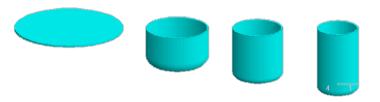
NAGFORM^{Sheet}

Overview

NAGFORM^{Sheet} is a knowledge based software program for designing forming sequence of sheet metal parts. It allows the user to capture manufacturing knowledge and use it to design forming progressions for similar parts in minutes. The sequence designs created in NAGFORM^{Sheet} can be quickly validated in NAGSIM.2D / NAGSIM.3D FEA simulation programs. NAGFORM^{Sheet} is available as a stand-alone software or as an add-on module with NAGFORM software program. The advantage of NAGFORM program with this module is that the user can compare the manufacturing steps for parts that can be cold forged from solid as well as formed from sheet. This can help in converting sheet metal parts to cold forged parts and vice versa.



Uses

- Determine material required, surface area and weight of formed part.
- Create sequence design for forming a part, in minutes.
- Save any automatic design as a reusable design template.
- Optimize and standardize designs.
- Search for knowledge on similar parts in design database
- > Help reduce number of operations required to form a part.
- > Obtain estimated forming loads and pressures.
- Create analysis file for NAGSIM.2D / NAGSIM.3D for design validation
- > Teach forming design to new personnel.

Limitations

NAGFORM^{Sheet} is not a FEA simulation program. It cannot predict metal flow defects and stresses in tools.

Create Part Model

In NAGFORM^{Sheet}, Geometric model of a part is constructed by joining simple building blocks called primitives. All primitives are defined by certain dimensions.

Based on the part dimensions and material, the program determines the <u>Volume</u>, <u>Surface</u> <u>Area</u>, <u>and Weights</u>. Complex parts can be created and designed using these primitives. The user can also create a sheet metal part model from a sketch created within NAGFORM or imported from a 2D Dxf drawing.





UNION - PRIMITIVES

UNION - Convert SOLID

SKETCH - from UNION

SKETCH

metry of Part1

⁰᠔∥∖∖

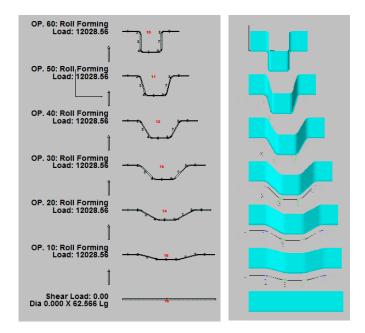
B

Entity



Automatic Designs of Forming Progressions

NAGFORM^{Sheet} utilizes a combination of design logic, knowledge based rules and simplified analyses to determine a forming progression automatically in minutes. In general, there is more than one forming sequence by which a part can be formed. The number of designs depends upon part geometry and, material being formed. NAGFORM^{Sheet} has its own design logic to determine various possible ways to form a part. Because the program looks for all possible designs and applies its logic without fail, NAGFORM^{Sheet} can determine design concepts that even an experienced designer may overlook.



Design Helper

The "Design Helper" is a diagnostic tool that helps the user get a sequence design when no design can be found through standard forming rules. It determines the extent to which certain rules need to be modified to get a sequence design.

NAGFORMSheet

Metal Forming Systems, Inc. 7974 Lilley Road, Canton Mi 48187 Tel: 734-451-5415 Fax: 734-981-4438 Web Site: www.nagform.com Email: gaurav@nagform.com

Template Designs for 'Similar Parts' or 'Family of Parts'

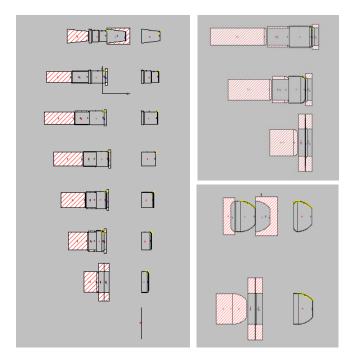
For any part that is similar to a template in the database, NAGFORM^{Sheet} can follow the template design files to create forming progressions in minutes. The users have the capability to create their own reusable template designs.

DXF Input and Output

In NAGFORM^{Sheet}, the geometry of parts can also be imported from DXF format from CAD systems such as AutoCAD, SolidEdge etc. The results of NAGFORM^{Sheet} sequence designs and 'Generic' tooling can be saved in DXF format for input to other CAD systems.

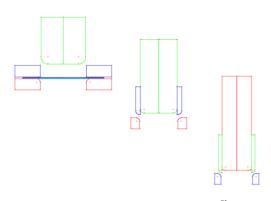
Generic Tooling for FEA Simulation

For the sequence designs obtained through NAGFORM^{Sheet} logic, 'Generic' tooling can be created automatically. This generic tooling can be used to simulate the forming operation in a FEA simulation program such as 'NAGSIM.2D' and 'NAGSIM.3D'.

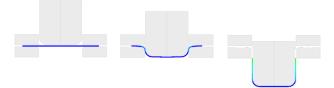


Integration with NAGSIM.2D

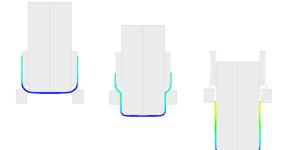
In NAGFORM^{Sheet}, simulation files for NAGSIM.2D can be automatically created for any selected part progression generated in Auto Design. To simulate, the user opens this file in NAGSIM.2D, meshes the parts and begins simulating. It takes only couple of minutes to go from NAGFORM's design concept to NAGSIM.2D simulation.



Default Tooling generated by NAGFORM^{Sheet}



Simulation Results Station 1 – NAGSIM.2D



Simulation Results Station 2 – NAGSIM.2D



Simulation Results Station 3 – NAGSIM.2D

Manual Design

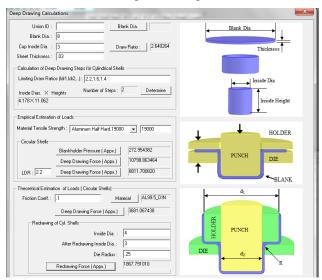
In addition to automatic design, NAGFORM^{Sheet} has a separate module for creating a forming progression manually. Using computer aided techniques, the user can quickly and easily construct a forming sequence according to his/her concept. The designer can also start from a NAGFORM^{Sheet} generated design and modify it.

NAGFORM^{Sheet}

Sheet Metal Process Calculator

NAGFORM^{Sheet} contains a calculator to help design the forming sequence. Following calculations can be performed:

- Deep Drawing of Circular Shells -
 - Given circular cup inside diameter, height and material, the calculator determines the number of deep drawing operations needed to form the cup.
 - Cup dimensions at each deep drawing operation are also calculated.
 - Determines the deep drawing force, redrawing force and blank holder pressure required.



• Deep Drawing of Rectangular Shells - Given dimensions of rectangular shell and material, the calculator determines the deep drawing force required with different types of blank holders.

Empirod Estimation of Loads Metrial Tensile Strength: Aluminum Half Hard.19000 Rectangular Shels Total Length of R. Sides : 7 Comer Redus of Rect. Shell : 2	
Shell Depth: 1 Cup Thicknes: 03 C Easy Draw without Blankholder C Easy Draw with Blankholder C Metal Camed Tightly for Flow	
Deep Drawing Force (Appx)	

• Stretch and Shrink Flanging - Given the dimensions before and after flanging, the program calculates the edge strains for shrink and stretch flanging processes. The edge strain can be compared with limiting strains for various materials to determine feasibility of flanging.

tretch Flange And Shrink Flange		
Flange Edge Radius Before Forming, F	Ri: 3	
Flange Edge Radius After Forming, F	Rf: [2.5	
Strain at Flange Edge	-0.166667	
Flange Edge Maximum Strain Limit		
Low-carbon steel, cold rolled	0.40	
	Ri	

• Bending Calculations – Given dimensions of the bend including sheet thickness, angle and K Factor of material, the program determines the bend allowance and setback for Vee Bending. The program also calculates the Vee bending and Wipe bending forces based on the tensile strength of the sheet material.

L1 2 L2 2 Sheet Thickness: 035 Thickness		
L 1 2 L 2 : 2 Sheet Thickness Inside Berd Radas: 125 Setback, SB B 150000 K Factor: Medium Steel - 30 Degy D Bend. Bend Allowance: 021432 Bend Allowance: 021432 Bend Allowance: 021432 Bend Allowance: 021432 Bend Allowance: 021432 Bend Allowance: 021432 Stein, Inres Suffice: 02064584 Ves Bending: Ves Bending: 578984 Lergth Betrie Bending: 578984 Lergth Betrie Bending: 578984 Lergth Betrie Bending: 578984 Lergth Betrie Bending: 578984 Lergth Allowance: 02064584 Ves Bending: Ves Bending: 578984 Lergth Allowance: 02064584 Ves Bending: 0200000 Die Opening: 024 Ves Bending: 0200000 Die Opening: 024 Ves Bending: 0200000 Die Opening: 024 Die Op	Air Bending	11
Sheet Thickness: 05 included Angle. Deg. : 90 Inside Bend Radau: 1725 Setback. 59 Setback.	L1: 2	$\pi \rightarrow 4 \xrightarrow{\sim} 1$
Sheet Thickness Trickded Argle, Deg : 90 Inside Bend Radas: 125 Setback, SB 9180000 K Fostor: Medium Steel - 30 Deg V Bend. Bend Allowance: 024432 Bend Allowance: 0264584 Ven Bendrag - Length Betone Bendrag Bend Allowance: 0264584 Ven Bendrag - Length Betone Bendrag Length Betone Bendrag Length Betone Bendrag Length Of Bend I Tende Steength: Steel 10 Cashon. 60000 — 60000 Length of Bend I Tende Steength: Steel 10 Cashon. 60000 — 60000 Length of Bendrag Length of Bendrag - 124 Thickness I 124 Ven Bendrag Faces IV 00000000 10000000	12:2	SetBack
Included Angle, Deg. [30] Included Angle, Deg. [30] Include Bend Raduz: [125 Setback. 58] B150000 K. Factor: Medun Sted: - 30 Deg V Bend. Deg Allowance Def		
Iniske Bend Padar::: 125 Seback, 58 8180000 K. Factor:: Medum Steel - 30 Deg V Bendt.:: 33 Cakuate Bend Allowance: 221452 Bend Deductor:: 6105508 Stain. Junes Suface: 00;84584 Vee Bending:: 00;84584 Vee Bending:: 782884 Length Below Bending:: 782884 Force Cakuation Terule Strength:: Steel 10 Cettor.: 6000 50000 Length of Bend:: 2 Thickness:: 00 Required Pad Force:: 100 Die Opening:: 24 Wes Bending Force:: 100 Bend, Bending:: 24 Thickness:: 00 Bend, Bend, Bending:: 24 Thickness:: 00 Bend, Bend, Ben	Sheet Thickness : 035	Included Angle
Iniske Bend Padar::: 125 Seback, 58 8180000 K. Factor:: Medum Steel - 30 Deg V Bendt.:: 33 Cakuate Bend Allowance: 221452 Bend Deductor:: 6105508 Stain. Junes Suface: 00;84584 Vee Bending:: 00;84584 Vee Bending:: 782884 Length Below Bending:: 782884 Force Cakuation Terule Strength:: Steel 10 Cettor.: 6000 50000 Length of Bend:: 2 Thickness:: 00 Required Pad Force:: 100 Die Opening:: 24 Wes Bending Force:: 100 Bend, Bending:: 24 Thickness:: 00 Bend, Bend, Bending:: 24 Thickness:: 00 Bend, Bend, Ben	Included Angle Deg : 90	Ť Š
Setback, SB \$160000 K: Factor: Medua Sted-30 Deg V Bends. 33 Cakulate Cakulate Bend Alowance: \$271432 Bend Deckulor: \$02580 Stain. Duter Sufface: \$026854 Vee Bending: Length Below Bending: Lumph Below Bending: \$78884 Force Cakulate \$787884 Tende Strongh: \$1800000 Length of Bending: \$78884 Force Cakulate \$17772 Dischners: \$130000000 Die Opening: \$12 Takines: \$130000000 Die Opening: \$12 Ves Bending Frace: \$10000000 Die Opening: \$10000000 Die Opening: \$10000000 Die Opening: \$10000000 Die		
Seback. S8 B18000 K. Factor: Medun Stell - 30 Deg V Bends. 33 Eak/Jable 23 Bend Alowarce 0.214432 Bend Deduction: B105508 Stain, Inner Sufface: 0.024584 Vee Bendrg: 0.024584 Vee Bendrg: 0.034584 U Bendrg (two 30 deg bendrg): \$78884 Force Calculation 100.00000 Length Bend: 100.00000 Die Opening: 24 Vee Bendrg Force 100.000000 Die Opening: 100.00000 Die Opening: 100.000000	Inside Bend Hadius : 125	Bend Allowance
K. Factor: Medum Steel: 90 Deg VBerk. 33 Calculate Bend Alowarce: 0214422 Bend Alowarce: 0264564 Use Bendrg: Largh Betree Bendrg: 177722 Stein. Innes Surface: 0264564 Vee Bendrg (wo 90 deg bendre) Largh Betree Bendrg: 5788984 Force Calculation Tensie Steeght: Steel: 10 Cabon. 60000 — 60000 Largh of Bende 12 Thickness: 100 Web Bendrg Face: 10000000 Web Bendrg Face: 10000000 Web Bendrg Face: 10000000	Setback, SB 0.160000	
Catulate Bend Advance: 0.21442 Bend Deduction: 0.00508 Stain. Durfs States: 0.0064564 Ves Bendrg: Length Betre Bendrg: 0.0064564 U Binding (two 5) ddg bendrg: 0.0000 Length Betre Bendrg: 0.0000 Length of Bend 0.0000 Textices: 0.00000 Pie Quering Tacce 0.00000 Ue Bendrg Frace: 0.000000		
Bend Alowarce: 0/214432 Bend Debuction: 0/05508 Stain. Uner Sulface: 0/05684 Voe Bendro _ Longh Beloe Bendro: 0/05684 Voe Bendro _ Longh Beloe Bendro: 0/05684 Use Bendro: 0/05684 Voe Bendro: 0/05684 Voe Bendro: 0/05684 Voe Bendro: 0/05684 Length elder Bendro: 0/0000 Length of Bend 0/0000 Die Openiey: 1/0 Vee Bendro Facce: 1/0 Monomou 1/0 Die Openiey: 1/4 Vee Bendro Facce: 1/0 Monomou 1/2 Thickness: 1/0 Monomou 1/2 Vee Bendro Facce: 1/0 Monomou 1/2 Vee Bendro Facce: 1/2 Monomou 1/2 Vee Bendro Facce: 1/2 Monomou 1/2 Monomou 1/2	K Factor: Medium Steel - 90 Deg V Bends,	.33
Bend Deductor: 8105508 Stain, Dues Suface: 9171732 Stain, Innes Suface: 9086584 Vee Bending: 8394492 U Bending (two 30 dep bending Length Belore Bending: 878884 Force Calculation: 100 Tende Strength: Steel 10 Cectorn. 6000 Length of Bend 2 Thickness: 03 Bie Opening: 24 Wes Bending Frace: 100.000000 Die Opening: 24 Ves Bending Frace: 100.000000 Ves Bending Frace: 100.000000 Ves Bending Frace: 100.000000	Cal	culate
Bend Deductor: 8105508 Stain, Dues Suface: 9171732 Stain, Innes Suface: 9086584 Vee Bending: 8394492 U Bending (two 30 dep bending Length Belore Bending: 878884 Force Calculation: 100 Tende Strength: Steel 10 Cectorn. 6000 Length of Bend 2 Thickness: 03 Bie Opening: 24 Wes Bending Frace: 100.000000 Die Opening: 24 Ves Bending Frace: 100.000000 Ves Bending Frace: 100.000000 Ves Bending Frace: 100.000000	D 141 0 0 0 1 1 1 0 0	
Stain User State: 0171732 Stain User State: 0084584 Vee Bendrg: 0084584 Vee Bendrg: 0084584 Vee Bendrg: 0084584 Lerght Betree Bendrg: 5788984 Force Calculation 60000 Lerght of Bend 10 Die Opening: 10 Vee Bendrg Force 10000000 Die Opening: 12 Vee Bendrg Force 10000000 Die Opening: 124 Vee Bendrg Force 10000000 Die Opening: 10000000	Bend Allowance : U.214432	
Strain. Inner Surlace: 0.084594 Vee Bending - Length Betre Bending: 3.894432 U Bending two 30 do pendil Length Betre Bending: 5.788894 Force Calculation Tensie Steerght: Sized 10 Catoon. 60000 T 66000 Length of Bend 2 Thickness: 103 Required Pad Force in Wiging 1000.00000 Die Opening: 24 Vee Bending Force 100.000000 Die Opening: 24 Vee Bending Force 100.000000	Bend Deduction : 0.105508	
Strain. Inner Surlace: 0.084594 Vee Bending - Length Betre Bending: 3.894432 U Bending two 30 do pendil Length Betre Bending: 5.788894 Force Calculation Tensie Steerght: Sized 10 Catoon. 60000 T 66000 Length of Bend 2 Thickness: 103 Required Pad Force in Wiging 1000.00000 Die Opening: 24 Vee Bending Force 100.000000 Die Opening: 24 Vee Bending Force 100.000000	Strain Outer Surface 0171732	
Vee Bendrg - Length Beloe Bendrg : 884432 U Bendrig (two 50 do bendr) Length Beloe Bendrg : 5786584 Force Calculation Tende Steergh : Steel 10 Caton. 60000 60000 Length of Bend : 2 Thickness : [0] Required Pad Force in Wiring : [20 Use Bendrg Force : 600.00000 Die Opening : [24 Use Bendrg Force : 600.00000		
Vee Bendrag: Length Belore Bendrag: Length Betore Bendrag: 578884 Forse Scientific Wes 0 de photom Length Betore Bendrag: 578884 Tensile Steength: Steel 10 Cabon. 60000 Econg to 4 Bendrag 700.00000 Thickness: 03 Required Pad Force N Wing: 124 Ues Bendrag Face. 100.00000 Ues Bendrag Face. 100.00000 Wes Bendrag Face. 100.000000 Wes Bendrag Face. 100.00000 Wes Bendrag Face. 100.000	Strain, Inner Surface : -0.084584	Thursday of David
U Bending (two 50 deg bendi) Length Below Bending : \$788884 Force Calculator Tensie Stiength: Steel 10 Cateon. 60000 © 60000 Length of Bend : 2 Thichness: 103 Required Pad Force in Wiging 1200.000000 Die Opening: 24 Ves Bending Tarce 100.00000 Die Opening: 24 Ves Bending Tarce 100.00000	Vee Bending - Length Before Bending : 3.894492	Length of Bend
Length Betroe Bending: 578984 Teroite Steerd 10 Carbon. 60000 Length of Bend (2) Teroite Steerd 10 Carbon. 60000 Length of Bend (2) Thickness: (3) Required Pad Force N Wide) (24 Use Bending Face. (24) Use Bending Face. (24) (24) (24) (24) (24) (24) (24) (24)		
Force Calculation Tendie Steerght: Steel 10 Cathon. 60000 ■ 66000 Length of Bend 2 Thickness: 03 Processor 1280.000000 Die Opening: 24 Vest Bending Factor 100.000000 Vest Bending Factor 100.000000 Die Opening: 24 Vest Bending Factor 100.000000		
Tensie Steer, 10 Cabon, 6000 Length of Berni [2 Thickness: [03 Required Pad Force Mylion] [200,00000 Die Opening: [24 Ves Bendhorg Force, [800,00000] [24] [200,00000]		
Length of Bend : 2 Thichness : 03 Prequised Pad Farce In Wiging 1200 000000 Die Opening: 24 Vee Bending Farce : 600.000000 Elength of Bend		
Thickness: 03 Required Pad Farce in Wiging 1200.000000 Die Opening: 24 Vee Bending Farce 600.000000 Vee Bending Farce 1200.000000		VEE BENDENG
Thickness: 03 Required Pad Farce in Wiging 1200.000000 Die Opening: 24 Vee Bending Farce 600.000000 Vee Bending Farce 1200.000000	Length of Bend : 2	
Required Pad Face in Wrining 1700.000000 Die Opening: 24 Ves Bending Face 160.000000 Ves Pachter Face 160.000000		
Ves Bending Force		
Vee Bending Face 600.000000	Required Pad Force in Wiping 1200.0000	10
Vee Bending Face 600.000000	Die Opening : 24	
Vites Paratine France 150,000000		
Wipe Bending Force 150.000000 NUTRE DESERVICE	Vee Bending Force 600.00000	Length of Bend
	Wipe Bending Force 150.00000	NUDE DENDRIC

• Spring Back Calculations - Given the material properties, bend angle and bend radius, the program calculates the spring-back in terms of change in bend angle and radius.

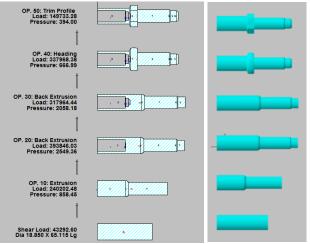
ring Back Calculation		
Bend Radius, r1:	.125	
Thickness :	.03	
Included Angle, a1:	90	al Thickness
Modulus of Elasticity :	3000000	
Basic Calculation Without Strain Ha	srdening	
Yield Stress :	20000	al - Included Angle rl - Bend Radius
	Determine	a2 - Included Angle after Spring Back
	<u></u>	r2 - Bend Radius after Spring Back
Advanced Calculation - Strain Hard	lening Matl.	
	Material	
Matl. Strain Hardening Coeff. :		
Matil. Strain Hardening Coeff. : Matil. Strain Hardening Exponent :		
	Determine	
Matl. Strain Hardening Exponent :	Determine	

NAGFORMSheet

Metal Forming Systems, Inc. 7974 Lilley Road, Canton Mi 48187 Tel: 734-451-5415 Fax: 734-981-4438 Web Site: www.nagform.com Email: gaurav@nagform.com

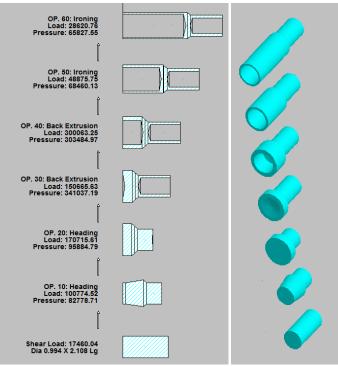
NAGFORM + NAGFORM^{Sheet} Module

This option allows full capabilities of NAGFORM program with additional capabilities of NAGFORM^{Sheet} module. User can design forging sequence for cold forged part as well as design forming sequence for sheet metal parts.



Cold forged progression design using NAGFORM

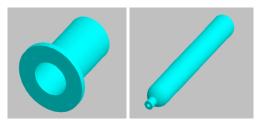
In certain cases, sheet forming processes such as 'Ironing' to reduce part thickness and 'Drawing' to reduce outside diameter of thin section can be combined with cold forging processes to manufacture parts with thick and thin sections. Examples of such parts are ammunition shells and high pressure cylinders.



Cold forging with ironing process using NAGFORM

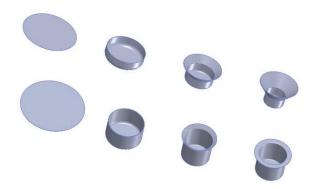
Additional features of NAGFORM + NAGFORM^{Sheet} program:

- Perform comparative study of parts that can be made from sheet metal as well as wire/rod
- Help in converting sheet metal parts to cold forged part and vice versa
- Help in eliminating welding in assembly of sheet metal part with thick / solid parts

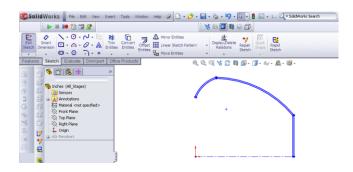


NAGFORM^{Sheet} SolidWorks Interface

The 'NAGFORM-SolidWorks Interface' toolbar allows the user to automatically generate '3-D SolidWorks' drawings of NAGFORM Sheet metal parts and progression results.



Sample NAGFORM progressions generated in SolidWorks



Sample Sketch exported into SolidWorks