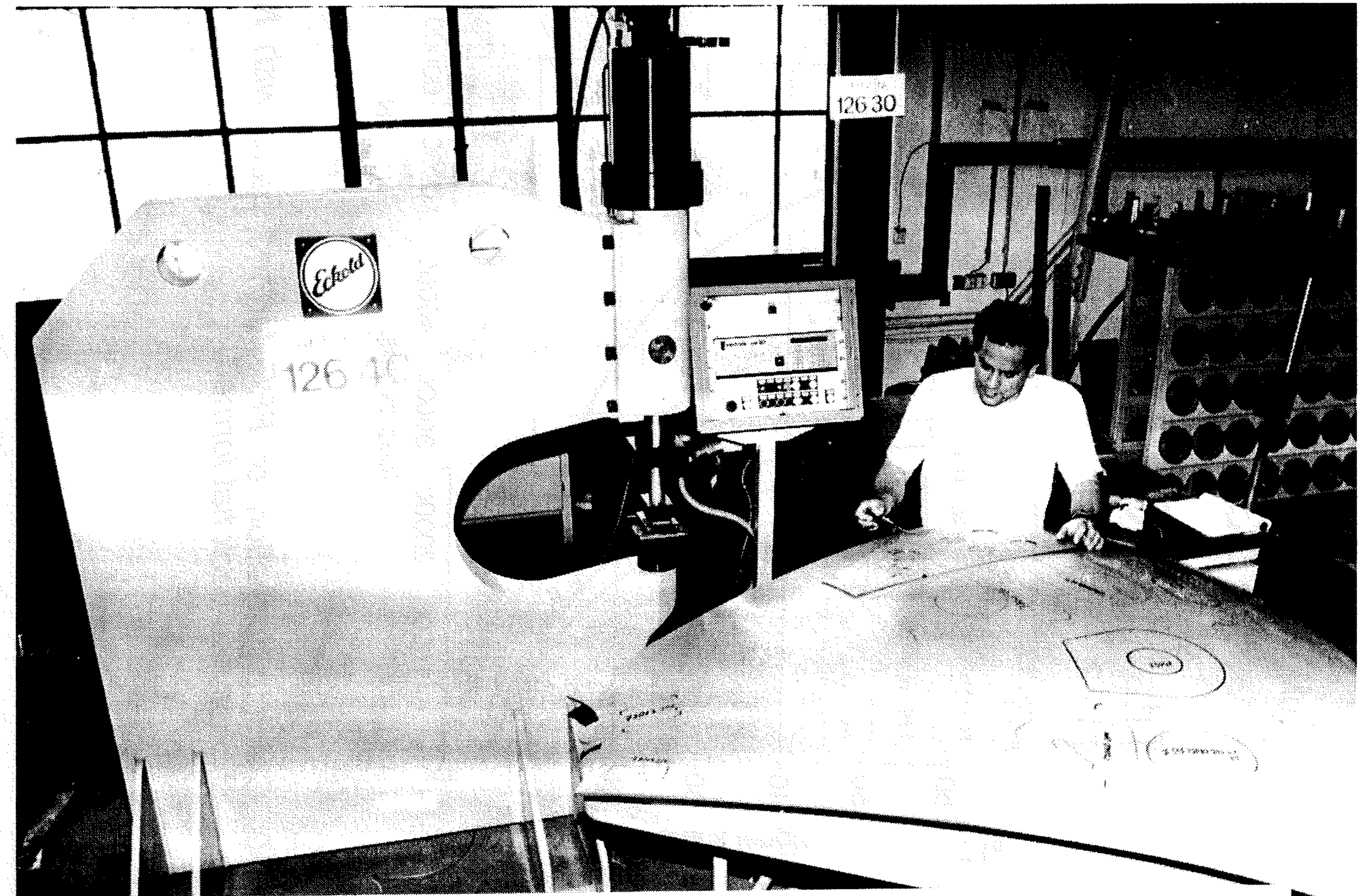

Fig. 9: *Hydraulic Eckold-press with FPF-tool and checking model with crack stoppers.*

A 330 / 340

Titanium Crack Stoppers

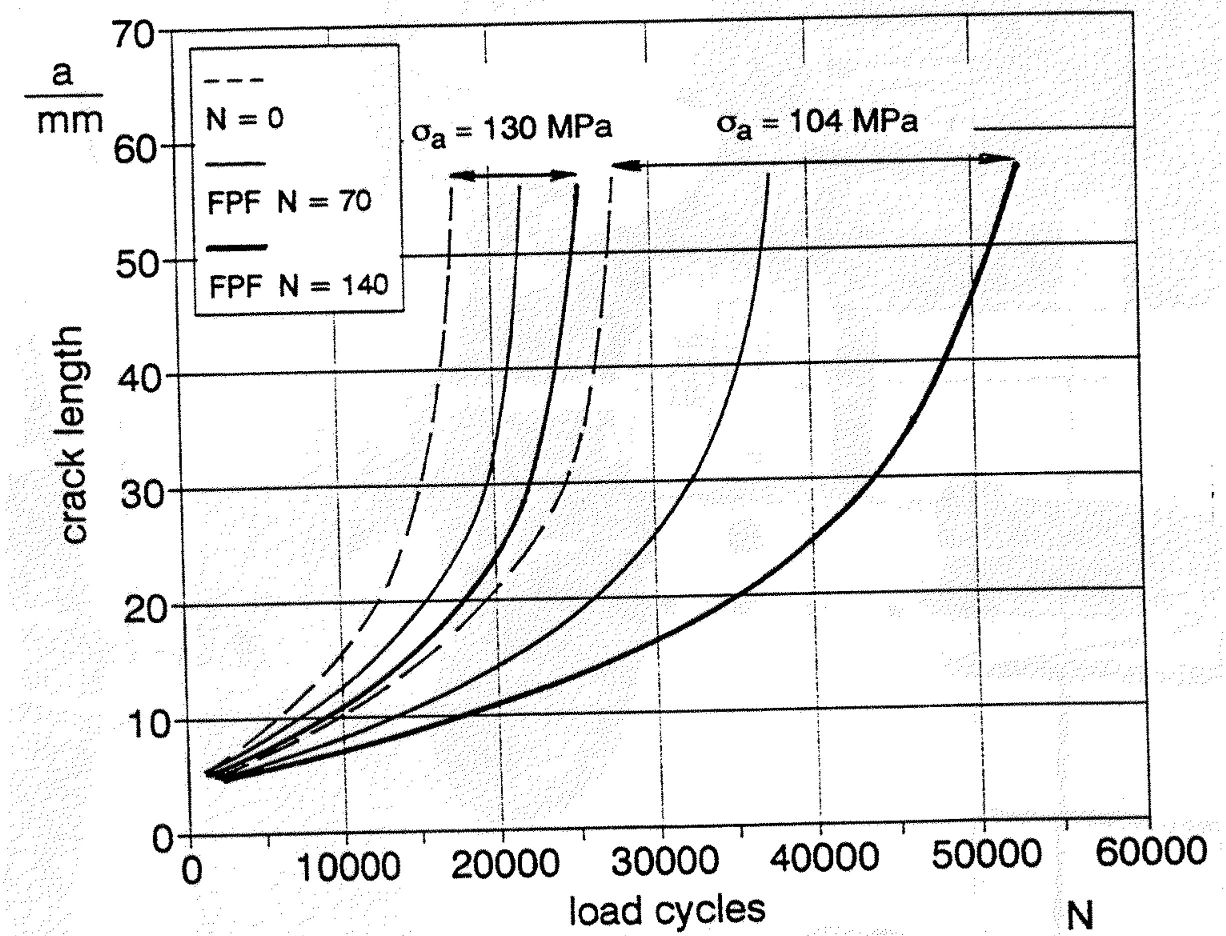

Fig. 10: Crack propagation of FPF formed parts with N-strokes and back flat formed.